Karl A. LeBlanc
Andrew Kingsnorth
David L. Sanders
Editors

Management of Abdominal Hernias

Fifth Edition

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Preface

Quantum leaps in mesh technology and minimally invasive surgery have seen the practice of hernia surgery improve beyond recognition since the first edition of this book was written 30 years ago. The pace of progress continues with the introduction of robotics and advanced techniques of abdominoplasty. Such progress results from the contributions of many individual surgeons. We would like to acknowledge our good fortune in having the benefit of such a galaxy of internationally renowned experts who have shared their experiences to compile this text.

To update each chapter and introduce new topics, an extensive review of the literature has been undertaken, in order to identify important advances which can be translated into general surgical practice. What has emerged is an in-depth consideration of all aspects of hernia management and of each type of abdominal wall hernia. Our approach has not been uniform; we have allowed the contributors to emphasise the facts that they deem important to their area of specialisation in hernia surgery. The common varieties receive extra attention and discussion. Topics covered in depth include the management of patients with co-morbidities, particularly morbid obesity, ambulatory surgery and anaesthesia and choice of mesh. The avoidance of wound dehiscence is of fundamental importance to the avoidance of abdominal incisional hernias, and a chapter has been introduced on this topic.

Although much of the content of this book will not be relevant to low-income countries due to cost considerations, because of increasing interest in globalisation and volunteerism, we have commissioned a chapter on management of giant inguino-scrotal hernia, as it would be carried out in a poorly resourced, but optimally managed, environment. For the surgeon starting out on a career specialising in abdominal wall surgery, the description of rare intraoperative and postoperative complications will reduce the risk of poor outcomes.

Finally, continued progress in the surgical treatment of hernias relies on fresh talent and an early recognition of potentially revolutionary changes in clinical practice. With this in mind, Andrew Kingsnorth and Karl LeBlanc have recruited David Sanders, a younger surgeon already experienced and specialised in hernia surgery, to assist in editing this book. Although the content is directed primarily at the specialist, individual chapters can be accessed to provide important insights for other surgical disciplines and the non-specialist.

Baton Rouge, LA, USA — Karl A. LeBlanc
Plymouth, UK — Andrew Kingsnorth
Barnstaple, UK — David L. Sanders

Preface for First Edition (1988)

Another book on hernia? Well, not quite! My intention was to produce a neat practical book on hernia, not an exhaustive text. But a book about hernias would be incomplete without mention of the past; hence, the 'practical book' has become encrusted with history and anecdote, and conceivably the book is more readable for this. Almost all the material included has already been published elsewhere—the skeleton is the section on hernia in the current edition of Rob and Smith's *Operative Surgery*, also published by Butterworths, whereas other parts have appeared in *The Lancet*, the *British Journal of Surgery*, the *Annals of the Royal College of Surgeons of England*, *Surgery*, *Surgical Review I* and *Recent Advances*. The work on economics and administration has appeared in *The Lancet*, the *Health and Social Service Journal*, various Department of Health publications and, most importantly, the Royal College of Surgeons of England Guidelines for Day Case Surgery (1985).

I am grateful to the respective editors and authorities for permission to reproduce from these articles and in some cases to expand them. Hernias, their complications and their management continue to use much surgical resources; repair of a groin hernia is the commonest operation in males and the third commonest operation in British hospitals. Sadly, the results of hernia surgery are still far from ideal. Long hospitalisation spells, perioperative complications and, above all, unacceptable recurrence rates disfigure our surgical audit. Practically every book about hernias reiterates the cliché that too often the repair of a hernia is undertaken by the inexperienced or infrequent operator—the statement has added cogency in an era of healthcare cost containment and computerised medical records. It is now easy to compare durations of stay and complication rates and then, using record linkage, to identify the recurrence receiving treatment elsewhere some years later. You no longer need a surgical training to undertake this accounting of results! The results of hernia repair are improved by specialisation. The Shouldice Clinic in Toronto dictates the gold standard. The anatomical variations and technical difficulties of hernia surgery are such that the advisability of specialist hernia units, similar to the regional cardiothoracic units in the National Health Service, merits consideration. Whereas we can debate whether primary hernia repair should remain in the province of the 'general surgeon', recurrent and incisional hernia repairs demand extra skills and such cases should always be referred to experts. The prevention of iatrogenic, incisional hernia should be a priority for abdominal surgeons and gynaecologists, yet in all series of incisional hernioplasties, surgeon failure at the initial operation is often well documented.

The use of inappropriate suture material, sloppy technique, haematoma and sepsis are the all too frequent progenitors of the troublesome incisional hernia. In setting out my stall, 20 years' experience of hernia surgery, I acknowledge the influence of teachers, particularly the late Frederick Gill, PRCSI, who persuaded me to make myself a surgeon; Austin Marsden, FRCS, who convinced me there is a hernia problem; and Sir Hugh (Lyn) Lockhart-Mummery who taught me so much about surgical technique and its gentleness. To these gentlemen I owe a major debt. Caroline Doig, Allan Kark, Nick Barwell, James Bourke and Frank Glassow have all shared their experience and interest in hernia surgery with me. Percy Payne and

Maurice Down have explained all about trusses and demonstrated these appliances to me. Above all, these two gentlemen told me much of the history of British hernia surgery which has corrected my perspective of the recent past.

My colleagues in Stockton-on-Tees and in the North East have referred many of the more complex hernias to me, hernias that have presented technical challenges but afforded me new insights into the anatomy and pathology of hernia. Former junior colleagues have contributed greatly; P. Tiwari, Ranu Singh, A. K. Sahay, Dirk Muller, Denis Quill, Peter Gillen and Bruce Waxman deserve a mention. Permanent members of our department who have a major impact on my perception of hernia surgery include Laurence Rosenberg and Greg Rubin. Mary Fell has undertaken all our socio-economic interviewing and managed all our research into these fields. Irene Anderson has checked references and done a myriad of secretarial tasks. Elizabeth Clemo and her staff at North Tees Medical Library have undertaken all the library searches. The libraries of the Royal Society of Medicine and the Royal College of Surgeons of England have tracked down all the more difficult and obscure books I needed. Alexandra Maclean kindly checked and indexed the references for me.

The photographic work has been done by Ken Watson. Peter Gill and Elizabeth Dillon have undertaken numerous X-ray and ultrasound examinations of hernias for me over the years, and both deserve my particular thanks. Angus McNay and Katherine Denham have helped me with statistical problems. I thank Ron Lawler for the photomicrographs at the Department of Medical Photography at North Tees. The artwork is by Gillian Lee, and it has been a great pleasure to work with her. Surgery books are nothing without artwork; Gillian has put as much into this venture as I have. John Lunn advised me about anaesthesia and persuaded me about other aspects of hernia surgery and surgical audit. Former registrars have assisted me very generously in preparing the various drafts of the text: Simon Raimes, Nigel Fox, Stewart Nicholson, Tom Keane and Paul Stuart deserve my special thanks for their patience and tolerance in that task. The main burden of turning all this into a book has fallen to Julie Davies. She has painstakingly converted all my handwriting into neat typescript, word processed this and finalised the ultimate manuscript. Books need publishers and sub-editors; Butterworths have supported and encouraged me throughout the enterprise. My particular thanks go to John Harrison and to Bob Pearson for all the work they have undertaken. Lastly, and most importantly, my personal secretary, Anne Lindsley, has kept our surgical service on the road despite my involvement in this project. To all of these colleagues, and to many others, I must express my thanks for their help and enthusiasm.

Note on Terminology. Hernia repair, herniotomy, herniorrhaphy and hernioplasty are terms that are almost but not quite interchangeable. Herniotomy (Gk temnein, to cut), herniorrhaphy (Gk *rhaphe,* a seam) and hernioplasty (Gk *plassein*, to mould) connote slightly different meanings. Herniotomy is appropriate to the inguinal operation in children only and I have used it solely in that context. Otherwise, sometimes herniorrhaphy or sometimes hernioplasty is correct, but to switch terms about within the book makes reading difficult. I have, therefore, settled for hernioplasty throughout, perhaps realising that effective hernia surgery requires all the skills of tissue handling and repair that plastic surgeons so rightly emphasise.

Stockton-on-Tees, UK H. Brendan Devlin

Preface for Second Edition (1998)

This second edition reflects the rapidly changing world of hernia surgery since 1988. A new, younger author has participated fully in this new edition. Three events have precipitated the need for a new edition: the concept of the 'tension-free' repair introduced by Irving Lichtenstein, the revolution caused by the laparoscope and the increased role of economics in the contemporary cost-constrained healthcare system. The realisation from the work of Raymond Read, that underlying most, or all, abdominal wall hernias is a defect in the fascia transversalis and that this layer needs replacing, is the seminal advance of replacement by prosthetic mesh introduced by Lichtenstein. This has very important messages for hernia surgeons. Incorporation of this concept into everyday practice is a powerful reason why a new book about hernias is needed. The new biocompatible plastic meshes and the widespread adoption of mesh replacement repairs in hernia surgery is an important, almost revolutionary, development of contemporary surgery. The laparoscope and its need for a role has captured patients' and surgeons' imaginations and required some overview of the use of this tool in hernia repair. Coupled with this, added cogency has been given to questions of cost and outcomes in evaluation of laparoscopic surgery. The laparoscope makes this new edition inevitable.

There is now a consensus that money will always be limited for surgery and surgeons must perforce adopt cost-efficient and cost-effective surgery. These important conclusions are spelt out in the (Revised) Guidelines for Day Case Surgery issued by the Royal College of Surgeons of England in 1992. Above all, this new edition has benefitted from the resurgence of interest in the age-old problem of hernia surgery. The authors' friendship and conversations with many hernia surgeons worldwide are reflected in this new text. European surgeons Kark, Schumpelick, Paul, Nilsson, Stoppa and Kux; transatlantic surgeons Wantz, Gilbert, Skandalakis, Bendavid, Alexander and Rutkow; Indian surgeons Sahay, Doctor and Rajan; and many others worldwide have all indirectly participated in this work.

In this second edition, the artwork is again drawn by Gillian Lee. It has been an enormous pleasure for both of us to work with her. Elizabeth Clemo and the librarians at North Tees General Hospital and Tina Craig and Michelle Gunning of the Library, Royal College of Surgeons of England, have always very willingly helped find different texts for us. Our secretaries Valerie Peel and Jill Laurence have worked fabulously to put the manuscript into shape. Our publishers, especially Nick Dunton, have been a great support throughout the whole venture. Doreen Ramage, our senior production editor, has patiently guided us throughout; we thank her particularly. Finally, we have written the book together, so whatever its faults and omissions they are our failings alone.

Stockton-on-Tees, UK — H. Brendan Devlin
Plymouth, UK — Andrew N. Kingsnorth

Preface for Third Edition (2003)

The first edition of this book was a monograph written by the late H. Brendan Devlin and was a landmark in the scientific analysis of surgery of the abdominal wall, which discarded many of the older out-of-date concepts. We are heavily indebted to Brendan not only for providing the basis for this text but also for the inspiration to follow along a line of inquiry for evidence-based material to present to our readers. At the same time we have not neglected the importance of historical and economic aspects of hernia surgery and some of our own personal views.

Andrew Kingsnorth assisted Brendan in writing the second edition of this book, and Karl Le Blanc now adds an entirely new perspective from North America with particular emphasis on the use of prosthetic materials and laparoscopic techniques. We have thoroughly revised and added to all the chapters resulting in an increase in material of approximately 50% and the addition of hundreds more up-to-date references. We have also provided the reader with clear line drawings of operative techniques, photographs and several short video clips on CD. This extra effort should allow the reader the ability to adopt and apply much of the information and operative techniques that are presented. The technological revolution that began a decade ago, and still continues to evolve, has therefore been fully recognised in this text which we believe will appeal to surgeons in training and those already experienced in managing abdominal wall hernias. It is hoped that this work will be an effective reference to all those that possess this book.

Plymouth, UK — Andrew N. Kingsnorth
Baton Rouge, LA, USA — Karl A. LeBlanc

Preface for Fourth Edition (2013)

The literature in hernia surgery is vast, and keeping abreast of developments is a never-ending task that one or two individuals may find difficult to fit into their daily routine. With this in mind, for the fourth edition of this book, we have recruited selected experts to write each chapter, so that a ray of discerning knowledge is beamed into each crevice of the hernia story to create a comprehensive and authoritative text. A detailed description of the anatomy of the abdominal wall is of utmost importance and a primary concern for planning all hernia operations. Recent technical developments will influence our decision making now and in the future. More training is needed to increase awareness of a large number of prosthetic meshes, innovative plastic procedures and the appropriate use of biologic meshes. Each requires a thorough knowledge of the literature and outcomes research rather than the mere use of a technique or product because it is new and 'seems like a good idea'.

The long-term outcomes of our patients are now an area of important consideration and can no longer be overlooked in the discussion of consent prior to surgery. This discussion includes the issue of postoperative pain, quality of life, recurrence rates and cosmesis. Hernia science is a relatively new specialty, and its future will be defined by the introduction of 'physiologic' repairs and the prosthetic meshes used. Biologic products may be used for tissue replacement, for tissue reinforcement or simply as a 'bridge' to synthetic materials that will perform as good as or better than the biologic materials.

This text strives to introduce these concepts and to educate readers about the current state of the art in hernia surgery and to prepare them for future considerations of which we should all be aware at this point.

Plymouth, UK — Andrew N. Kingsnorth
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About the Editors

Karl A. LeBlanc MD, MBA, FACS, FASMBS, *General, bariatric and abdominal wall surgeon, Baton Rouge, LA, USA, 1984-present. Attended the Louisiana State School of Medicine in Shreveport, LA, and USA from 1974–1978, followed by a General Surgical Residency from 1978–1983. From 1983–1984, he returned to his hometown of Breaux Bridge, LA, USA but saw the need to pursue his career in a larger city. He remains active in the private practice of general surgery, specializing in herniology and bariatric surgery. He is Professor of Surgery at the Louisiana State School of Medicine Department of Surgery and Associate Medical Director of Surgery of the Our Lady of the Lake Physician Group.*

Born in a rural area of southern Louisiana known for its "Cajun" heritage, he pursued his undergraduate education in nearby Lafayette, LA at the University of Southwestern Louisiana. Even at that early age, he was interested in the medical field. During his surgical residency, the interest in hernia was sparked and this has been with him ever since. During this residency, he was able to become familiar with laparoscopic surgery and used it for diagnostic purposes. Once the laparoscopic era of general surgery began, he rapidly engaged in the advancement of this wonderful tool. His research led to his performance of the world's first laparoscopic incisional hernia repair in 1991.

He is a founding member of the Americas Hernia Society and has served as its President. He sits on the Editorial Board of the journals *Hernia* and the *Journal of the Society of Laparoendoscopic Surgery* and a peer reviewer for numerous national and international journals. He has lectured internationally on numerous topics. He has edited or co-edited five surgical texts, some of which has been translated into Turkish and Chinese. He has authored numerous articles and/or book chapter contributions. Research continues to be an area of interest and he serves a principal investigator of several projects at this time.

Andrew Kingsnorth JP, BSc (Hons), MB BS, MS, FRCS, FACS (1948-) *General, pancreatic and abdominal wall surgeon, Derriford Hospital, Plymouth, UK and Professor of Surgery Peninsula College of Medicine, 1996–2013. Qualified at the Royal Free Hospital School of Medicine in London in 1973 and undertook postgraduate training in Norwich, Oxford, Harvard, Edinburgh and Cape Town. Appointed consultant surgeon, senior lecturer and subsequently reader in surgery at the University of Liverpool (1987–1996) before moving to Plymouth.*

Born into the austerity of post-War Britain, Andrew was brought up in rural Kent and educated at Sevenoaks School where he acquired a lifelong interest in voluntary service and internationalism. He has been Arris & Gale Lecturer (1983) and Hunterian Professor (2007) at the Royal College of Surgeons of England. He is Past-President of the Pancreatic Society of Great Britain and Ireland, Founding President of the British Hernia Society, Past-President of the European Hernia Society and President of the Section of Surgery of the Royal Society of Medicine.

In 1993 he chaired the Royal College of Surgeons of England working party that introduced the first national *Guidelines for the Management of Adult Inguinal Hernia*. In 1998 he established the Plymouth Hernia Service, the first specialist hernia unit in a public hospital, and pioneered the Lichtenstein operation in the UK. In 2007, he was the first surgeon outside India to use low-cost mosquito net mesh for hernia repair in low-resource countries. With Dr. Ravindranath Tongaonkar (q.v.) and David Sanders (q.v.) he has carried out clinical and laboratory research to support the global use of mosquito net mesh hernioplasty. Andrew has championed the Chevrel (q.v.) prefascial, onlay incisional hernia repair with a series of over 500 cases.

Between 2001 and 2014, Andrew participated in over 30 humanitarian surgical missions to Eastern and Central Europe, Central Asia, The Far East, SE Asia, Africa and South America. In 2005 he established a Hernia charity which is now the largest and most active such organisation in the world (www.herniainternational.org.uk). In 2010, *The Times of London* in a survey of top doctors, noted that Andrew was "regarded as the UK's expert on hernias".

Andrew retired from academic and clinical practice in 2013, but continues to lecture occasionally and acts as Director of Hernia International.

David L. Sanders BSc(Hons), MBChB, FRCS, MD, PGDipMedEd, *received his undergraduate degree from the University of Edinburgh in 2003. He received postgraduate training in the South West of England and a trauma fellowship in South Africa. His doctorate thesis was on the influence of mesh and fixation techniques on infection in abdominal wall hernia repair. In 2016 he was appointed consultant upper GI surgeon and specialist in abdominal wall reconstruction at North Devon Hospital, Barnstaple, Devon, UK.*

David specializes in surgery of the gallbladder, anti reflux, hiatal surgery and hernia surgery. He is an internationally recognized expert in the field of abdominal wall reconstruction with numerous publications in the field of hernia surgery and several book chapters. He has given numerous invited lectures on the topic both nationally and internationally. David is on the board of the British Hernia Society, Chaired the National Institute for Clinical Excellence approved commissioning guidance for groin hernia, was involved in developing the RightCare patient decision aid for inguinal hernias and is on the European working group that developed the Abdominal Wall Closure Guidelines and the International Hernia Guidelines. David is the editor of the Bulletin of the Royal College of Surgeons of England.

Hugh Brendan Devlin CBE, MA, MD, MCh (Dublin), FRCS (England), FRCS (Ireland), FRCS (Edinburgh), FACS (1932–1998) *Consultant Surgeon, North Tees General Hospital, Stockton-on-Tees. Director, Surgical Epidemiology and Audit Unit, Royal College of Surgeons of England. Research Associate, Department of Surgery, University of Newcastle upon Tyne, Council Member, Royal College of Surgeons of England*.

Brendan pioneered the use of surgical audit. When he was appointed to Stockton-on-Tees in 1970 the hospital was run down and morale was low. Four years later, he commissioned the new North Tees General Hospital and worked hard to put it on the surgical map. This he did, by his reputation as a teacher and by his publications, which always dealt with common conditions. His first success was to organise better postoperative care for patients with colostomies. He became Chairman of the British Standards Institution Committee on Stoma Appliances and founded the British Colostomy Society.

Brendan's enduring interest however was in hernia and he was the most prominent exponent of the Shouldice tissue repair in the UK during the 1970s. Realizing that too often hernias were being repaired by partially trained juniors using techniques that had been proven to be inadequate, he set up a multi-centre audit of hernia surgery. This generated guidelines, innumerable publications and this classic textbook (initially a monograph), the second edition of which was written jointly with Andrew Kingsnorth (q.v.) and published shortly before his untimely death in 1998.

In 1982 together with John Lunn, Brendan set up the Confidential Enquiry into Perioperative Deaths (CEPOD). The study became a national one (NCEPOD), providing annual reports. The report on the management of emergency hernia surgery revealed preventable causes of perioperative deaths, such as lack of intensive therapy beds and lack of staff and resources at night. He was elected to the Council of the Royal College of Surgeons in 1986. There he set up and chaired the clinical audit committee. As Chairman of the examination committee he reformed FRCS examinations.

Brendan travelled widely to examine and to give lectures. He gave the Arris and Gale lecture in 1970, the Bradshaw lecture and oration in 1996, and a Hunterian oration in 1997. He was a member of many distinguished societies and on the editorial board of many prestigious surgical journals. He was appointed Commander of the British Empire (CBE) in 1994.

After his retirement he continued to work for the King's Fund on the commissioning of medical services in London and the organisation of audit.

Part I

General Topics

1 General Introduction and History of Hernia Surgery

Andrew Kingsorth and David L. Sanders

Ancient and Renaissance Hernia Surgery

The high prevalence of hernia, for which the lifetime risk is 27% for men and 3% for women [87], has resulted in this condition inheriting one of the longest traditions of surgical management. Descriptive anatomy of the anterior abdominal wall dates back over 6000 years, to the beginning of civilization, the Valley of the Nile and the ancient Egyptian papyri. These texts, often by unknown authors, were written in a time when medicine was magico-religious and the first steps in inductive reasoning were being taken. The Egyptians (1500 BC), the Phoenicians (900 BC) and the Ancient Greeks (Hippocrates, 400 BC) diagnosed hernia. During this period a number of devices and operative techniques have been recorded. Attempted repair was usually accompanied by castration, and strangulation was usually a death sentence. The word 'hernia' is derived from the Greek (hernios), meaning a bud or shoot. The Hippocratic school differentiated between hernia and hydrocele—the former was reducible and the latter transilluminable [88]. The Egyptian tomb of Ankh-ma-Hor at Saqqara dated to around 2500 BC includes an illustrated sculpture of an operator apparently performing a circumcision and possibly a reduction of an inguinal hernia [94] (Fig. 1.1). Egyptian pharaohs had a retinue of physicians whose duty was to preserve the health of the ruler. These doctors had a detailed knowledge of the anatomy of the body and had developed some advanced surgical techniques for other conditions and also for the cure of hernia. The mummy of the pharaoh Merneptah (1215 BC) showed a complete absence of the scrotum, and the mummified body of Rameses 5th (1157 BC) suggested that he had had an inguinal hernia during life with an associated faecal fistula in the scrotum and signs of attempts at surgical relief.

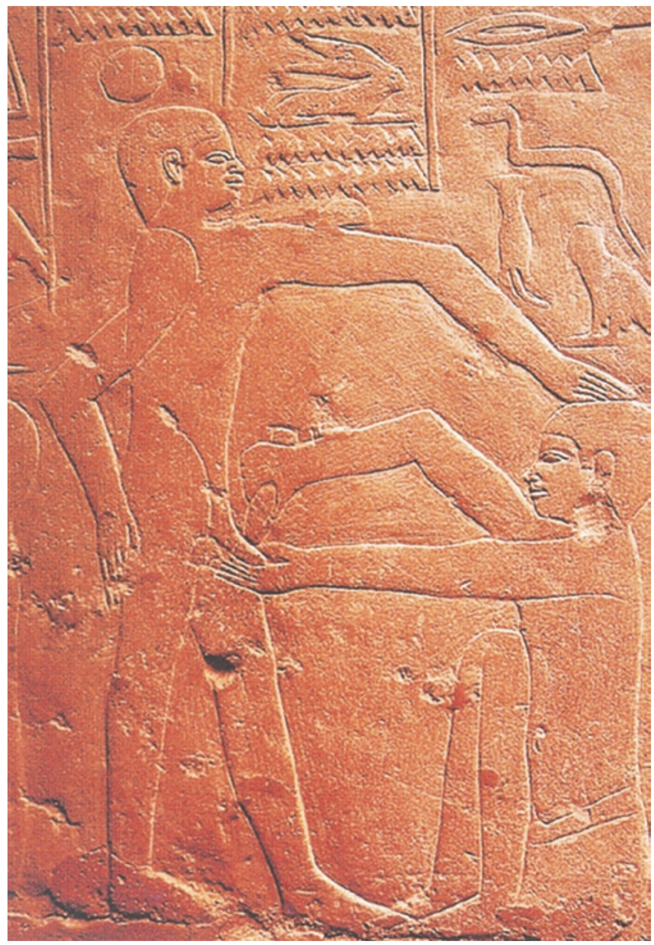

Fig. 1.1 Egyptian tomb of Ankhmahor (Saqqara). The operator (*bottom right*) rubs in something with an instrument and seems to perform a reduction of an inguinal hernia

Greek and Phoenician terracottas (Figs. 1.2 and 1.3) illustrate general awareness of hernias at this time (900–600 BC), but the condition appeared to be a social stigma, and other than bandaging, treatments are not recorded. The Greek physician Galen (129–201 AD) was a prolific writer and one of his treatises was a detailed description of the musculature of

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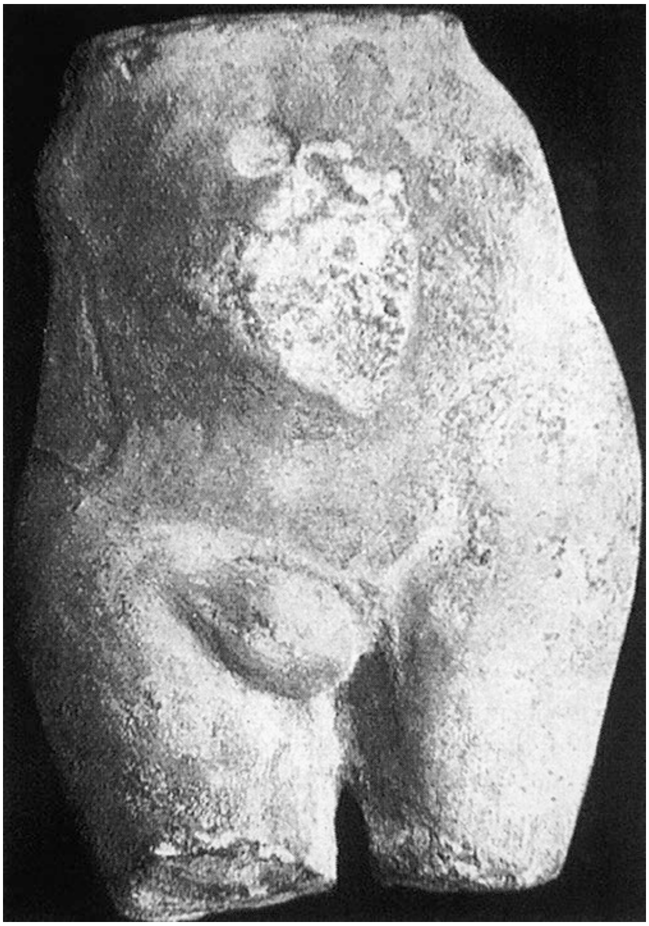

Fig. 1.2 Terracotta ex voto shows femoral hernia (from Geschichte der Medizin (1922))

Fig. 1.3 Phoenician terracotta figure (female) shows umbilical hernia (fifth–fourth century BC) (from Museo Arquelogico, Barcelona, Spain)

the lower abdominal wall in which he also describes the deficiency of inguinal hernia. He described the peritoneal sac and the concept of reducible contents of the sac.

Celsus (AD 40) was a prolific writer, and although he had no medical training, he documented in encyclopaedic detail the Roman surgical practice: taxis was employed for strangulation, trusses and bandages could control reducible hernia, and operation was only advised for pain and for small hernias in the young. The sac could be dissected through a scrotal incision, the wound then being allowed to granulate. Scar tissue was perceived as the optimum replacement for the stretched abdominal wall. A common method of treating hernia at this time was to reduce the contents of the sac and then attempt to obliterate it by a process of inflammation and gangrene by applying pressure to the walls of the sac through clamping the hemiscrotum between two blocks of wood. The last of the Graeco-Roman medical encyclopaedists, Paul of Aegina (625–900 AD), distinguished complete scrotal from incomplete inguinal herniation or bubonocele. For scrotal hernia, he recommended ligation of the sac and the cord with sacrifice of the testicle. Paul was the last of the great surgeons who wrote several books, which gave detailed descriptions of operative procedures including inguinal hernia.

Aulus Cornelius Celsus (first century AD) who first described the importance of surgical closure of the abdominal wall [104]. The procedure was termed 'gastrorrhaphy' originating from the Greek 'gastir' meaning abdomen and 'rhaphy' meaning suture. In fact, what Celsus was describing was a layered closure of the abdominal wall to prevent an incisional hernia. A century later, Aelius Galenus (Fig. 1.2), better known as Galen of Pergamon, a Roman of Greek origin and arguably the most prominent physician of the Greco-Roma period, provided a detailed description of mass closure of the abdominal wall [105]:

> In stitching the needle should be thrust from without inwards through skin and rectus muscle, and then from within outwards through the muscle and skin, repeating this until the wound is closed. Some operators include the peritoneum in the stitches, but this is not usual. The dressing should be soft wool dipped in oil moderately warm and cover the space between the flanks and armpit.

It seems that Galen was aware of the risk of incisional hernia following abdominal surgery, and he describes in detail the paramedian incisions, in order to prevent a hernia from developing [105], an incision which was used commonly until the late twentieth century:

> A wound in this situation is less dangerous than in the mid-line, since the thin aponeuroses are lacking. In the mid-line stitching is accomplished with difficulty and the intestines are more likely to protrude and be hard to replace.

The works of Galen were later translated into Latin and helped to form the basis of modern surgery.

The Middle Ages (AD500–AD1500)

In the Middle Ages, the notable techniques of Greco-Roman surgery were largely lost. This was an age of faith and scholasticism. During this period, different types of abdominal wall hernia were rarely differentiated. However, Arnaud de Villeneuve, a French physician and surgeon, described an epigastric hernia in 1285, and another Frenchman, Guy de Chauliac (1300–1368), wrote *De ruptura*, which classified different types of hernias and distinguished between umbilical and epigastric hernia; however in his classification, they were not given these names [106, 107].

The drawing of the Vitruvian Man by Leonardo da Vinci (circa 1487) is considered to be one of the world's greatest works of art. It is da Vinci's representation of ideal human proportions described by the ancient Roman architect Vitruvius in Book III of his treatise *De Architectura*. The left inguinal region of the Vitruvian Man demonstrates a spherical fullness above his groin, above and medial to the pubic tubercle. This corresponds to the classical manifestation of an inguinal hernia. Leonardo da Vinci made the drawing in the coronal plane to illustrate the geometrical dimensions of the human body through the observation of living subjects and cadaveric dissection [108] (Fig. 1.4).

During the dark time of the Middle Ages, there was a decline of medicine in the civilized world, and the use of the knife was largely abandoned, and few contributions were made to the art of surgery, which was now practised, by itinerants and quacks. With the rise of the universities such as the appearance of the school of Salerno in the thirteenth century, there was some revival of surgical practice [94]. At this time three important advances in herniology were made: Guy de Chauliac, in 1363, distinguished femoral from inguinal hernia. He developed taxis for incarceration, recommending the head-down, Trendelenburg position [58]. Guy was French and studied in Toulouse and Montpelier and later learned anatomy in Bologna from Nicole Bertuccio. Guy wrote extensively about hernia in his book Chirurgia principally about diagnosis and methods of treatment (Fig. 1.5). He described four surgical interventions, one of which was a herniotomy without castration, another consisting of cauterization of the hernia down to the os pubis and third consisting of transfixion of the sac to a piece of wood by a strong ligature. His fourth method however was conservative treatment with bandaging and several weeks of bed rest accompanied by enemas, bloodletting and special diet. At the time he was the authoritative expert on hernia.

Franco's book *Traites des Hernies* [61] standardized the practice of hernia surgery at the time and diminished the influence of the itinerant practitioners (Fig. 1.6). Franco popularized the punctum aurium and using this instrument made a small incision in the upper scrotum, isolated the hernia sac from the spermatic cord and then encircled it with a gold thread, thus sparing the testis. He chose gold thread because this was considered to be the best nonreactive material. In spite of the known hazards and high mortality of operating on a strangulated hernia, Franco advised early intervention and rejected the conservative measures employed such as bloodletting and tobacco enemas. As a result he saved numerous patients with life-saving operations. He wrote many up as case reports illustrating his management and surgical techniques. He recommended reducing the contents and closing the defect with linen suture (Fig. 1.7). His beautifully written manuscript was rediscovered and published again in 1925 by Walter van Brunn. As shown in the illustration, the unusual feature of the book was the patients posing in everyday attire as if they were going about their everyday life.

In 1559 Stromayr, a German surgeon from Lindau, published a remarkable contribution to surgery. His book *Practica Copiosa* describes sixteenth-century hernia surgery in great detail and is comprehensively illustrated. Stromayr differentiated direct and indirect inguinal hernia and advised excision of the sac and of the cord and testicle in indirect hernia [96]. Having differentiated and classified the two types of inguinal hernia, Stromayr recommended a testis sparing procedure for the direct type. His operation for high ligation of an indirect sac at the internal ring is illustrated in Fig. 1.8. Stomayr also advanced the technology of trusses, which he designed to be adapted to the rigours of everyday life. The Renaissance brought burgeoning anatomic knowledge, now based on careful cadaver dissection. William Cheselden successfully operated on a strangulated right inguinal hernia on the Tuesday morning after Easter 1721. The intestines were easily reduced and adherent omentum was ligated and divided. The patient survived and went back to work [54] (Fig. 1.9).

Without adequate interventional surgery, some patients survived hernia strangulation when spontaneous, preternatural fistula occasionally followed infarction and sloughing of a strangulated hernia. Cheselden's Margaret White survived for many years 'voiding the excrements

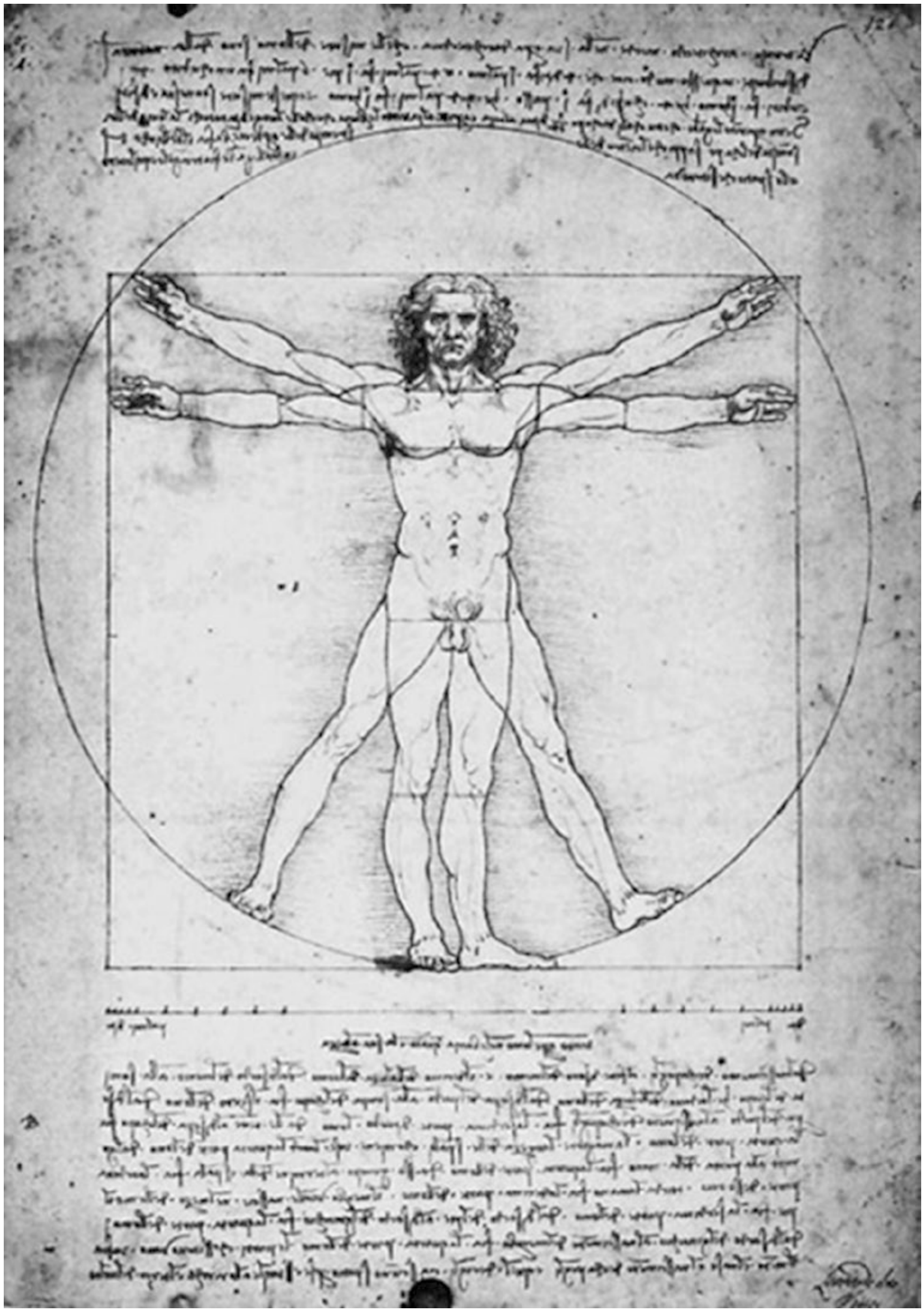

Fig. 1.4 Vitruvian Man (from Ashrafian)

through the intestine at the navel' after simple local surgery for a strangulated umbilical hernia [54]. The closure of such a fistula in the absence of distal bowel pathology was described by Le Dran, who had noted that it was quite common for poor people with incarcerated hernias to mistake the tender painful groin lump for an abscess and incise it themselves. He found that these painful wounds with faecal fistulas required no more than cleaning and dressing. Often the wound would heal, nature preferring to send the faeces along the natural route to the anus [72] (Fig. 1.10).

The Anatomical Era

The great contribution of the surgical anatomists was between the years 1750–1865 and was called the age of dissection [94]. The main contributors were Antonio Scarpa

Fig. 1.5 The visit of surgical patients in Chirurgia. Guy de Chauliac, fifteenth-century manuscript (from the Bibliothèque Nationale, Paris, France)

and Sir Astley Cooper and few major advances in our knowledge of the anatomy of the groin have been made since this time. The names of these great anatomists are Pieter, Camper, Adrian van der Spieghel, Antonio Scarpa (Fig. 1.11), Percival Pott, Sir Astley Cooper, John Hunter, Thomas Morton, Germaine Cloquet, Franz Hesselbach, Friedrich Henle and Don Antonio Gimbernat.

The Dutchman Camper was a polymath who described a fascia, which is sandwiched in between the skin and deep fascia and can only be separated from this fascia below the inguinal ligament where the space between them accommodates lymph glands and cutaneous vessels of the groin. Below the external ring, Camper's fascia becomes the dartos muscle of the scrotum, which like the platysma is a muscle of the superficial fascia. Camper was the author of the definitive surgical text on hernia. Camper also contributed to anatomical descriptions of the foot, upper limb and axilla. His explanation of the aetiology of inguinal hernias significantly affected surgical practice at the time [109].

Adrian van der Spieghel (1578–1625) was educated at the University of Padua, and he occupied the chairs of anatomy at the University of Modena and later Pavia. He was Flemish

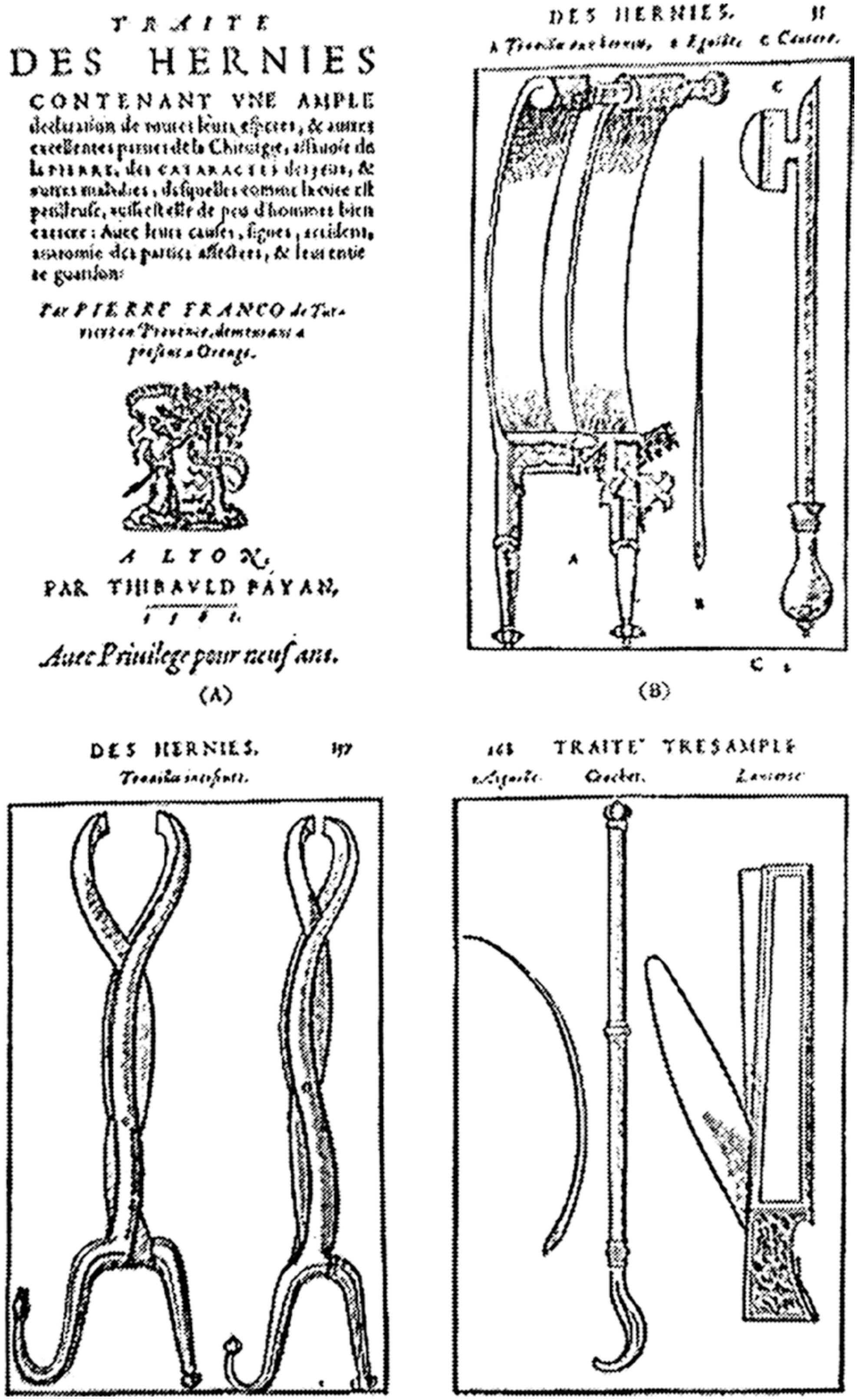

Fig. 1.6 Frontispiece and surgery instruments in Traités des Hernies (by Pierre Franco, Vincent, Lyon [61])

and another polymath. He was privileged to have two of the most accomplished anatomists of that period, Fabricius ab Aquapendente and Yulius Casserius, as his teachers. He first described Spiegel's lobe (caudate lobe) of the liver and the linea semilunaris (Spiegel's line) on the lateral side of the rectus abdominis muscle. Spigelian hernia (lateral ventral

Fig. 1.7 Woman with femoral hernia. In Die Handschrift des Schmitt- und Augenartztes. Caspar Stromayr (by Walter von Brunn (1925))

Fig. 1.8 The dissection of the sac and cord in an indirect hernia, carried to the level of the internal ring (in von Brunn (1925))

hernia) was named after him. He was a renowned physician in his time and was the first to give a detailed description of malaria. He made significant contributions as a botanist: the genus *Spigelia*, which has six species, is named after him [110].

Sir Percival Pott described the pathophysiology of strangulation in 1757 and recommended surgical management (Fig. 1.12): 'I am perfectly satisfied that the cause of strangulated hernia is most frequently a piece of intestine (in other respects sound and free of disease) being so bound by the said tendon, as to have its peristaltic motion and the circulation through it impeded or stopped' [86]. Pott was trained at St Bartholomew's Hospital and wrote the manuscript *A Treatise on Rupture*. This publication brought him into conflict with the Hunters who accused him of plagiarism for his description of congenital hernia, which they claimed to have described 2 years previously. He emphasized that the hernia sac was peritoneum continuous with the general peritoneal

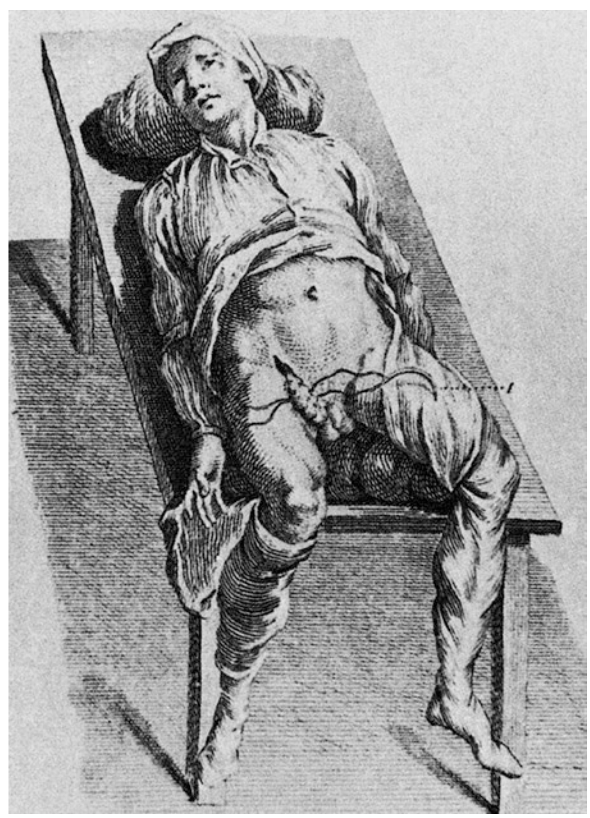

Fig. 1.9 Ligation of strangulated omentum in a strangulated right scrotal hernia. The wound then granulated. The patient survived and the hernia did not recur (operation by Cheselden in 1721 [7])

Fig. 1.10 Development of a preternatural colon fistula (colostomy) after strangulation of an umbilical hernia. The wound was trimmed. The patient survived many years 'voiding' the excrements at the umbilicus (operation by Cheselden about 1721 [7])

cavity and had not been in any way ruptured or broken, which until that time was the popular theory of causation of hernia.

Fifty years later Astley Cooper (Fig. 1.13) implicated venous obstruction as the first cascade in the circulatory failure of strangulation: 'By a stop being put to the return of blood through the veins which produces a great accumulation of this fluid and a change of its colour from the arterial to the venous hue.' Nevertheless ligature, the insertion of setons and castration remained the mainstays of treatment prior to the publication of Astley Cooper's monograph in 1804 [56] (Fig. 1.14). Sir Astley Cooper (1768–1841) trained at St Thomas' Hospital, London, and became a surgeon at Guy's Hospital and from 1813 to 1815 was Professor of Comparative Anatomy of the Royal College of Surgeons. Cooper published six magnificent books, two of which covered the subject of hernia, which were liberally illustrated by his own hand from dissections he had performed personally. Cooper was a charismatic lecturer and socialite and had an

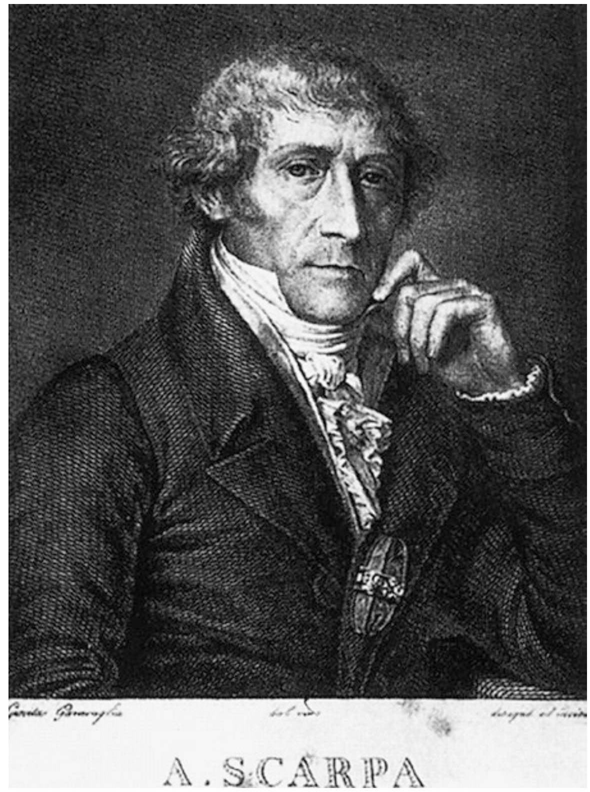

Fig. 1.11 Antonio Scarpa (1752–1832) professor of surgery and anatomy in Pavia, Italy

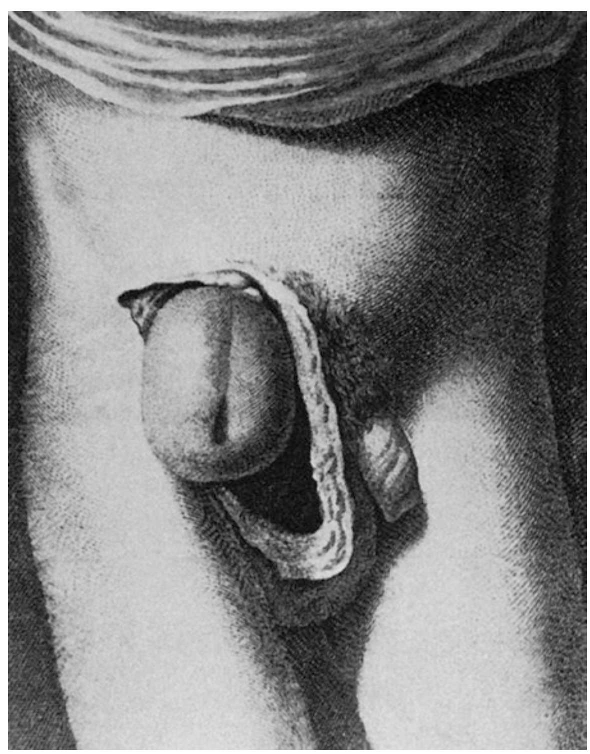

Fig. 1.12 Intestine strangulated by the 'tendon' so that the venous circulation through it is stopped, leading to gangrene (described by Pott in 1757 [9])

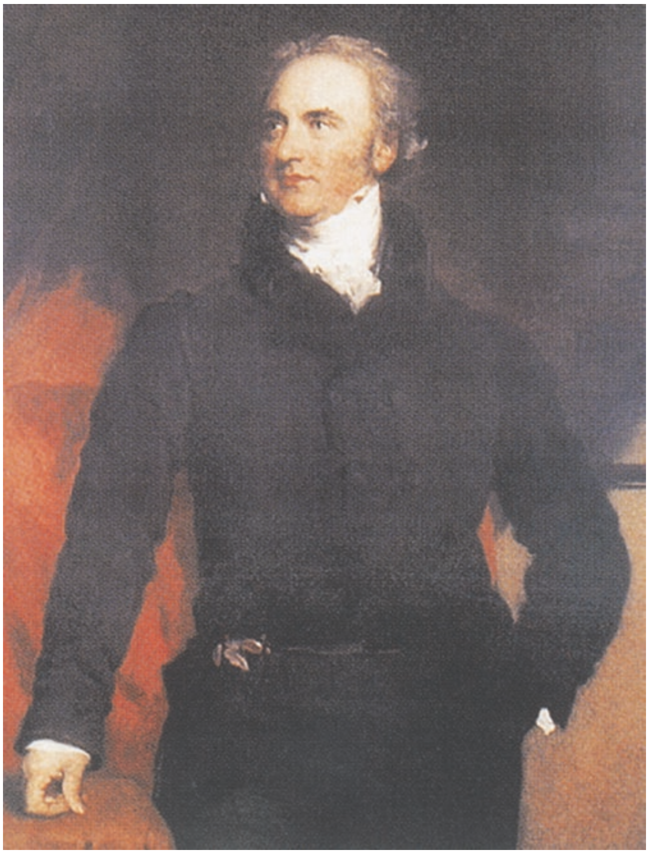

Fig. 1.13 Sir Astley Paston Cooper (1768–1841). Surgical anatomist, London, England

extensive surgical practice, which included being sergeant surgeon to King George IV. Cooper's recognition of the transversalis fascia positions him as one of the most important contributors to present day surgery which emphasizes this layer as being the first layer to be breached in groin hernias.

John Hunter (1728–1793) was born in Glasgow but became a pupil at St Bartholomew's Hospital to Percival Pott and later served as a surgeon at St George's Hospital where he established his well-known anatomy lessons and later the Hunterian museum which is now housed in the Royal College of Surgeons of England. Hunter's contribution was to define the role of the gubernaculum testis that directed the descent of that organ with the spermatic vessels into the scrotum around the time of birth. Thomas Wharton (1813–1849) also a London surgeon working at the North London Hospital, in his short life wrote three anatomical texts, two of which were the subject of inguinal hernia and the groin. He first gave an accurate description of the conjoined tendon of the internal oblique and transversus muscles and their termination and attachment to the outer portion of the rectus sheath.

The first accurate description of the iliopubic tract, an important structure utilized in many sutured repairs for inguinal hernia, was made by Jules Cloquet (1790–1883). Cloquet

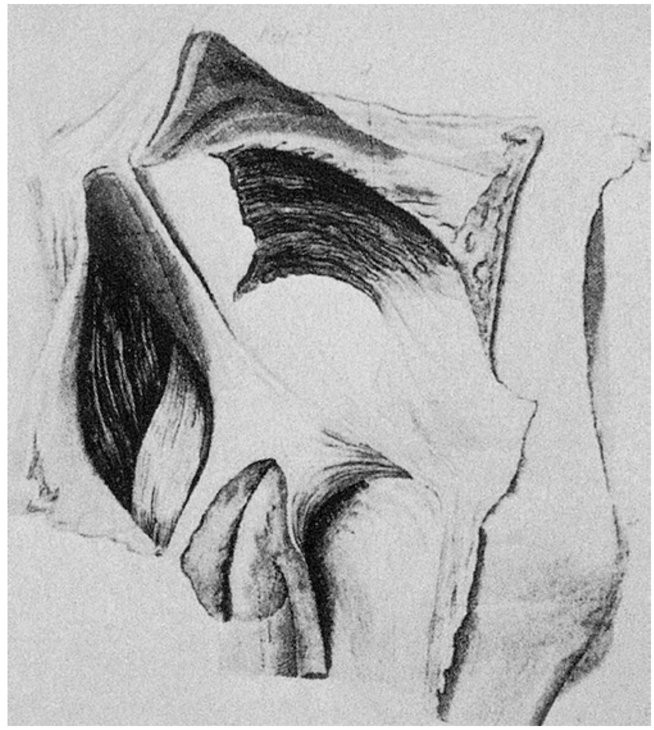

Fig. 1.14 Anatomy of the fascia transversalis. Cooper [56] demonstrated the fascia extending behind the inguinal ligament into the thigh to be the femoral sheath. He first recognized the fascia transversalis and its importance in groin herniation

was Professor of Anatomy and Surgery in Paris and surgeon to the Emperor. Cloquet researched the pathological anatomy of the groin in numerous autopsy dissections and their reconstruction in wax models. He was the first to observe the frequency of patency of the processus vaginalis after birth and its role in the production of a hernia sac later in life. Franz Hesselbach was an anatomist at the University of Wurzburg who described the triangle now so important in laparoscopic surgery which originally defined the pathway of direct and external and supravesical hernias (Fig. 1.15). The triangle as defined today is somewhat smaller. Friedrich Henle (1809–1885) was another German latterly working in the University of Gottingen. Henle described an important ligament running from the lateral edge of the rectus sheath and fusing with the pectineal ligament. This structure when present could be utilized to anchor sutures in herniorrhaphy. Finally Don Antonio Gimbernat (1742–1790) was a Spanish surgeon working in Barcelona and also surgeon to King Charles III and President of the College of Surgeons of Spain. Gimbernat not only defined the lacunar ligament as a distinct anatomical structure but also showed how its division in strangulated femoral hernia was usually the point of obstruction and allowed reduction of the contents of the sac. His publication *Nuevo metodo de operar en la hernia crural* was translated from Spanish into English by Thomas Beddoe 2 years later with additional plates for his new method of operating on femoral hernia.

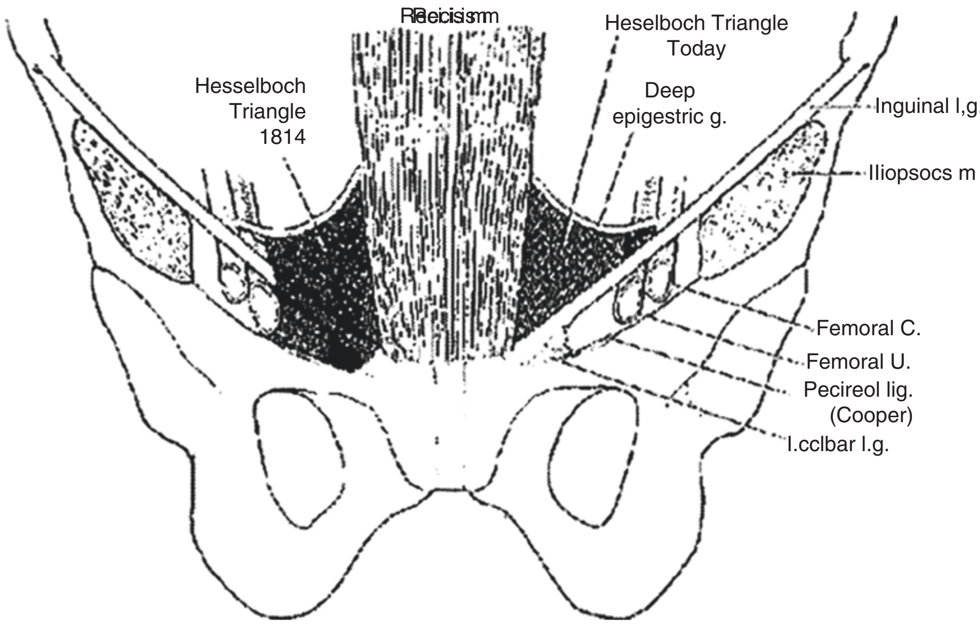

Fig. 1.15 The triangle of Hesselbach described in 1814, and as understood today. In Hernias (by Skandalakis et al. (1983))

From his careful anatomical study in the inguinal region, he made a detailed description of the lacunar ligament, which John Hunter called Gimbernat's ligament in his honour. Gimbernat was also a radical surgical educator and health services innovator of the Enlightenment [111].

The Era of Antisepsis and Asepsis

Before bacteria were recognized and simultaneously the need for meticulous cleanliness in the environment of the operating theatre, postoperative sepsis was virtually routine and mortality rates extremely high. Oliver Wendell Holmes in 1842 and Semmelweiss in 1849 emphasized the importance of hand washing before operating. However, identifying and understanding the problem of infection and the causal bacteria, had to await the discoveries of Louis Pasteur which were later put into practice by Joseph Lister (1827–1912). The application of Lister's principles of providing clean linen and special coats, special receptacles for antiseptic dressings, cleansing sponges soaked in carbolic acid and thymol and the segregation of post-mortem examinations and operating theatres profoundly influenced British and European surgeons and decimated postoperative infection rates. Modern surgery commenced with Lister's discoveries [74].

Other important innovations were acquired before operative surgery presented a minimal danger to the patient. Ernst von Bergman invented the steam sterilizer in 1891 and introduced the word 'aseptic'. Halsted with the nurse Caroline Hampton introduced rubber gloves in 1896, and together with the introduction of a face mask by von Miculicz, the conversion from antiseptic to aseptic technique was finally set for the techniques of modern hernia surgery to develop [59].

The Dawn of Anaesthesia

The removal of pain during surgical operations not only eliminated the terror of the surgical operation from the patient but also enabled more careful anatomical dissection and reconstruction and the evolution of planned surgical procedures [94]. An American dentist Horace Wells pioneered the use of nitrous oxide as an anaesthetic, but his first public attempt at demonstrating a painless dental extraction was a failure. It was left to his associate William Thomas Green Morton to demonstrate the first successful anaesthetic using sulphuric ether in the theatre of the Massachusetts General Hospital in Boston. The operation on Edward Gilbert Abbott was for removal of a tumour angioma in the neck. Following this demonstration on 16 October 1846, the practice spread widely into Europe, and Listen in London used it for a thigh amputation on Frederick Churchill on 21 December 1846. With patients no longer fearing pain, the scene was set for the great technological advances of the second half of the nineteenth century.

The Technological Era

Initial surgical attempts at hernioplasty were based on static concepts of anatomic repair using natural or modified natural materials for reconstruction. Wood [103] described subcutaneous division and suture of the sac and fascial separation of the groin from the scrotum. Czerny (1876), in Prague, pulled the sac of an inguinal hernia through the external ring, ligated it, amputated the redundant sac and allowed the neck to spring back to the deep ring [57]. MacEwen [79], of Glasgow, bundled the sac up on itself and stuffed it back along the

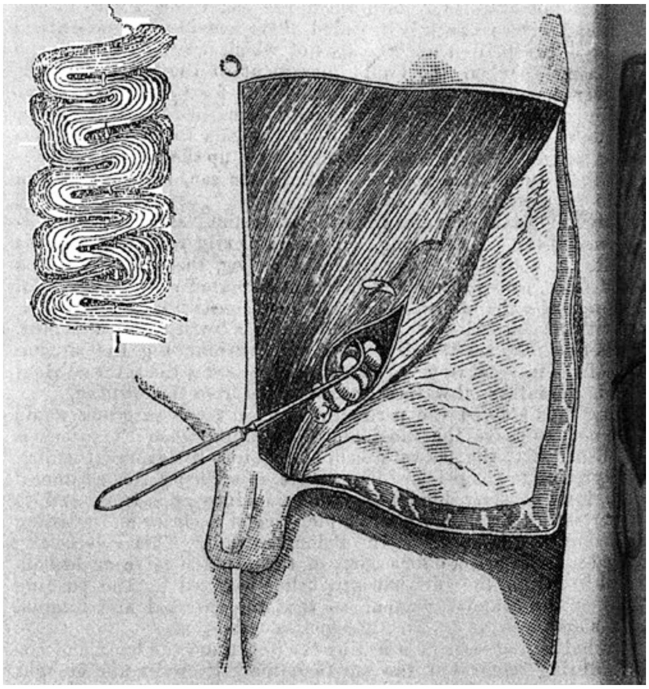

Fig. 1.16 The operation of McEwan 1886. The dissected indirect sac is bundled up and then used as an internal stopper or pad to prevent further herniation along the valved canal

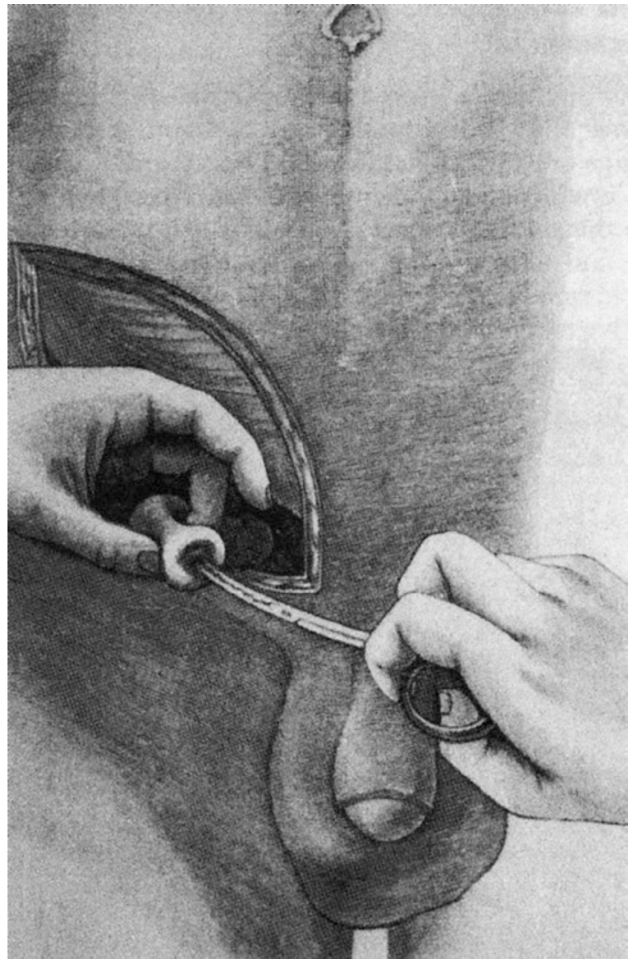

Fig. 1.17 Invagination of the sac which is fixed laterally by suturing its stump to the external oblique. No formal dissection or repair of the deep ring was made (operation by Kocher in 1907)

canal so that it would act as a cork or tampon and stop up the internal ring (MacEwan 1886) (Fig. 1.16). Kocher [70], surgery's first Nobel Prize winner, invaginated the sac on itself and fixed it laterally through the external oblique [70] (Fig. 1.17). Suffice to say, none of these operations has stood the test of time.

As so often in surgery, a new concept was needed before further progress could be made in herniology. Two (Figs. 1.18 and 1.19) pioneers—the American Marcy [80] and the Italian Bassini (1884)—vie for priority for the critical breakthrough [46–48]. Both appreciated the physiology of the inguinal canal, and both correctly understood how each anatomic plane, the transversalis fascia, transverse and oblique muscles, and the external oblique aponeurosis, contributed to the canal's stability. Read, having carefully surveyed all the evidence, agrees with Halsted [65, 67] that Bassini got there first [89].

Although both contributed to herniology, Bassini made another seminal advance when he subjected his technique to the scrutiny of the prospective follow-up. The paper of Bassini [48] is truly a quantum leap in surgery; indeed, if it is read alongside the contribution of Haidenthaller, from Billroth's Clinic—reporting a 30%, early recurrence rate—which appears in the same volume of Langenbeck's Archiv fur Klinische Chirurgie, Bassini's stature is further enhanced [64].

Marcy directed his attention to the deep ring in the fascia transversalis; his operation for indirect inguinal hernia entailed closure of the deep ring with fascia transversalis only, the object being the recreation of a stable and competent deep ring. In 1871 he reported two patients operated on during the previous year 'in which I closed the (deep) ring with the interrupted sutures of carbolized catgut followed by permanent cure' [81].

Bassini had become interested in the management of inguinal hernia in about 1883, and from 1883 to 1889, he operated on 274 hernias. After trying the operations of Czerny and Wood, he modified his approach and attempted a radical cure, so that the patient would not require a truss after surgery. He decided to open the inguinal canal and approach the posterior wall of the canal; gradually he was focusing onto the deep ring and fascia transversalis. Seven times he opened the canal, resected the sac and closed the peritoneum at the internal ring. He then constructed a tampon of the excess sac at the internal ring and sutured this sac stump, or tampon, to the deep surface of the external oblique. One of his seven patients died 3 months after the operation from an unrelated cause. Post-mortem examination showed the

Fig. 1.18 Henry Orville Marcy (1837–1924), Boston surgeon, anatomist, and philanthropist. The first American student of Lister (courtesy of the New York Academy of Medicine Library)

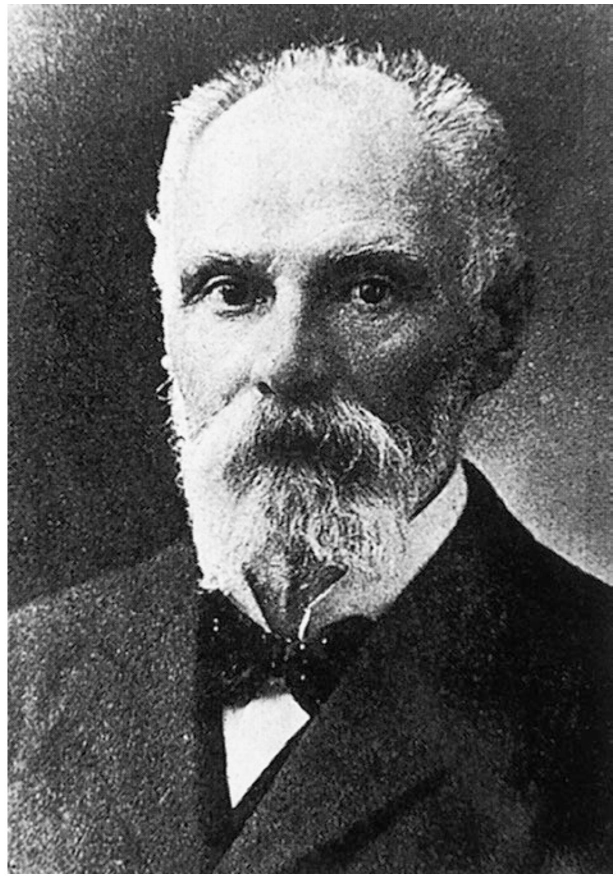

Fig. 1.19 Edoardo Bassini (1844–1924) invented the first successful inguinal hernioplasty

sutured portion of the neck, the 'stopper' or tampon, to be completely reabsorbed. Bassini deduced that although the risk of recurrent herniation was diminished by this technique, it did not afford adequate tissue repair; and some external support—a truss—would still be needed to prevent recurrence. He now proceeded to complete anatomical reconstruction of the inguinal canal.

> This might be achieved through reconstruction of the inguinal canal into the physiological condition, a canal with two openings one abdominal the other subcutaneous and with two walls, one anterior and one posterior through the middle of which the spermatic cord would pass. Through a study of the groin, and with the help of an anatomical knowledge of the inguinal canal and inguinal hernia, it was easy for me to find an operative method, which answered the above described requirements, and made possible a radical cure without subsequent wearing of a truss. Using the method exclusively I have, during the year 1884, operated on 262 hernias of which 251 were either reducible or irreducible and 11 strangulated.

His series included 206 men and 10 women; the non-strangulated cases were 115 right, 66 left and 35 bilateral inguinal hernias. The age range was 13 months to 69 years. The operations were performed under general narcosis and there were no operative deaths; however, three patients who each had strangulated hernias died postoperatively—one of sepsis, one of shock and one of a chest infection. Bassini's patients were carefully followed up, some to 4¾ years, and seven recurrences were recorded. There were, in fact, eight recurrences; Bassini failed to tabulate case 65, a 54-year-old university professor in Padua with a strangulated right direct inguinal hernia, with a recurrence at 8 months. The wound infection rate was 11 in 206 operations, and the time to healing averaged 14 days [48]. These statistics compare favourably with reports made up to the 1950s.

Bassini dissected the indirect sac and closed it off flush with the parietal peritoneum. He then isolated and lifted up the spermatic cord and dissected the posterior wall of the canal, dividing the fascia transversalis down to the pubic tubercle. He then sutured the dissected conjoint tendon consisting of the internal oblique, the transversus muscle and the 'vertical fascia of Cooper', the fascia transversalis, to the posterior rim of Poupart's ligament, including the lower lateral divided margin of the fascia transversalis. Bassini stresses that this suture line must be approximated without difficulty; hence the early dissection separating the external oblique from the internal oblique must be adequate and allow good development and mobilization of the conjoint tendon (Fig. 1.20).

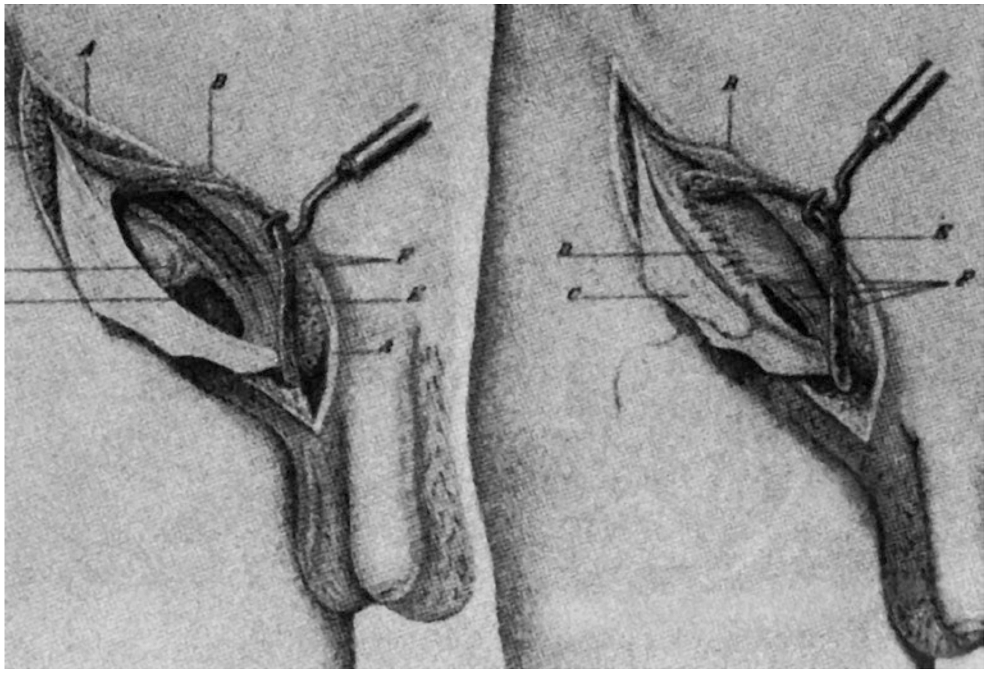

Fig. 1.20 Suturing the 'triple layer' (F) (fascia transversalis, transversus tendon and internal oblique) to the upturned edge of the inguinal ligament. An anatomical and physiological repair of the posterior wall of the inguinal canal preserving its obliquity and function (operation by Bassini in 1890 [20])

The Bassini legacy was popularized by Attilio Catterina, Bassini's assistant in Padua in 1887 who later became professor in Genoa in 1904. Catterina was entrusted by Bassini to teach the exact surgical technique. To do this he wrote an atlas of *The Operation of Bassini*! This adds 16 life-sized colour plates by the artist Orazio Gaicher of Cortina. This book was published in London, Berlin, Paris and Madrid in the 1930s and described in detail the uncorrupted Bassini technique, especially the division of the transversalis fascia, resection of the cremaster muscle and complete anatomical survey of all the relevant anatomy nowadays considered so essential [50, 51]. This represented a foretaste of the Shouldice operation [99, 100]. The illustrations show quite clearly that Bassini resected the cremaster muscle (Fig. 1.21) and completed division of the posterior wall of the inguinal canal (Fig. 1.22). The Shouldice and Bassini hernioplasties are therefore essentially the same.

By contrast, Haidenthaller, from Billroth's Clinic in Vienna, reported 195 operations for inguinal hernia, with 11 operative deaths and a short-term recurrence rate of 30.8% [64]. Although Halsted made important contributions to herniology, his general technical contributions of precise haemostasis, absolute asepsis and the crucial importance of avoiding tissue trauma are easily overlooked. Halsted was always concerned to achieve optimum wound healing, and he not only practiced surgery but he experimented and theorized. His observation on closing skin wounds is best repeated verbatim: 'The skin is united by interrupted stitches of very fine silk. These stitches do not penetrate the skin, and when tied they become buried. They are taken from the underside of the skin and made to include only its deeper layers—the layers which are not occupied by sebaceous follicles' [65–68]. In today's world haematoma, sepsis and damaged tissue leading to delayed healing mean not only a poor surgical outcome but weigh heavily on the debit side of any economic evaluation. These Halstedian principles should be rigidly applied by any surgeon who undertakes hernia surgery.

Halsted must also be given priority for recognizing the value of an anterior relaxing incision, first described by Wolfler in 1892 [102] and subsequently popularized in the USA by Rienhoff [90] and in England by Tanner [98]. Apart from Halsted, countless other authors have corrupted or simplified the original Marcy-Bassini concept of a review of the posterior wall of the canal and the correction of any deficits in it, the reconstruction of the patulous deep ring for indirect herniation and the repair of the stretched fascia transversalis in cases of direct herniation. Bull and Coley independently sutured the internal oblique and the aponeurosis over the cord [49, 55], whereas Ferguson [60] advised against any mobilization of the cord and, therefore, any review of the posterior wall of the canal: Ferguson [60].

Imbrication, or overlapping, of layers was introduced by Wyllys Andrews in 1895 in Chicago [43]. Andrews confessed that his technique was an outgrowth of experience with MacEwan, Bassini, Halsted and similar operations. Andrews laid great stress on careful aseptic technique: 'Finally, I unite the skin itself with a buried suture which does not puncture any of its glands or ducts'. Andrews used cotyledon only as a dressing. Again the importance of careful surgical technique is emphasized. Andrews stressed the importance of the posterior wall of the canal: 'The posterior

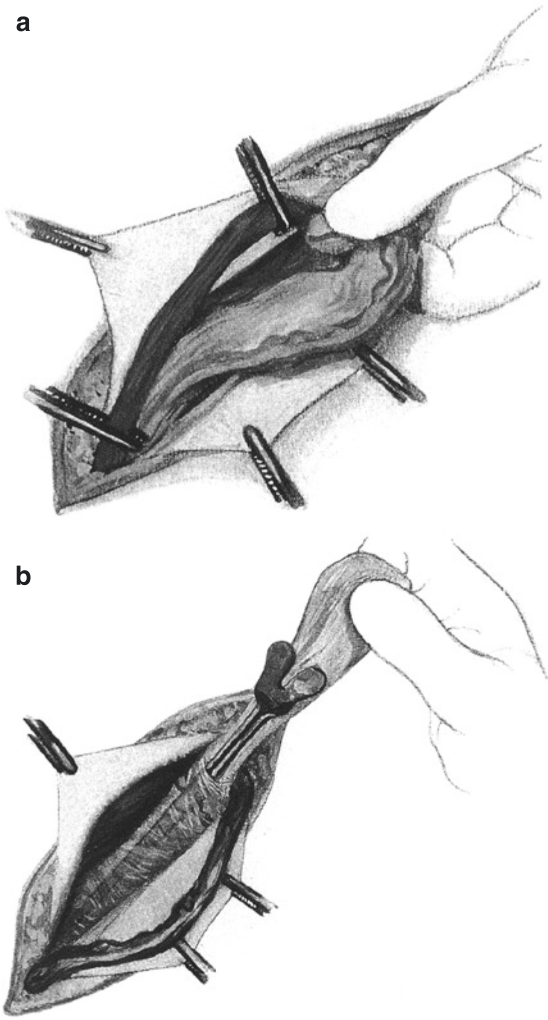

Fig. 1.21 (**a**) Bassini completely isolated and excised the cremaster muscle and its fascia from the cord. He thus ensured complete exposure of the deep ring and all the posterior wall of the inguinal canal, an essential prerequisite to evaluate all the potential hernial sites. (**b**) Bassini stressed the complete exposure and incision of the fascia transversalis of the posterior wall of the inguinal canal. To complete the repair, he sutured the divided fascia transversalis, together with the transversus muscle, and the internal oblique muscle, 'the threefold layer', to the upturned inner free margin of the inguinal ligament [24]

wall of the canal is narrowed by suturing the conjoined tendon and transversalis fascia firmly to Poupart's ligament'. Andrews recommended the kangaroo tendon introduced by Marcy. Andrews then reinforced the posterior wall with the upper (medial) margin of the external oblique aponeurosis, which he drew down behind the cord and sutured to Poupart's ligament. Andrews' intention was to interlock or imbricate the layers. The lower (lateral) flap of the external oblique aponeurosis was then brought up anterior to the cord. Andrews concluded his article: 'Any successful method of radical cure must be a true plastic operation upon the musculo-aponeurotic layers of the abdominal wall. Cicatricial tissue and peritoneal exudate are of no permanent

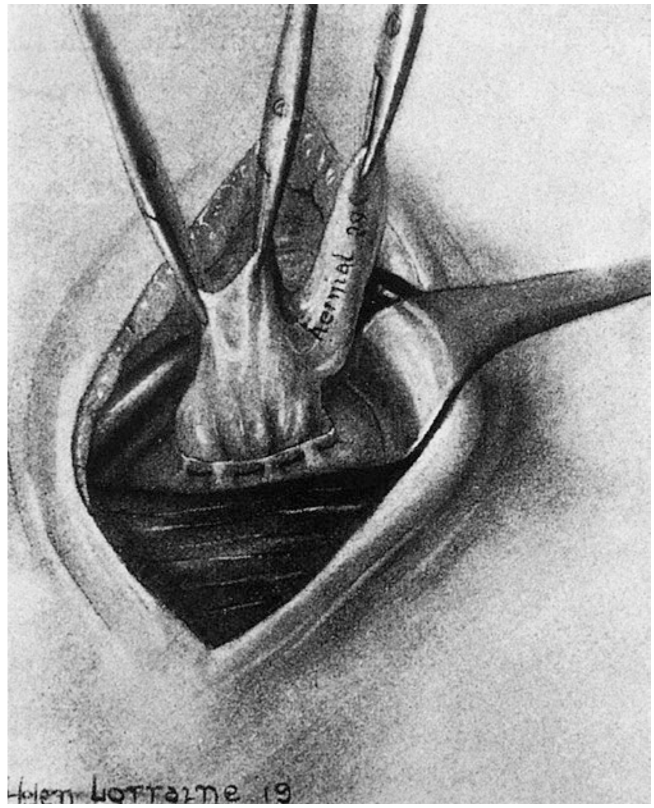

Fig. 1.22 Transabdominal approach to the groin through a muscle-splitting incision above the inguinal canal with subsequent closure of the peritoneal sac away from the canal

value'. Andrews had visited Bassini in Padua on several occasions to acquaint himself with the revolutionary operation. However, in his future descriptions of the operation, Andrews failed to mention that Bassini had divided the posterior wall of the inguinal canal, and these erroneous observations were passed on to a generation of European and American surgeons because Catterina's atlas was not published in Europe until the 1930s. Andrews description of Bassini's operation was therefore the only definitive description and the classical Bassini operation became corrupted until it was reintroduced as the Shouldice operation in the 1950s.

Perhaps we should pause at about 1905 and summarize what empiricism had achieved thus far. First, all authors agree that division of the neck of the sac and flush closure of the peritoneum is imperative to success. Second, dissection of the deep ring with exploration of the extraperitoneal space to allow adequate closure of the fascia transversalis anterior to the peritoneum emerges as a cardinal feature. Marcy and Bassini stress the fascia transversalis repair, Halsted emphasized it, and Andrews' diagram suggests it. Ferguson did not examine the entire posterior wall, but tightened the internal ring lateral to the emergent cord. All are agreed that the deep ring is patulous in indirect herniation, and consequently the fascia transversalis must be repaired. In the English literature, Lockwood in 1893 clearly emphasized the fascia transversalis and Bassini's 'triple layer'. Lockwood obtained good results by repairing this important layer [75, 76]. Third, preservation of the obliquity of the canal is suggested by Marcy and Bassini, and by the later Halsted and Bloodgood papers.

Fourth, double breasting (imbrication) of aponeurosis gives improved results and is recommended by Andrews. Lastly, all the authors stress careful technique. Avoidance of tissue trauma, haematoma and infection leads to impressively better results. Sepsis is an important antecedent of recurrence.

After the nineteenth-century advances of Marcy and Bassini, and the important contribution to surgical technique by Halsted, little of major importance was contributed until the 1920s. Countless modifications of Marcy's and Bassini's operations were made and reported frequently. The Bassini operation re-emerged as the Shouldice repair in 1950s (Fig. 1.23). Earl Shouldice (1890–1965) also promulgated the benefits of early ambulation and opened the Shouldice Clinic, a hospital dedicated to the repair of hernias to the abdominal wall. A huge experience accumulated with an annual throughput of 7000 herniorrhaphies per year enabled the surgeons at the Shouldice Clinic to study the pathology in primary and recurrent hernias and to emphasize adjuncts to successful outcomes. Continuous monofilament wire was used in preference to other suture materials, and the hernioplasty incorporated repair of the internal ring, the posterior wall of the inguinal canal and the femoral region. The cremaster muscle and fascia with vessels and genital branch of genitofemoral nerve were removed, and the posterior wall after division was repaired by a four-layer imbrication method using the iliopubic tract as its main anchor point. The landmark publication with long-term follow-up was produced by Shearburn and Myers in 1969, and from this time until the introduction of mesh, the Shouldice operation became the gold standard for inguinal hernia repair [92].

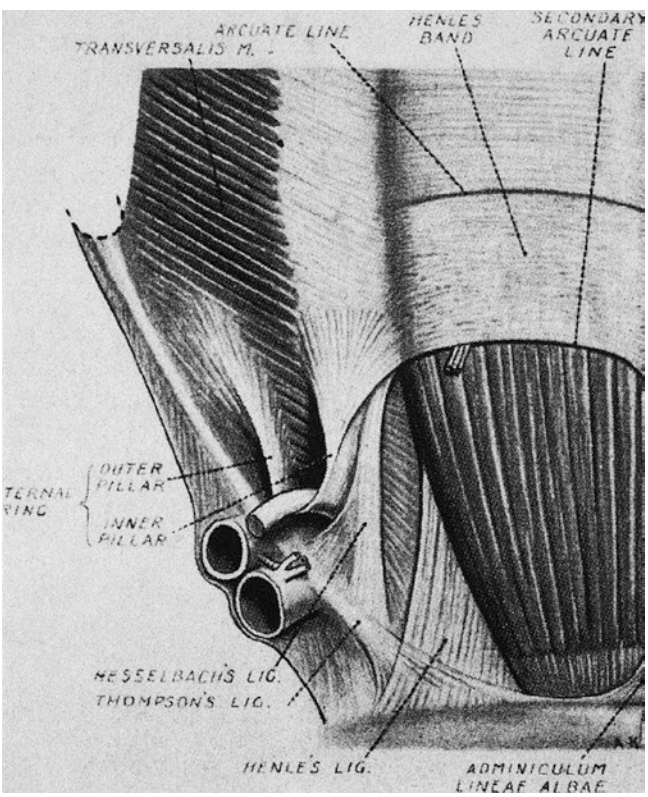

Fig. 1.23 The 'shutter mechanism' of canal and the internal anatomy of the deep ring, demonstrating the sling of fascia transversalis which pulls the deep ring up and laterally when the patient strains [50]

The Extraperitoneal: Preperitoneal Approach to the Groin

Alternatives to the anterior (inguinal) approach to the internal ring include the transabdominal (laparotomy) [71, 97] and the extraperitoneal (preperitoneal) [52]. Marcy recognized the advantages of the transabdominal intraperitoneal approach to the ring in 1892:

> It may rarely happen to the operator who has opened the abdomen for some other purpose to find the complication of hernia. When the section has been made considerably large, as in the removal of a large tumour; the internal ring is within reach of the surgeon. Upon reflection, it would naturally occur to any operator that under these conditions it is better to close the internal ring, and reform the smooth internal parietal surface from within by means of suturing. My friend, Dr. N. Bozeman of New York, easily did this at my suggestion in a case of ovariotomy more than 10 years ago.

Marcy attributed the transabdominal technique to the French in 1749 [82]. Lawson Tait recommended midline abdominal section for umbilical and groin hernia in 1891 [97]. LaRoque, in 1919, recommended transabdominal repair of inguinal hernias through a muscle-splitting incision about 1 in. (2.5 cm) above the ring. The peritoneum was opened, the sac dissected and then inverted into the peritoneal cavity by grasping its fundus and pulling it back into the peritoneal cavity. The sac was excised and a repair of the deep ring effected [71] (Fig. 1.24). LaRoque believed that the transabdominal approach provided absolute assurance of high ligation of the hernia sac and wrote three papers with accumulative experience of almost 2000 inguinal hernia repairs [91].

Battle, a surgeon at St Thomas' Hospital, London and the Royal Free Hospital, described his approach to repair of a femoral hernia in 1900. Battle pointed out the difficulties of diagnosing femoral hernia and the difficulties, principally the age, sex and comorbidity, of managing patients with femoral hernia. He approached the hernia sac from above through

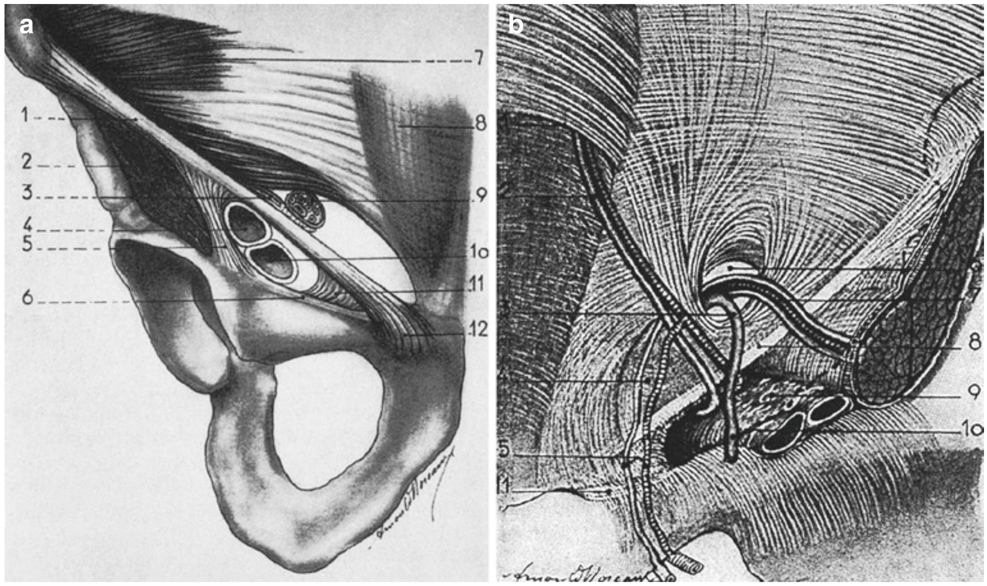

Fig. 1.24 (**a**) Fruchaud's concept of the myopectineal orifice ("l'orifice crural classique') incorporating the inguinal and the femoral canals. An external view showing the two canals separated by the inguinal ligament and internal dissection (**b**) demonstrating how the muscles of the groin form a tunnel down to the myopectineal orifice [51]

an incision splitting the external oblique above the inguinal ligament. After dealing with the peritoneal sac, Battle repaired the femoral canal, constructing a 'shutter' of the aponeurosis of external oblique which he sutured to the pectineus fascia and the pectineal ligament across the abdominal opening of the femoral canal [45, 91]. The Battle operation like many operations for groin hernia has now passed into oblivion.

The extraperitoneal-preperitoneal approach owes its origin to Cheatle [52] who initially used a midline incision but subsequently (1921) changed to a Pfannenstiel incision [52, 53]. Cheatle explored both sides, and inguinal and femoral protrusions were reduced and amputated. If needed, for strangulation or adhesions, the peritoneum could easily be opened. The fascia transversalis was visible and easily repaired. Cheatle advised against this approach for direct hernia because the direct region was usually obscured and distorted by the retraction of the rectus muscles. However, Cheatle's landmark contribution had a minimal impact at the time and remained little used for many years [91].

A.K. Henry, a master anatomist, rediscovered and popularized the extraperitoneal approach in 1936 [69]. At this time he was the Director of the Surgical Unit, Kasr-el-Aini Hospital and Professor of Clinical Surgery in the University of Cairo although he later returned to the Hammersmith Hospital and subsequently became Professor of Anatomy at the Royal College of Surgeons in Ireland. The full impact of the Cheatle/Henry operation was not recognized until after the Second World War, when McEvedy [83], adopted a unilateral oblique incision retracting the rectus muscle medially to approach a femoral hernia. In the USA, Musgrove and McCready [85] adopted the Henry approach to femoral hernia [85]. Mikkelsen and Berne [84] reported inguinal and femoral hernias repaired by this technique and commended the excellent access obtained even in the obese. Furthermore, femoral, inguinal and obturator hernias were all repairable through this 'extended suprapubic approach' [84].

Two Europeans: Lytle and Fruchaud

In the immediate aftermath of the Second World War, two European surgeon anatomists, Lytle and Fruchaud, are important contributors. Lytle was principally concerned with the anatomy and shutter mechanism of the deep inguinal ring. He dissected the deep ring and in a remarkable film demonstrated its prophylactic mechanism in indirect herniation. He was concerned to preserve the mechanism of the ring and at the same time to reinforce its patulous medial margin in indirect herniation. He emphasized that manoeuvres which damaged the lateral 'pillars of the ring' inevitably compromised the physiological shutter mechanism. In a subsequent study, he clearly described the embryological anatomy of the ring and how it could be repaired, in the fascia transversalis layer, without losing its function [78] (Fig. 1.25).

A remarkable Frenchman, Henri Fruchaud, published two books in Paris in 1956: *L'Anatomie Chirurgicale de la Region de l'Aine* (Surgical Anatomy of the Groin Region) [62, 63] and *Le Traitement Chirurgical des Hernies de l'Aine* (Surgical Treatment of Groin Hernias) [62, 63]. Fruchaud combined traditional anatomical studies of the groin, the work of Cooper, Bogros and Madden, with his own extensive anatomical and surgical experience. He invented an entirely new concept—'the myopectineal orifice'—which combined the traditionally separate inguinal and femoral canals to form a unified highway from the abdomen to the thigh. The abdominocrural tunnel of fascia

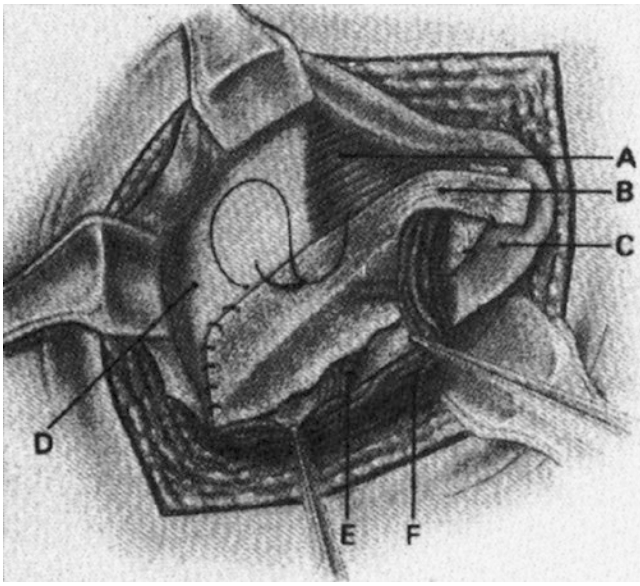

Fig. 1.25 The Lichtenstein's tension-free hernioplasty [150]

transversalis extended through this myopectineal orifice, through which all inguinal and femoral hernias pass, as do the iliofemoral vessels. Based on this anatomical concept, Fruchaud recommended complete reconstruction of the endo-fascial wall (fascia transversalis) of the myopectineal orifice. This unifying concept forms the basis for all extraperitoneal mesh repairs, open or laparoscopic, of groin hernias (Fig. 1.26). Fruchaud's two books were never published in English (until recently by Bendavid), and therefore his findings remained relatively obscure and did not have the full impact and recognition until the laparoscopic era of hernia repair [94]. The concept of Fruchaud has been expanded by Stoppa in France and Wantz in the USA into the 'giant reinforcement of the peritoneal sac' repairs of inguinal hernias [95, 99–101].

Inguinal Hernias in Soldiers in Georgian England

Hernias in England during the Georgian period of the early eighteenth century were prevalent amongst servicemen typically recruited from amongst the malnourished. Civilian medical practice had deemed the rupture incurable consequently taking a palliative approach. For the military this was unacceptable; wastage rates due to ruptures were high and servicemen were valuable commodities. Treatment (experimentation) was a contentious activity relying on the whim of patronage and wartime budgets. Two clinical trials with the War Office funding were carried out between 1721 (Grenton) and 1770 (Lee) and were eventually exposed as ineffectual and 'polemic doggerel and quackery'.

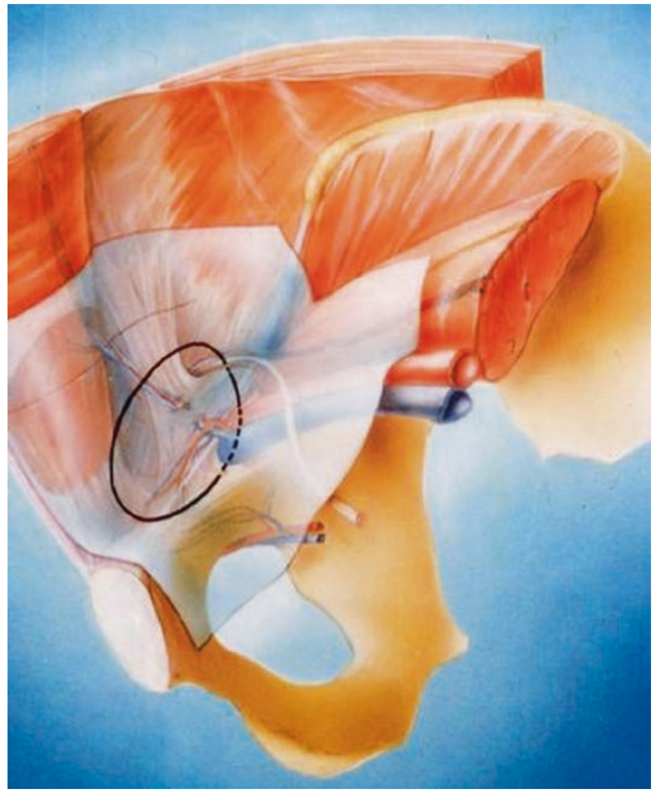

Fig. 1.26 Myopectineal orifice of Fruchaud

The four major characteristics of eighteenth-century hernia treatment in Britain were as follows:

1. It was considered an unmanly ailment that questioned the virility and general health of the afflicted.
2. Hernia was a chronic disorder only to be managed by palliative nonoperative procedures.
3. Most hernias were inguinal.
4. Afflicted males were poor and usually labourers.

In 1776, Dr. George Carlisle reported biographical and autopsy details of an ex-serviceman, John Hollowday, who died of natural causes aged approximately 80 years with a massive inguinoscrotal hernia stretching down to his knees (Figure). Such a hernia was apparently not an uncommon finding in ex-military men, and Hollowday had initially concealed the hernia 'to avoid the scoffs of his companions'. The hernia increased in size until Hollowday was adjudged unfit to serve, and he was admitted as an out-pensioner to the Royal Hospital Chelsea in 1725 whilst still in his mid-30s. Neglected hernias such as these can now only be found in third-world countries such as Africa.

Radical cures for hernia in the eighteenth century included escharotics (a caustic seal of the inguinal rings with scar tissue), castration (the skin was used to close the opening) and trusses (after reduction of the hernia) which were of multiple types and military trusses were mass produced. To treat this massive problem of hernia, a rupture hospital (voluntary) was opened in Greenwich in 1756 but which only stayed open until 1765.

The exact number and rate of hernia occurrences in the Georgian British Army is unknown. However, the periodically malnourished, diseased and constipated, occasionally physically overworked and perpetually unfit British troops manning camps and barracks ringing with hacking smokers' coughs and a distinctive short consumptive bark may be a gross characterisation, but we should not detract from the fact that the underlying causes of hernia were endemic characteristics of eighteenth-century soldiers and soldiering. To counter this debilitating disorder, the Army required an efficacious cure that conventional therapeutics could not deliver. But even though patronage was directly responsible for the establishment of a preferred treatment in a military hospital, the management of rupture slipped back into the margins of military and medical consciousness. The cure for inguinal hernia had to wait for at least another 100 years.

A Royal Rupture

Caroline of Ansbach had married Prince George Augustus of Hanover in 1705, becoming Princess of Wales in 1714 when the British throne passed from the Stuart Queen Anne to Caroline's father-in-law, George I. It would be another 13 years before Caroline and her husband came to the throne themselves, but already their lives acquired greater political significance. They helped to define the character and the promise of Britain's new Hanoverian dynasty and guaranteed the future of the Hanoverian line. The physical health of Caroline and her husband could be seen as underwriting the nation's new succession.

Caroline was a model of good motherhood. Seven of her children (two boys and five girls) survived into adulthood. She was celebrated for breastfeeding her children. Even her adventurous decision to inoculate the princes and princesses for smallpox—a highly controversial parenting choice in the 1720s—ultimately contributed to an image of Caroline as a caring forward-thinking mother. She also became a queen with an important political role, even acting a Regent during her husband's long visits to Hanover. This in turn had an impact on the way that her general health was perceived, and the potential threat to political stability should she die prematurely.

There was intense, daily media speculation about Caroline's health. The details of the days leading up to the eventual strangulation of the hernia and the ensuing events were recorded by her husband's vice-chamberlain, Lord Hervey. Since the birth of her youngest daughter Louisa, 12 years previously Caroline had an umbilical hernia, which she had kept secret from all but a few close confidantes. Even her husband, though was aware of the hernia, was encouraged to disregard it as a minor nuisance. Her first recorded symptoms, some months previously, had arisen as she inspected one of her favourite projects, a library testifying to her intellectual aspirations. Yet the manner in which she would soon resort to quack cordials and conceal the true nature of her infirmity. On Wednesday, 9 November 1737, Caroline experienced severe abdominal pain, the first clear sign that the hernia had become strangulated. However, the increasingly numerous doctors were not allowed a thorough examination for fear of letting out her secret. When they did attend, they suggested the standard remedies of bleeding, blisters, elixirs, enemas and laxatives.

The true cause of Caroline's mounting intestinal obstruction was only discovered on Saturday, 12 November, when the king finally broke his silence and ordered his House Surgeon, John Ranby, to examine the queen's abdomen. After consultation between Ranby and the other doctors, the decision was taken to lance the incarcerated hernia. During the night of 12 November, the wound was again inspected, the doctors observing the 'signs of a mortification' and determining that there could be hardly any hope of recovery. In spite of this, the queen survived for another week. Her strangulated bowel ruptured on Thursday, 17 November, covering the bed and floor with what Hervey described as 'immense quantities of excrement'. On Sunday, 20 November, with most of her family near her, the queen died.

The public account of the duration and nature of Caroline's sufferings were downplayed, since they were not in keeping with the wholesome and robust image of Hanoverian royalty that had been propagated as part of Britain's new constitutional settlement. The image needed to be qualified. Alured Clarke, the Dean of Exeter and later founder of the Royal Devon and Exeter Hospital, epitomised a new emphasis on fortitude as Caroline's most admirable characteristic. Other English and Latin eulogies printed after her death repeatedly return to her prolonged ordeal as confirming her nobility rather than detracting from it.

Caroline's strangulated hernia was no more a private condition than the notorious madness of her grandson, George III would be. It was a subject for debate and discussion, but more than that, it was also an encouragement to consider anxieties and contradictions in the prospect of public discussion itself. In Hervey's opinion, the medical establishment had failed his friend, the queen [112].

Winston Churchill's Hernia Repair

Schein and Rodgers reported an interesting vignette of Winston Churchill's hernia repair in 1947. On an early summer morning, June 11, in a small private nursing home on Berwick Street, London, within walking distance of Harley Street, the 73-year-old Winston Churchill had his inguinal hernia repaired by Thomas Dunhill who was only 2 years younger than his patient. Both elderly gentleman, the patient and his surgeon, were rather short in stature, grey haired and balding, but the patient was corpulent and stocky and his surgeon was lean and agile.

Dunhill was described by his colleagues, as 'modest, courteous, professionally correct and of complete intellectual integrity'. He was a master surgeon being appointed to the Royal household in 1928 and in 1930 as honorary surgeon to King George V and later to King Edward VIII and King George VI. In 1935, on his 60th birthday, Dunhill retired from the staff of St Bartholomew's Hospital and engaged in a flourishing private practice at No 54 Harley Street. He was born and educated in Australia and after qualifying in medicine came to London as first assistant to Professor George Gask at the new Professorial Unit at the University of London at St Bartholomew's Hospital. In 1939, he was awarded an honorary FRCS England, the first time this title had been bestowed on a surgeon who was in active practice.

Winston Churchill first became aware of his hernia on 5 September 1945, writing to his wife Clementine that he had recently ruptured himself and developed a painless swelling and would have to be fitted with a truss. He was consulted by Lord Moran, long-time president of the Royal College of Physicians who in turn consulted Brigadier Edwards the consulting surgeon for the army in Italy who advised that Churchill should buy a truss in Milan.

For almost 2 years, nothing was heard about Churchill's hernia until in June 1947 in Moran's diaries, it is reported that the hernia was now much larger, it had been increasingly difficult to control with a truss and it was hardly ever out of his mind. Thomas Dunhill has been selected as the prospective surgeon.

Churchill's habits of smoking cigars and alcohol consumption were well known, and he undoubtedly suffered from chronic obstructive airway disease and obesity. The operation would therefore have been challenging.

On the morning of the operation Churchill was found in bed reading loudly from Thomas Babbington McCauley's essays. The operation was performed under general anaesthesia, presumably ether, and lasted for more than 2 h. The type of hernia and the method of repair were unknown but were probably a type of Bassini procedure. Postoperative recovery was uneventful with the patient experiencing little discomfort.

Dunhill's herniorrhaphy proved successful and durable for Churchill's groin remained asymptomatic for the next 17.5 years until his death. Dunhill stopped operating in 1949 when he had only three patients left, 'The King (George VI), Queen Mary and Winston Churchill'.

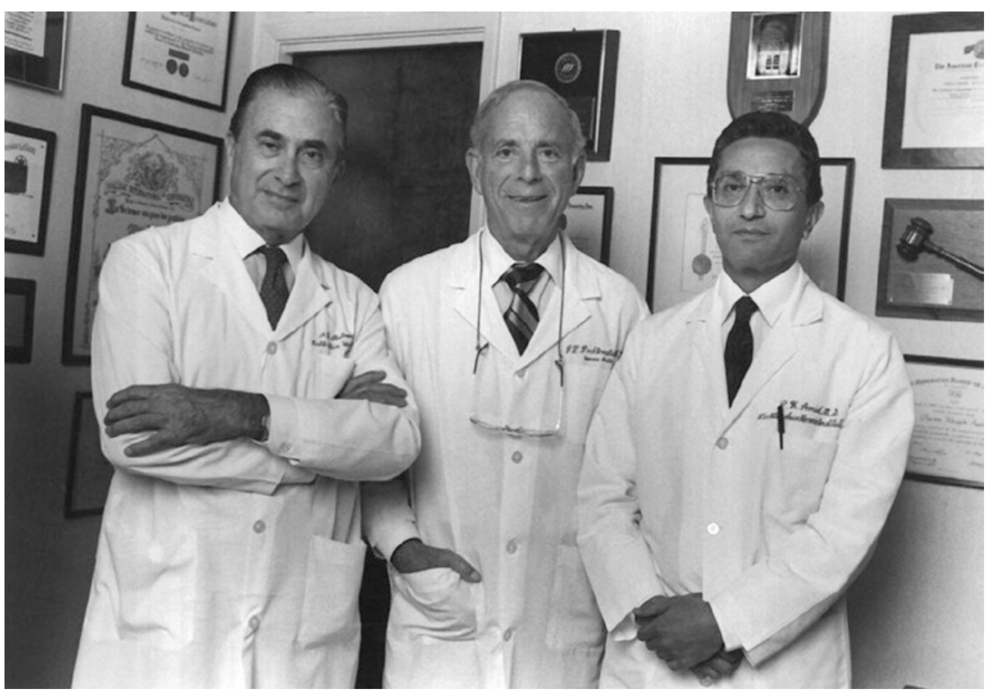

Fig. 1.27 Drs. Shulman, Lichtenstein and Amid, pioneers at the Lichtenstein Clinic

Tension-Free Hernia Repair

Irving Lichtenstein is the seminal thinker who introduced tension-free prosthetic repair of groin hernias into everyday, commonplace, outpatient practices. As well as being an office procedure under local anaesthetic, Lichtenstein pioneered the idea that hernia surgery is special, that it must be performed by an experienced surgeon and cannot be relegated to the unsupervised trainee doing 'minor' surgery. The key feature of Lichtenstein's technique is the 'tensionless' operation. With his co-workers Shulman and Amid, he has developed a simple prosthetic operation, which can be performed on outpatients [44, 73] (Fig. 1.27). As a pioneer, Lichtenstein worked hard to promulgate his ideas but even so the first edition of his book *Hernia Repair Without Disability* written in 1970 sold rather poorly and never went beyond the first printing [91]. Subsequent additions, however, required numerous reprints to meet demand paralleling the increase in popularity and worldwide success of the mesh-patch repair devised by Lichtenstein.

Mesh Technology (See Chap. 20)

Mesh hernioplasty would not have been possible without the pioneering engineering work of Karl Ziegler and the clinical research and development of Francis Usher [113].

Laparoscopic Repair

Laparoscopic repair continues to develop its place in the surgical armamentarium of inguinal hernia. The use of the laparoscope has been extended to repair incisional, ventral, lumbar, and paracolostomy hernias. This latter technique is rapidly gaining in popularity.

The first attempt to treat an inguinal hernia with the laparoscope was made by P. Fletcher of the University of the West Indies in 1979 [19]. He closed the neck of the hernia sac. The first report of the use of a clip (Michel) placed laparoscopically to close the neck of the sac was made by Ger in 1982, who reported a series of 13 patients: all the patients in this series were repaired through an open incision except the 13th patient who was repaired under laparoscopic guidance with a special stapling device. The 3-year follow-up of that patient revealed him to be free of an identifiable recurrence. Ger continued his efforts to repair these hernias laparoscopically. He reported the closure of the neck of the hernia sac using a prototypical instrument called the 'Herniostat' in beagle dogs [20]. The results in these models appeared to be promising. In that same article, he reported the potential benefits of the laparoscopic approach to groin hernia repair as: (1) creation of puncture wounds rather than formal incisions, (2) need for minimal dissection, (3) less danger of spermatic cord injury and less risk of ischaemic orchitis, (4) minimal risk of bladder injury, (5) decreased incidence of neuralgias, (6) possibility of an outpatient procedure, (7) ability to achieve the highest possible ligation of the hernial sac, (8) minimal postoperative discomfort and a faster recovery time, (9) ability to perform simultaneous diagnostic laparoscopy, and (10) ability to diagnose and treat bilateral inguinal hernias. These potential advantages and advances in the laparoscopic repair of hernias continue to be the recognized goals that each method is attempting to achieve.

Bogojavalensky, a gynecologist, presented the first known use of a prosthetic biomaterial in the laparoscopic repair of inguinal and femoral hernias in 1989 [4]. He placed a roll of polypropylene mesh into indirect hernias of female patients. The neck of the internal inguinal ring was then closed with sutures. Popp repaired a coincidental direct hernia that was found at the time of a uterine myomectomy [35]. He recognized the need to provide coverage of a wider area than that of the defect itself. To accomplish this, he placed a 4 × 5-cm oval dehydrated dura mater patch over the defect. This was secured to the peritoneum with catgut sutures that were tied extracorporeally. Popp expressed concerns that the intra-abdominal repair of inguinal hernia could lead to adhesive complications and suggested that a preperitoneal approach might be preferable.

Schultz published the first patient series of laparoscopic herniorraphy in 1990 [39]. Rolls of polypropylene were stuffed into the hernial orifice, which was then covered by two or three flat sheets of polypropylene mesh (2.5 × 5 cm) over the defect. These rolls of mesh were not secured to either the fascia or peritoneum. To achieve access to the hernia defect, he incised the peritoneum. Following the placement of the rolls, he closed the peritoneum with clips. This probably represents the earliest attempt at a type of transabdominal preperitoneal (TAPP) repair that is commonly used today. Corbitt modified this technique by inverting the hernia sac and performing a high ligation with sutures or with an endoscopic stapling device [8]. Despite the initial success of these early reports, because of recurrence rates approaching 15–20%, these techniques were abandoned [9]. The lack of extensive dissection with the above methods, however, remained appealing. A similar concept was applied in the intraperitoneal onlay patch (IPOM) technique. Salerno, Fitzgibbons and Filipi investigated this type of repair in the porcine model [38]. They placed rectangular pieces of flat polypropylene mesh to cover the myopectineal orifice and secured it with a stapling device. The success of these repairs led them to apply this method in clinical trials.

At about the same time, Toy and Smoot reported upon their first ten patients that were repaired with the IPOM technique [41]. They secured an expanded polytetrafluoroethylene (ePTFE) patch to the inguinal floor with staples that were introduced by a prototypical stapling device of their own design, the 'Nanticoke Hernia Stapler'. They successfully used this fixation device in 20–30 patients without adverse results. A subsequent report of their first 75 patients was published in 1992 [42]. In this later series, the same prosthetic biomaterial (7.5 cm × 10 cm) was attached with the Endopath EMS® stapler. After a follow-up of up to 20 months, the recurrence rate was 2.4%. They noted a significant decrease in postoperative pain and an earlier return to normal activity as compared to the open repair of the hernia defect. Others reported similar results [24–28, 40, 159].

Fitzgibbons later abandoned the IPOM repair except for simple indirect inguinal hernias [16]. One patient developed a postoperative scrotal abscess that may or may not have been related to the placement of the mesh in that position. This patient was noted to have firm attachment of the appendix to the site of the polypropylene mesh. He also noted that, in follow-up of these patients, the patch material could be pulled into the hernial defect because it was affixed to the peritoneum alone rather than fascia. Because of these adverse events, he believed that the transabdominal preperitoneal (TAPP) approach, which had been reported by Arregui [1] for inguinal hernia repair, was more appropriate. In this repair, the peritoneum is incised and dissected away from the transversalis fascia to expose the inguinal floor. The mesh material is then secured to that fascia which was believed to ensure superior fixation and tissue ingrowth. Both the TAPP and IPOM techniques require the entry into the abdominal cavity.

In a continuing effort to prevent bowel contact to the prosthesis, Popp described a method to dissect the peritoneum away from the abdominal wall prior to the incision of the peritoneum in the TAPP repair in 1991 [36]. Saline was inserted into the preperitoneal space with a percutaneous syringe. This 'aquadissection' was found to be helpful in the dissection of this area to create a space in which to operate within the preperitoneal space. This early concept probably led to the idea that the entire dissection could be accomplished from within the preperitoneal space, thereby eliminating the need to enter the abdominal cavity.

Additional variations that did not gain acceptance were the 'ring-plasty' and a preperitoneal iliopubic tract repair. The former method was simply a sutured repair that approximated the deep structures of the lateral iliopubic tract to the proximal arching musculotendinous fibres of the transversus abdominis muscle [11, 23]. The latter technique was also a 'tissue' repair but secured the iliopubic tract to the transversus abdominis muscle [17, 18]. This repair incorporated the use of an inlay of a prosthetic material but still had the disadvantage of being a repair under tension. These methods may have limited usage in rare circumstances.

In these earlier years, the predominant laparoscopic method of inguinal herniorraphy was the TAPP approach using either a polypropylene mesh or an expanded polytetrafluoroethylene material [5, 23, 36]. In 1992, Dulucq [12, 13] was the first surgeon to perform 'retroperitoneoscopy' to effect a repair of an inguinal hernia without any direct entry into the abdominal cavity. In 1993, Phillips and Arregui separately described a technique that did not utilize a peritoneal incision in the repair of the inguinal floor [2, 34]. The dissection of the preperitoneal space was accomplished under direct visualization of the area via a laparoscope placed into the abdominal cavity. The laparoscope was then moved into the newly dissected preperitoneal space to complete the repair. Ferzli and McKernan later popularized the technique of Dulucq preferring the term 'totally extraperitoneal' [15, 31]. Using the 'open' entry into the preperitoneal space, the dissection of the space was carried out under direct visualization. This totally extraperitoneal (TEP) repair was identical to that of the TAPP but appeared to incur less risk of injury to the intra-abdominal organs.

Currently, the majority of laparoscopic inguinal hernia repairs are approached by either the TAPP or TEP method and utilize a polypropylene mesh biomaterial. The majority of the surgeons that perform the TEP repair utilize the commercially available dissection balloons to create the space within the preperitoneal area to perform the repair.

In an earlier multicentre report, the recurrence rate of these repairs was 0.4% in 10,053 repairs with a median follow-up of 36 months [14]. The surgeons that continue to perform the laparoscopic herniorraphy believe that the goals that were anticipated by Ger have been realized.

The improvement in recovery in laparoscopic cholecystectomy patients and results that were seen in herniorraphy patients encouraged attempts to repair ventral and incisional hernias in 1991. The initial report by LeBlanc involved only five patients using an ePTFE patch biomaterial [24, 26, 159]. Although the overlap of the hernia defect by the prosthesis was only 1.5–2 cm, these patients were free of recurrence after 7 years of follow-up. The fixation used was that of the 'box-type' of hernia stapler without the use of sutures. Sutures were used only to aid in the positioning of the patch. These sutures were removed from the prosthesis at the completion of the stapling of the patch. With further patients and follow-up, no recurrences were noted [25, 27, 28]. Barie proposed the use of a polyester material covered on the visceral side with a mesh of absorbable polyglactin [3].

Park modified the technique for the repair of large ventral hernias by utilizing the transfascial fixation of the ePTFE or Prolene® mesh with transabdominally placed Prolene® sutures passed through a Keith needle [32]. In their series of 30 cases, only 1 recurrence was noted. This repair used a fascial overlap of 2 cm. Holzman placed a Marlex® prosthesis with a 4 cm overlap onto normal fascial edges and secured them with an endoscopic stapler [22]. He found this technique to be safe and effective. In separate investigations, Holzman, Park and others compared the open versus laparoscopic methods and found that the laparoscopic repair was associated with fewer postoperative complications, a shorter hospital stay and lower recurrence rates than open prosthetic repair [6, 10, 22, 33, 37]. The largest study published at that time confirmed that the laparoscopic repair of incisional and ventral hernias can be accomplished with reproducibility and with excellent results [21]. Additionally, the long-term follow-up of LeBlanc's patients has proven that this is a durable procedure when the tenets that are noted below are applied:

1. A minimum prosthetic overlap of 3 cm
2. Helical tacks placed at 1–1.5 cm intervals
3. Transfascial sutures placed at 5 cm intervals [29, 30]

Others, however, do not share this view. Some surgeons, notably in Spain, preferred the use of the 'double-crown' technique [7] (Morales-Conde 2001, Personal Communication). In this technique no sutures are used. Instead, two concentric rows of helical tacks are placed, the first at the periphery of the biomaterial as in the sutured technique and the second, inside of this one, near the hernia defect itself. The initial reports seem to have similar results as that of the authors using the transfascial sutures.

Incisional Hernia Repair

It was not until the second half of the nineteenth century at the start of the era of modern abdominal surgery that postoperative eventrations, what we now call incisional hernia, increased in number and were documented [114–119]. At the same time, surgical techniques aimed at their correction, developed and multiplied. Despite this, an awareness of the importance of the integrity of the abdominal wall in preventing herniation originated in the early years of written history and thereafter each historical time period has played a role in developing our understanding of incisional hernias.

Before the introduction of anaesthesia in 1846 by William Morton and antisepsis by Joseph Lister in 1865, restraining methods were the treatments of choice for the rare cases of incisional hernia [118, 120]. As survivable abdominal surgery became more common, so too did the incidence of incisional hernias. In the *Annals of Surgery* in 1901, Brindley Eads wrote, "The occurrence of ventral hernia as a sequence of abdominal section is so common that it should command our thoughtful consideration" [114].

These sentiments were reinforced in several other publications at the time [115, 116]. Since then, many thousand peer-reviewed articles on the topic of incisional hernia have been published. Many of these introduced a new technique or suggested a modification of an established technique for the repair of incisional hernia. Whilst several have played an important role in shaping incisional hernia surgery, this historical review only mentions the most significant of these. Surgical repair developed along three lines:

1. Simple laparoplasty: suturing
2. Organic auto or heteroplasty: grafting
3. Alloplasty: the use of prosthetics

Simple Laparoplasty: Suturing

Simple suturing and more complex darns were the most commonly utilized repairs in this period. In 1886, Maydl performed an incisional hernia repair by dissecting out the various musculo-fascial layers and repairing them separately [121]. Quenu also advocated layered closure of postoperative eventration using simple sutures [122]. Others, such as Jonnesco, proposed the use of 'U'-shaped stitches through the rectus sheath, and Frappier described the mass closure of the hernia defect with 'figure-of-eight' sutures [123, 124]. In 1899, Mayo described his famous transverse overlapping technique for umbilical hernia (pants over vest), and this was adopted by many surgeons for the repair of incisional hernia [125]. Others, such as Witzel [126], Goepel [127] and Bartlett [128], described the repair of incisional hernia from continuous fascial sutures from the external oblique [126–128].

In 1954, a British surgeon, Rodney Maingot, described his extraperitoneal 'keel' technique for the repair of large incisional hernia [129]. The technique involved widely excising the stretched overlying skin and scar tissue and dissecting the fascial flaps well back to expose healthy margins. The peritoneal hernia sac was then inverted 'like a boat's keel' and the fascial edges approximated with interrupted sutures of floss silk. The approximated edge was then inverted with a continuous suture. Maingot described good results from 81 patients in which he had performed this operation. Despite these good results, suture repair, in all but the smallest of hernias, resulted in unsatisfactorily high recurrence rates [130]. This spurred surgeons to explore alternative techniques to reinforce the abdominal wall.

Organic Auto- or Heteroplasty: Grafting

In 1910, Kirschner (of the whom the *k-wire,* used in orthopaedic surgery, is named) used heterologous, homologous and autologous fascia, of which the latter was reported to have good results [131]. In 1912 Judd described an overlapping flap of peritoneum, muscle, fascia and scar tissue, and in 1913 Loewe described cutis grafts [132, 133]. Relieving or relaxing incisions were first described by Gibson in 1920 [134]. Nuttall described rectus muscle transplantation in 1926 [135]. This involved releasing the muscles at their origins, crossing them and suturing them to the opposite pubic bone. In the following years, free flaps were constructed from freeze-dried human fascia lata, dura mater and skin [117, 136–138]. Reconstruction with autologous material on the whole produced unsatisfactory results. Transplant harvesting was time consuming and was frequently followed by functional deficits at the donor sites. Moreover, the reconstructions often left bulges through denervated muscles and reherniation rates were high [139]. However, these attempts at grafting represented an important step in incisional hernia surgery and arguably were the precursors to biological collagen xenografts that are used today.

Alloplasty: The Use of Prosthetics

The first hernia prosthetics were made of metal. As early as 1900, Goepel and Witzel used silver wire braided meshes [126, 127, 140]. These early meshes were far from ideal. They were stiff, fragile and toxic sulphur silver formed on their surface. They were modified to contain braided stainless steel and were used as a bridging material between the two edges of the rectus muscles, sometimes as a double layer [141–143]. In 1948 Douglas and Throckmorton and several years later Koontz used tantalum gauze [144–146]. These meshes still fragmented and had extremely high rates of infection. Prefabricated perlon and nylon meshes were used by Cumberland; however, the nylon fell apart and the perlon caused an intense inflammatory response [147–149]. The plastics industry came of age during the Second World War. Steel and tantalum became precious metals allocated for military use. Desperate fabricators, who had never thought of plastic as a manufacturing material, began to reconsider. These 'new plastics' caught the attention of hernia surgeons and several new meshes with much more promising characteristics became available. These were polypropylene, polyester and expanded polytetrafluorethylene (ePTFE) [149–151].

Since the plastics era started, meshes have been manipulated to include changes in pore sizes, textures and additives. Additives include impregnated antimicrobials and elements of absorbable mesh or non-adhesion-forming substances in hybrid meshes. More recently biological materials have been introduced and provide a cross over between meshes and grafting. Most recently synthetic absorbable products have become available. The search for the 'ideal' mesh still continues today.

Whilst major developments in prosthesis aimed at repairing incisional hernias were being made, advances in surgical technique to prevent incisional hernia formation were also occurring. Perhaps the most significant of these was the work of Jenkins [152]. He used a mechanical and geometric approach to calculate the ideal suture length to wound ratio to prevent incisional hernia formation. Experimentally, Jenkins showed that the length of a midline laparotomy incision could increase up to 30% in the postoperative period. If the bites taken in suturing (and hence the length of the suture material used) were not large enough, the suture may cut through the fascia, resulting in wound dehiscence. His well-adopted rule states that the suture-length-to-wound-length ratio should be 4:1, and sutures should be placed 2 cm from the fascial edge and 2 cm from one another.

Some of the most important developments in incisional hernia repair during this time period have been in the technique for placing the mesh. For open incisional hernia repair, three methods for implantation of prosthetic mesh have dominated. The first involves placing the mesh inside the peritoneal cavity in contact with the viscera (intraperitoneal inlay or intraperitoneal onlay). Bare polypropylene mesh adheres to all adjacent tissues and therefore has the propensity for inducing extensive adhesions to viscera if placed in a position where it becomes adjacent to bowel. Erosion of the mesh then may occur into the intestines, which is a well-recognized drawback of this technique [153]. However, newer coated meshes, which reduce adhesion formation on the exposed visceral surface of the mesh, have reduced this risk [154]. The second is the premuscular onlay technique, in which the mesh is placed over the abdominal wall closure in the subcutaneous prefascial space. This technique was refined and popularized by Chevrel [155]. The third is the retromuscular sublay technique, in which the mesh is placed over the closed posterior rectus sheath and peritoneum. This technique was popularized by Rives and Stoppa [156, 157]. Stoppa, in fact, described retrofascial placement and Rives described retromuscular placement. The combined Rives-Stoppa technique has subsequently been adopted as the gold standard for traditional open incisional hernia repair. However, there is currently insufficient data in the literature to promote the Rives-Stoppa technique ahead of the Chevrel onlay repair [130].

Large incisional hernias with loss of abdominal domain from lateral retraction of the abdominal muscle present a difficult problem because of lack of healthy tissue for mesh placement or primary closure. In 1990, Oscar Ramirez, developed his 'component separation of the abdominal wall' technique to address this group of complex incisional hernias [158]. The advantage of the component separation technique is that the abdominal wall can be recreated in a one-stage procedure without the need of an additional musculofascial transfer (distant flaps) or the use of a bridging material.

In 1991, LeBlanc reported the first laparoscopic incisional hernia repair [159]. Although not considered to be a pathology that could benefit from this approach, laparoscopic repair of incisional hernias has attained wide acceptance in recent years because of the significant improvements in prosthetic materials and surgical technique.

Most recently the advent of robotic technology has resulted in a further evolution of hernia repair, especially incisional hernia repair. The short-term outcomes appear favourable, and it appears that the use of the surgical robot in hernia repair has established a firm foothold in the future of hernia repair.

Chronology of Hernia Surgery

Ancient	
1500 BC	Inguinal hernia described in an Egyptian papyrus. An inguinal hernia is depicted on a Greek statuette from this period
900 BC	Tightly fitting bandages are used to treat an inguinal hernia by physicians in Alexandria. A Phoenician statue depicts this
400 BC	Hippocrates distinguished hernia and hydrocele by transillumination
AD 40	Celsus described the older Greek operations for hernia
AD 200	Galen introduced the concept of 'rupture' of the peritoneum allowed by failure of the belly wall tissues
AD 700	Paul of Aegina distinguished complete and incomplete hernia. He recommended amputation of the testicle in repair
Medieval	
1363	Guy de Chauliac distinguished inguinal and femoral hernia
1556	Franco recommended dividing the constriction at the neck of a strangulated hernial sac
1559	Stromayr published Practica Copiosa, differentiating direct and indirect hernia and advocating excision of the sac in indirect hernia
Renaissance	
1700	Littre reported a Meckel's diverticulum in a hernial sac
1731	De Carengeot described the appendix in a hernial sac
1724	Heister distinguished direct and indirect hernia
1757	Pott described the anatomy of hernia and of strangulation
1756	Cheselden described successful operation for an inguinal hernia
1785	Richter described a partial enterocele
1790	John Hunter speculated about the congenital nature of complete indirect inguinal hernia
1793	De Gimbernat described his ligament and advocated medial rather than upward division of the constriction in strangulated femoral hernia. This avoided damage to the inguinal ligament and the serious bleeding, which sometimes followed
1804	Cooper published his three-part book on hernia—the plates are a tour de force; they are almost life sized and depict anatomy as never before. Cooper defined the fascia transversalis; he distinguished this layer from the peritoneum and demonstrated that it was the main barrier to herniation. He carefully delineated the extension of the fascia transversalis behind the inguinal ligament into the thigh as the femoral sheath and the pectineal part of the inguinal ligament—Cooper's ligament
1811	Colles, who had worked as a dissector for Cooper, described the reflected inguinal ligament
1816	Hesselbach described the anatomy of his triangle
1816	Cloquet described the processus vaginalis and observed it was rarely closed at birth. He also described his 'gland', so important in the differential diagnosis of lumps in the groin
1846	Anaesthesia discovered
1870	Lister introduced antiseptic surgery and carbolized catgut
1871	Marcy, who had been a pupil of Lister, described his operation
1874	Steele described a radical operation for hernia
1875	Annandale successfully used an extraperitoneal groin approach to treat a direct and an indirect inguinal and a femoral hernia on the same side in a 46-year-old man. Annandale plugged the femoral canal with the redundant inguinal hernial sacs
1876	Czerny pulled the sac down through the external ring, ligated it at its neck, excised it and allowed it to retract back into the canal
1881	Lucas-Championniere opened the canal and reconstructed it by imbrication of its anterior wall
1886	MacEwan operated through the external ring; he rolled up the sac and used it to plug the canal
1887	Bassini published the first description of his operation
1889	Halsted I operation described
1890	Coley's operation—placing the internal oblique anterior to the cord which emerged at the pubic end of the repair. This was the most pernicious and least effective corruption of Bassini's operation
1891	Tait advocated median abdominal section for hernia
1892	Wolfler designed the anterior relaxing incision in the rectus sheath to relieve tension on the pubic end repair and prevent recurrence at that site
1893	Lockwood emphasized the importance of adequate repair of the fascia transversalis
1895	W.J. Mayo—a radical cure for umbilical hernia
1895	Andrews introduced imbrication or 'double-breasting' of the layers
1898	Lotheissen used Cooper's ligament in repair of femoral hernia
1898	Brenner described 'reinforcing' the repair by suturing the cremaster between the internal oblique arch and the inguinal ligament. The fascia transversalis is not inspected. A serious corruption of the Marcy-Bassini strategy
1899	Ferguson advised leaving the cord undisturbed—a more serious corruption of Bassini
1901	McArthur darned his inguinal repair with a pedicled strip of external oblique aponeurosis
1902	Berger turned down a rectus flap to repair inguinal hernia
Modern aseptic	
1903	Halsted II operation. Halsted abandoned cord skeletonization to avoid hydrocele and testicular atrophy, and adopted Andrews' imbrication and the Wolfler-Berger technique of a relaxation incision and a rectus sheath flap
1906	Russell—the 'saccular theory' of hernias, postulating that all indirect inguinal hernias are congenital

1907	Kocher—revised operation for indirect hernia without opening the canal. The sac was dissected, invaginated and transposed laterally
1909	McGavin used silver filigree to repair inguinal hernias
1909	Nicol reported paediatric day-case inguinal herniotomy in Glasgow
1910	Kirschner used a free transplant of fascia lata from the thigh to reinforce the external oblique
1918	Handley reconstructed the canal using a darn/lattice technique
1919	LaRoque—transperitoneal repair of inguinal hernia through grid iron (muscle splitting) incision
1920	Cheatle—extraperitoneal approach to the groin through a midline incision
1921	Gallie used strips of autologous fascia lata to repair inguinal hernia
1923	Keith—classic review of the causation of inguinal hernia. He remarked that aponeurosis and fascia are living structures and speculated that a tissue defect could be responsible for the onset of hernias in middle age
1927	Keynes—surgeon to the London truss society—advocated elective operation using fascial graft techniques
1936	Henry—extraperitoneal approach to groin hernia
1940	Wakeley—a personal series of 2020 hernias
1942	Tanner popularized rectus sheath 'slide'
1945	Lytle reinterpreted the importance of the internal ring
1945	Mair introduced the technique of using buried skin to repair an inguinal hernia
1952	Douglas—first experimental studies of the dynamics of healing (aponeurosis) showed that aponeurotic strength was slow to recover and only reached an optimum at 120 days
1953	Shouldice—a series of 8317 hernia repairs with overall recurrence rate to 10 years of 0.8%. Emphasis on anatomic repair and early ambulation
1954	Roger Maingot describes the 'keel' technique for open incisional hernia repair
1955	Farquharson—an experience of 485 adults who had their hernias repaired as day cases
1956	Fruchaud—the concept of the myopectineal orifice and fascia transversalis tunnel for all groin hernias
1958	Marsden—a 3-year follow-up of inguinal hernioplasties. An important contribution to the evaluation of results
1958	Usher—the use of knitted polypropylene mesh in hernia repair
1960	Anson and McVay—classic dissections and evaluation of musculoaponeurotic layers based on a study of 500 body halves
1962	Doran described the pitfalls of hernia follow-up and set out criteria for adequate evaluation
1962	Chevrel describes the onlay repair for incisional hernia
1970	Lichtenstein showed the interdependence of suture strength and absorption characteristics with wound healing. Demonstrated experimentally the critical role of non-absorbable or very slowly absorbable sutures in aponeurotic healing
1972	Doran—critical review of short-stay surgery for inguinal hernia in Birmingham
1973	Glassow reported 18,400 repairs of indirect hernia with a recurrence rate less than 1%
1979	Laparoscopic hernia repair first attempted
1981	Read demonstrated a tissue defect, metastatic emphysema, in smokers with direct herniation
1981	Chan described patients developing hernia whilst undergoing continuous ambulatory peritoneal dialysis
1982	Rives describes retromuscular placement of mesh in ventral hernia repair
1983	Schurgers demonstrated an open processus vaginalis in a man 5 months after commencement on peritoneal dialysis
1984	Gilbert described the umbrella plug for inguinal hernia repair
1985	Read postulated an aetiological relationship between smoking, inguinal herniation and aortic aneurysm
1986	Lichtenstein described the tension-free repair of inguinal hernias
1989	Stoppa describes retrofascial placement of mesh in ventral hernia repair
1989	Gullmo demonstrates the value of herniorrhaphy in patients with obscure symptoms in the groin or pelvis and to exclude primary or recurrent hernia
1990	Robbins and Rutkow introduced the concept of a preformed mesh plug introduced into the hernia defect covered by a loose lying mesh patch Schultz first used a synthetic prosthetic biomaterial in the laparoscopic repair of an inguinal hernia
1990	Oscar Ramirez publishes his paper on anterior component separation
1991	LeBlanc performs laparoscopic incisional hernia repair
1992	Dulucq repairs an inguinal hernia laparoscopically without direct entry into the abdominal cavity
1993	First "Guidelines for the Management of Adult Inguinal Hernia" produced by the Royal College of Surgeons of England (Chairman of the Working Party—Kingsnorth
1993	Environmental factors in hernia causation redefined
1994	O Jeremy A Gilmore describes the surgical treatment of 1400 sportsmen with groin disruption detailing the pathophysiology and treatment
2000	Lowe publishes a case series of combined open and laparoscopic anterior component separation
2006	First open TAR (Transversus Abdominus release) performed by Yuri Novitsky
2007	Rosen publishes animal studies on laparoscopic anterior component separation
2008	Carbonell publishes the first series on posterior component separation
2013	Carbonell performs the first robotic posterior component separation (rTAR)
2014	Use of the surgical robot for hernia repair achieves approval by the USFDA

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2 Essential Anatomy of the Abdominal Wall

Vishy Mahadevan

The anatomy of the abdominal wall has been well documented in several standard anatomical reference texts. Detailed information is readily available from these sources. The line drawings in this chapter have been adapted from a small selection of publications in the anatomical and surgical literature, with particular emphasis being made in these illustrations, on applied surgical anatomy and surgically-significant anatomical variations and anomalies.

Certain pathological processes may, on occasion, distort the underlying anatomy, and the surgeon must be cognizant of, and take into account, these alterations. Only then will the surgeon be able to employ an appropriate and optimal surgical approach and thereby ensure successful outcome from hernia surgery. Optimally, the surgeon should tailor each operation to the specific anatomy encountered in the individual patient.

The impetus to revisit and redefine the anatomy of the anterior abdominal wall and in particular the anatomy of the inguinal region was driven chiefly by a desire to identify the reasons for the observed shortcomings of the traditional Bassini operation undertaken for the repair of inguinal hernias. This detailed re-examination of abdominal wall anatomy (both topographical and functional) has resulted in a significant enhancement in our understanding of the development of hernias and has also resulted in the generation of much practical advice for surgeons in the surgical management of hernias, in particular the management of variant forms of hernia that do not conform to standard descriptions.

Under normal circumstances the complex musculoaponeurotic elements within the abdominal wall are designed to retain the contents of the peritoneal cavity. There are, however, several specific and defined areas of natural weakness or relative deficiency within the musculoaponeurotic layers of the abdominal wall, and it is at these locations that there is a particular and predetermined tendency for hernias to present. Most notable among these areas of deficiency is the groin region in relation to the inguinal and femoral canals. Other sites of potential weakness include the umbilicus, epigastrium, lumbar triangle (of Petit), obturator canal, sciatic foramina, perineum, pelvic sidewall and the Spigelian line. The list is long, and it is most unlikely that a single clinician will encounter all types of abdominal wall hernias during a professional lifetime.

The work of Anson and McVay on the inguinal canal appeared in 1938 [1], and since then they and their associate Zimmerman have published extensively. Other notable contributors to the field of abdominal wall anatomy include Askar, Condon, Fruchaud, Lytle, Nyhus, Ruge, Skandalakis and Van Mameren.

External Anatomy: Surface Markings and Surface Features

Since the vast majority of abdominal wall hernias involve the *anterior* abdominal wall, it is the latter that will be the principal focus of this chapter. The geographical outline of the anterior abdominal wall is approximately hexagonal. It is bounded superiorly by the arched costal margin (with the xiphisternum at the summit of this arch) (Fig. 2.1). The lateral boundary on either side is defined, arbitrarily, as the midaxillary line (between the lateral part of the costal margin and the summit of the iliac crest). Inferiorly, on either side, the anterior abdominal wall is bounded, in continuity, by the anterior half of the iliac crest, inguinal ligament and pubic crest, with the two pubic crests meeting at the pubic symphysis. Situated vertically in the midline of the anterior abdominal wall is the linea alba. In the muscular or thin individual, the linea alba is manifest as a shallow furrow, being more evident above the level of the umbilicus. No such furrow is evident in the obese or rounded abdomen. The umbilicus lies, normally, at the junction of the upper three-fifths and lower two-fifths of the linea alba. In the healthy young adult, the rectus abdominis muscle is evident as a prominence on

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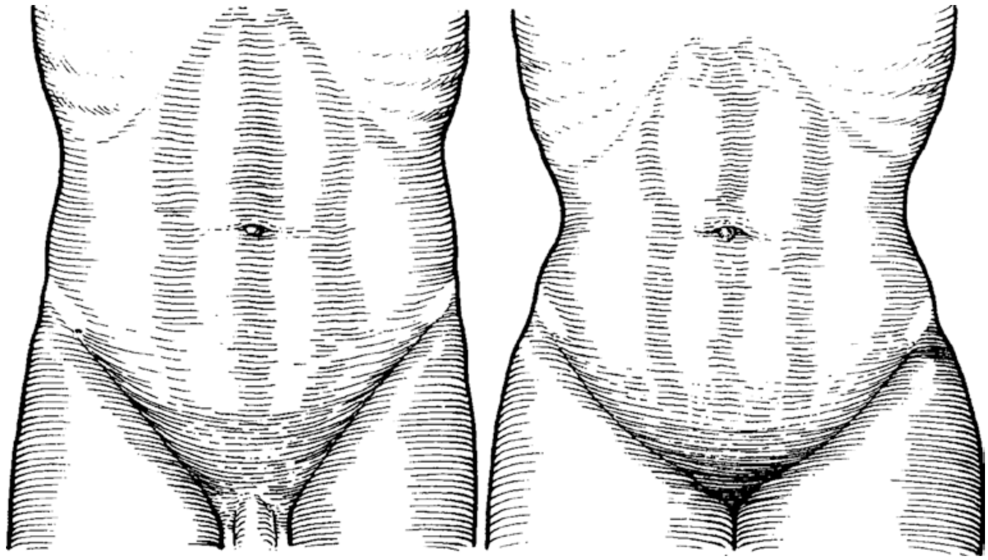

Fig. 2.1 Topographical anatomy of the abdomen—the distinctly different male and female characteristics are important in hernia surgery. The boundaries of the abdomen, the costal cartilages above and the crests of the iliac and pubic bones, and the inguinal ligament inferiorly are illustrated. The umbilicus, the rectus muscle, and the semilunar lines are important surface landmarks

either side of the vertical midline. The rectus muscle is particularly prominent inferolateral to the umbilicus: this rectus mound below the level of the umbilicus is of surgical importance. With ageing and obesity, the lower abdomen tends to sag. The rectus mound, however, does not shift and persists even into old age.

The linea semilunaris (semilunar line) is easily observed in the abdominal wall of a fit and muscular individual. By contrast, in the lax or obese abdominal wall, it is indistinct at best. The linea semilunaris indicates the outer margin of each rectus sheath and is a longitudinally disposed shallow groove with a gentle convexity facing laterally. It is most distinct in the upper abdomen where it commences at the tip of the ninth costal cartilage. At first it descends almost vertically, but inferior to the umbilicus it turns medially with a gentle curve to terminate at the pubic tubercle. It is along this line that the internal oblique aponeurosis splits into two laminae which run on either surface of the rectus abdominis to enclose the muscle in the upper two-thirds of the abdomen. The area corresponding to the inferior third of the semilunar line is also referred to as the Spigelian fascia and is one of the many documented sites of herniation (Chap. 18). In the lower abdomen, the relative configurations of the linea semilunaris and the rectus sheath differ between the sexes. This is chiefly due to the wider pelvis and greater pubic prominence which characterize the female form (Fig. 2.1).

The anterior superior iliac spine (ASIS) is the abrupt anterior extremity of the iliac crest. It is visible in the thin individual and readily palpable in all. The pubic tubercle can be felt as a bony nodule on the anterior aspect of the pubic crest, 2–3 cm lateral to the pubic symphysis. A line joining the ASIS to the pubic tubercle denotes on the surface, the location of the inguinal ligament. The base of the triangular superficial inguinal ring is superomedial to the pubic tubercle. Inferolateral to the pubic tubercle is the femoral ring (the proximal, open end of the femoral canal and through which a femoral hernia enters the femoral canal).

The deep inguinal ring (internal inguinal ring) may be represented on the surface by a point marked 2 cm vertically above the midpoint of the inguinal ligament (the latter point is halfway between the ASIS and pubic tubercle).

The inguinal canal may be indicated on the surface as an oblique band, 1.5–2 cm wide, running above and parallel to the medial half of the inguinal ligament.

The anterior abdominal wall is a many-layered structure (Fig. 2.22), a feature which is readily discernible in a transverse section through the abdomen of a cadaver as well as in an axially viewed CT or MR image of the abdominal wall (Figs. 2.45 and 2.46). A detailed and critical appreciation of these multiple layers, their relationship to each other, their individual textures and consistencies and variations in consistency of a given layer in different parts of the anterior abdominal wall is all crucial not only to a proper understanding of the development of abdominal wall hernias but also to the rational and optimal surgical management of the condition.

From the surface inwards, the multiple layers which make up the anterior abdominal wall are, successively:

- Skin
- Superficial fascia comprising two layers, an outer fatty layer known as Camper's fascia and an inner fibrous (fibroelastic) layer known as the membranous layer of superficial fascia or eponymously as Scarpa's fascia.
- Musculoaponeurotic plane (which is structurally complex and made up of several layers)
- Transversalis fascia (part of the endoabdominal fascia)
- Layer of extraperitoneal fat (or properitoneal fat)
- Parietal peritoneum

Skin

The skin over the anterior abdominal wall is thin compared with that of the back. It is relatively mobile over the underlying layers except in the vicinity of the umbilicus where it is tethered to subjacent layers and consequently relatively immobile.

The surgeon must be aware of the elastic and connective tissue lines in the skin if optimal postoperative cutaneous healing is to be achieved. Natural elastic traction lines in the skin of the anterior abdominal wall (known as relaxed skin tension lines or Kraissl's lines) are disposed transversely. Above the level of the umbilicus, these tension lines run almost horizontally, while below this level they run with a slight inferomedial obliquity (Fig. 2.2). Incisions made along, or parallel to, these lines tend to heal without much scarring, whereas incisions made at right angles to these lines gape and tend to splay out and eventually result in somewhat prominent scars. The longitudinal contraction of the healing wound, particularly when the wound crosses a skin delve or body crease, can result in unsightly scarring and wound contracture, and for these reasons vertical incisions over the groin should, whenever possible, be avoided.

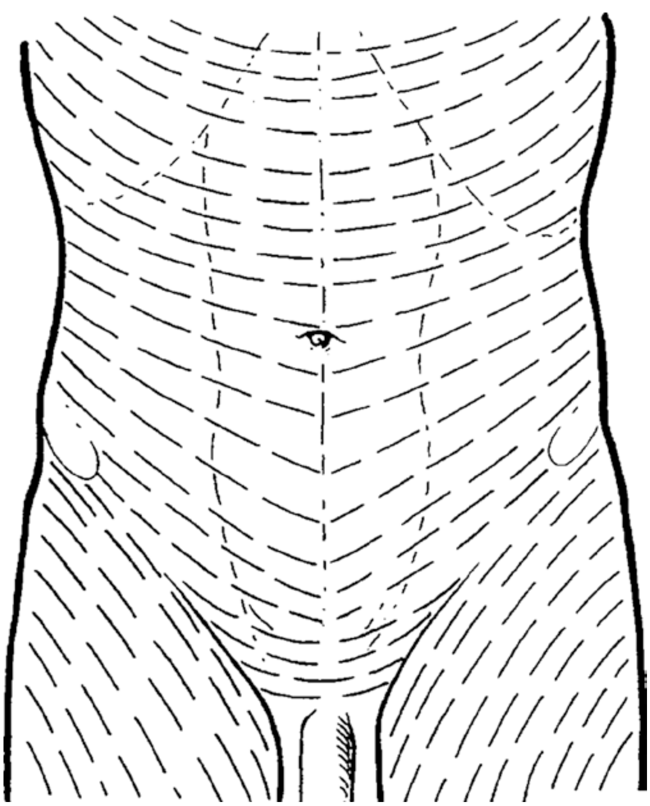

Fig. 2.2 Tension lines of the skin. Incisions at right angles to these lines tend to splay and lead to unsightly scars. This adverse phenomenon is enhanced if the incision also crosses a joint crease. Vertical incisions in the groin for hernia repair are particularly unsightly

However, rapid and unrestricted surgical access to the abdominal cavity often requires a generous vertical incision, and these continue to remain useful and popular in everyday general surgical and gynaecological practice, particularly in emergency surgery (Fig. 2.2).

The Subcutaneous Layer

Deep to the skin lie the subcutaneous areolar tissue and fascia. Superiorly over the lower chest and epigastrium, this layer is generally thin and less organized than in the lower abdomen where it becomes bilaminar—a superficial fatty stratum (Camper's fascia) and a deeper, stronger and fibroelastic layer termed membranous layer of superficial fascia (or Scarpa's fascia). Scarpa's fascia is well developed in infancy, forming a distinct layer which must be separately incised when the superficial inguinal ring is approached in childhood herniotomy.

It is to be noted that traced laterally around the abdominal wall, Scarpa's fascia can be made out distinctly only as far as the midaxillary line. Posterior to that line, Scarpa's fascia thins out gradually, and no Scarpa's fascia is evident in the posterior abdominal wall. Traced superiorly, Scarpa's fascia is seen to cross over onto the anterior chest wall, superficial to the costal margin, as a very thin layer, known as the retromammary fascia. This retromammary extension which can be traced as far superiorly as the second intercostal space is easier to demonstrate in the premenopausal adult female. Deep to the retromammary fascia is the retromammary space which separates the retromammary fascia from the underlying pectoral fascia and pectoralis major muscle.

Even in the adult, Scarpa's fascia is more prominent, of firmer consistency and more readily demonstrable in the lower abdomen than in the upper abdomen. It is generally more membranous, contains a small amount of elastic tissue and is almost devoid of fat. Traced inferiorly, the abdominal subcutaneous fat merges imperceptibly with the subcutaneous fat of the thigh. Scarpa's fascia, by contrast, crosses into the thigh anterior to the inguinal ligament and fuses with the deep fascia of the thigh (fascia lata) at the groin crease (flexure skin crease of the hip joint) below the level of the inguinal ligament, as far medially as the pubic tubercle and laterally as far as an area just inferior to the anterior superior iliac spine. Medially, Scarpa's fascia is prolonged into the anterior part of the perineum (urogenital region of the perineum) as the superficial perineal fascia (Colles' fascia) (Fig. 2.3). In the male, this extension is prolonged into the scrotum and also around the penile shaft. The fascia lata in the upper medial aspect of the thigh has certain anatomic features which are of importance to the hernia surgeon. It is traversed, from superficial to deep, by the great saphenous vein and other struc-

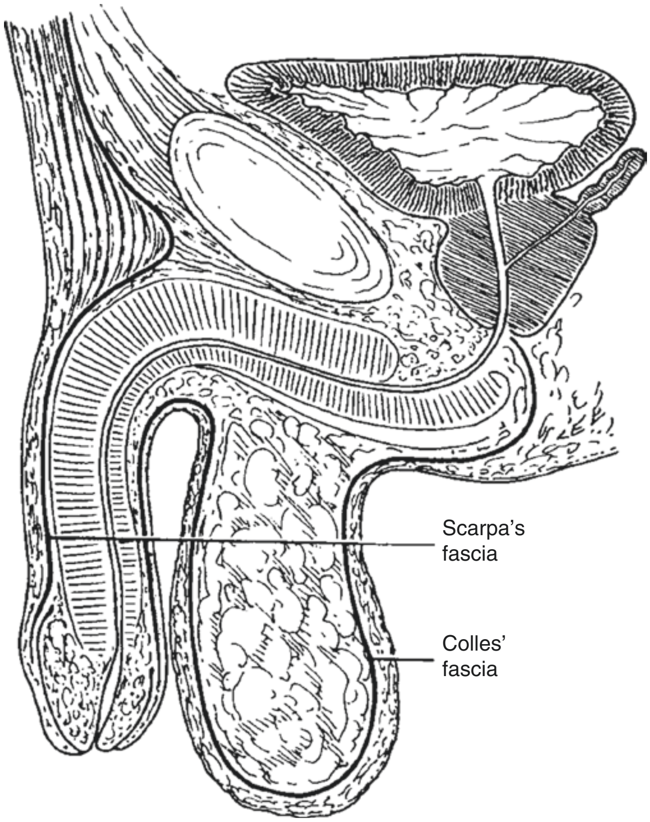

Fig. 2.3 The membranous layer of superficial fascia (Scarpa's fascia) is stronger over the lower abdomen where it forms a distinct layer that requires division in groin hernia operations

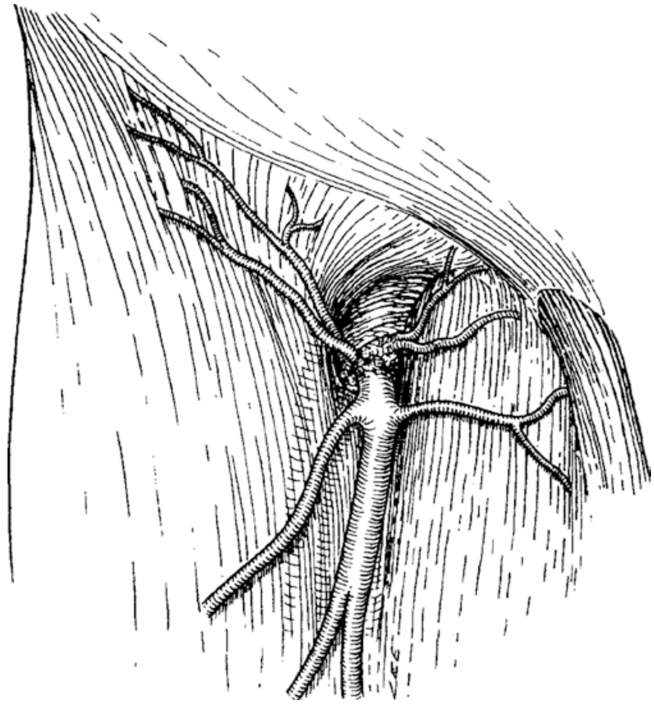

Fig. 2.4 In the upper thigh the long saphenous vein goes from superficial to deep to join the femoral vein which is contained in the femoral sheath, an extension of the extraperitoneal fascia

tures, at the saphenous opening or fossa ovalis. The attenuated connective tissue, the cribriform fascia, packs and 'closes' the saphenous opening. Although the cribriform fascia lies in the same plane as the deep fascia, it has many of the structural characteristics of superficial fascia. Thus, it is loose and fatty in texture and is easily distorted by the dilatation of any of the structures in its vicinity, e.g. a varicose saphenous vein, enlarged lymph nodes and lymphatics and a femoral hernia. The cribriform fascia contributes to the anterior boundary of the femoral canal at this site (Fig. 2.4).

The arterial supply to the anterior abdominal wall is derived from a number of vessels, large and small, which conform to a reasonably constant pattern. Superficially these vessels anastomose to make a network in the subcutaneous tissue. The seventh to tenth intercostal arteries and musculophrenic arteries bilaterally and the right and left superior epigastric arteries (terminal branches of the right and left internal thoracic arteries, respectively) supply the abdominal wall cephalad to the umbilicus. Caudal to the umbilicus, the 11th intercostal and subcostal arteries bilaterally make a modest contribution, while the superior epigastric vessels anastomose with the inferior epigastric vessels inside the rectus sheath either within the substance of the rectus abdominis muscle or deep to the muscle and together supply most of the infraumbilical part of the anterior abdominal wall. The inferior epigastric artery arises from the external iliac artery just proximal to the inguinal ligament. The inferior epigastric artery and accompanying veins form the lateral margin of Hesselbach's triangle [2]. The deep inguinal ring and thus the neck of an *indirect* inguinal hernial sac lie lateral to these vessels, while the neck of a direct inguinal hernia sac is medial to these vessels.

In addition to the serially arranged vessels described above, there are three small superficial branches of the femoral artery in the upper thigh. These branches are the superficial circumflex iliac artery passing laterally and upwards superficial to the inguinal canal, the superficial epigastric artery coursing upwards and medially towards the umbilicus and the superficial external pudendal artery making its way medially to supply the skin of the penis and scrotum. All these arteries are frequently encountered in inguinal and femoral hernioplasty, and all anastomose adequately with their neighbours and with their counterparts across the midline. In most instances they can be divided with impunity, but very occasionally they are an auxiliary source of blood supply to the testicle (Fig. 2.5). The corresponding and accompanying veins drain to the great saphenous vein.

The veins draining the lower abdomen enter the femoral vein via the great saphenous vein through the saphenous opening or directly into the external iliac vein. From the upper abdomen venous blood eventually drains into the subclavian veins either via tributaries of the internal thoracic veins or via tributaries of the axillary veins.

The finer details of the vascular supply of the anterior abdominal wall are beyond the scope of this chapter but are

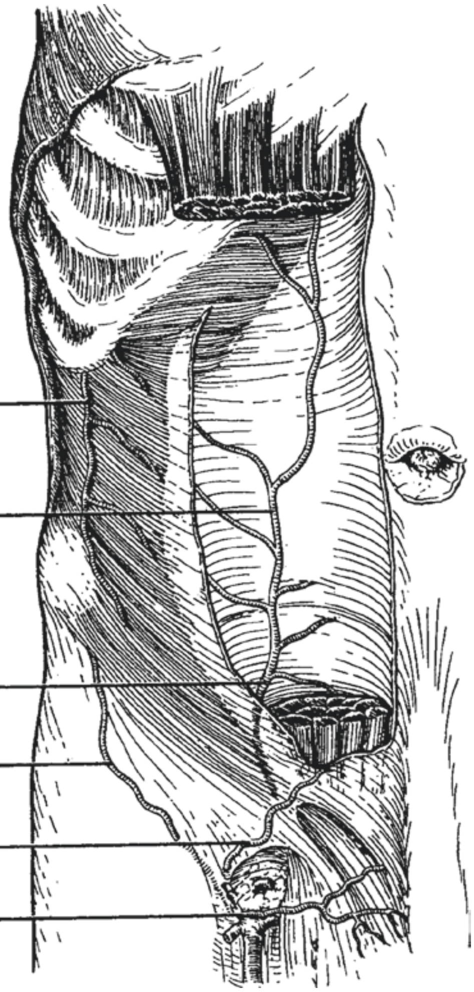

Fig. 2.5 The vasculature of the abdomen and groin is of particular interest to the surgeon. Fortunately the vessels all anastomose freely, so surgery does not need to be locked into vascular anatomy, except for the anastomosis of the pudendal with the cord vessels over the pubis. Care should be taken not to dissect the superficial tissues medial to the pubic tubercle to avoid threat to the pudendal anastomosis and the testicle

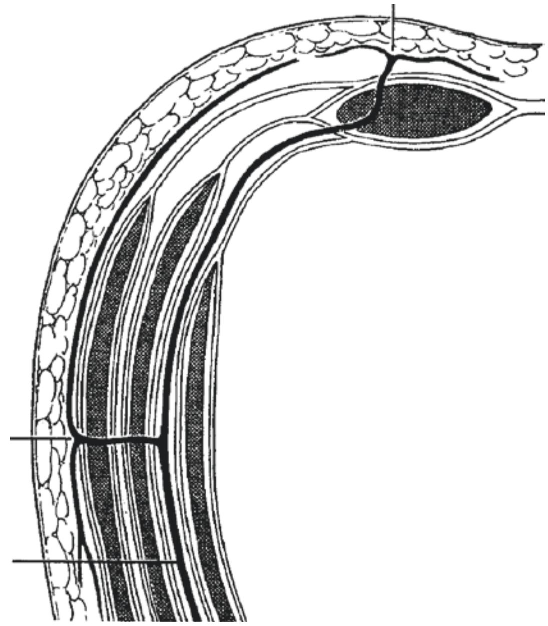

Fig. 2.6 The lower abdomen is segmentally supplied by the intercostal nerves. Each nerve has a lateral cutaneous branch which gives anterior and posterior divisions in the subcutaneous tissue. When a local anesthetic is administered, it is important to block the anterior division of the lateral cutaneous branch of these nerves

of paramount importance in the context of tissue transfer in plastic and reconstructive surgery. (The interested reader may consult [3].)

Superficial Nerves

The cutaneous nerves to the anterior abdominal wall are arranged and distributed segmentally, as in the anterior chest wall. The lower five intercostal nerves and the subcostal nerve (12th thoracic nerve) having run in their respective intercostal spaces cross the costal margin obliquely to enter the neurovascular plane of the anterior abdominal wall (i.e. the plane between the internal oblique and transversus abdominis) to supply the abdominal parietes. While still in the intercostal space, each gives off a lateral cutaneous branch which enters the overlying digitation of the external oblique muscle; this branch divides into a small posterior nerve which extends back to supply the skin overlying the latissimus dorsi and a larger anterior nerve which supplies the external oblique muscle and the overlying subcutaneous tissue and skin. The main stem of the intercostal nerve continues forwards in the neurovascular plane and enters the rectus sheath from behind by piercing the posterior lamella of the internal oblique aponeurosis. It gains the surface by passing through the rectus abdominis muscle which it supplies before emerging through the anterior rectus sheath a centimetre or so from the midline (Fig. 2.6).

The most caudal of the abdominal wall nerves are derived from the ventral ramus of the first lumbar spinal nerve; they are the iliohypogastric and ilioinguinal nerves. The ilioinguinal nerve is generally the smaller of the two—although occasionally, it may be the larger of the two. Rarely the ilioinguinal nerve is very small and may even be absent. The anterior cutaneous branch of the iliohypogastric nerve emerges through the aponeurosis of the external oblique, 1 or 2 cm above the superficial inguinal ring, and innervates the skin in the suprapubic region. The ilioinguinal nerve enters the inguinal canal at its lateral extremity (and not through the deep inguinal ring), and running through the canal usually inferolateral to the spermatic cord (or uterine round ligament), it becomes superficial by emerging through the superficial inguinal ring to supply the anterior one-third of the scrotal skin (vulval skin in the female) and a small area of the medial upper thigh and suprapubic skin (Fig. 2.7).

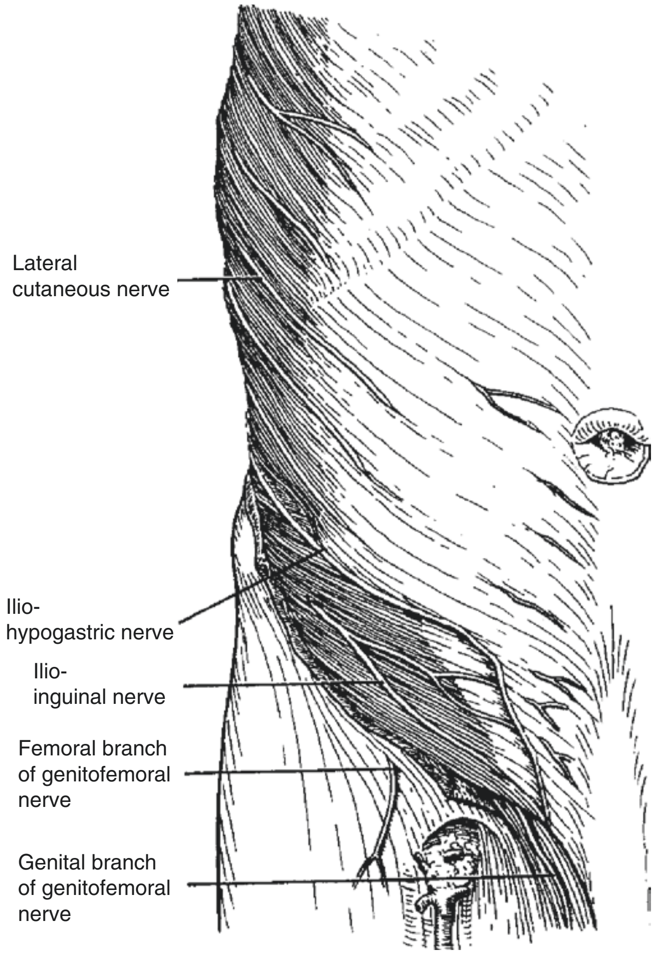

Fig. 2.7 The groin area is innervated principally by branches of the first lumbar nerve—the iliohypogastric and ilioinguinal nerves. These nerves innervate the skin area over the iliacc crest (the lateral branch of the iliohypogastric nerve), the suprapubic region (the anterior branch of iliohypogastric nerve), and the front and side of the scrotum and upper medial thigh (the ilioinguinal nerve after it emerges from the inguinal canal)

The genitofemoral nerve is derived from the ventral rami of the first and second lumbar spinal nerves and completes the innervation of the anterior abdominal wall and groin areas. At first it passes obliquely forwards and downwards through the substance of the psoas major. It emerges from the muscle and crosses its anterior surface behind the posterior parietal peritoneum, running posterior to the ureter. It divides at a variable distance from the deep inguinal ring into a genital and a femoral branch.

The genital branch, a mixed motor and sensory nerve, enters the inguinal canal at or just medial to the deep inguinal ring. The nerve penetrates the fascia transversalis of the posterior wall of the inguinal canal either through the deep ring or separately medial to the deep ring. The nerve traverses the inguinal canal lying between the spermatic cord above and the inguinal ligament inferiorly; the nerve is vulnerable to surgical trauma as it progresses along the floor of the canal (the gutter produced by the inturned lower edge of the inguinal ligament). The genital branch supplies motor innervation to the cremaster muscle and sensory innervation to the fascial coverings of the spermatic cord (or coverings of the uterine round ligament in the female). It may supply the skin of the scrotum.

The femoral branch enters the femoral sheath overlying the femoral artery and supplies a small area of skin over the upper part of the femoral triangle (Fig. 2.8).

The posterior two-thirds of the scrotum is supplied by S2 and S3 through the perineal and posterior femoral cutaneous nerves. The anterior scrotal cutaneous supply is frequently disrupted in open repair of inguinal hernias (Fig. 2.9) no doubt due to injury to the ilioinguinal nerve (caused inadvertently or otherwise).

The sensory nerve supply of the upper anterior and anterolateral thigh is derived from the lateral cutaneous nerve of the thigh, the femoral branch of the genitofemoral nerve, the ilioinguinal nerve and the genital branch of the genitofemoral nerve (Fig. 2.10). There is overlap between the territories of these nerves, and their pathways also show considerable variation.

The lateral cutaneous nerve of the thigh arises from the ventral rami of the second and third lumbar nerves. It emerges from the lateral border of the psoas major and crosses the

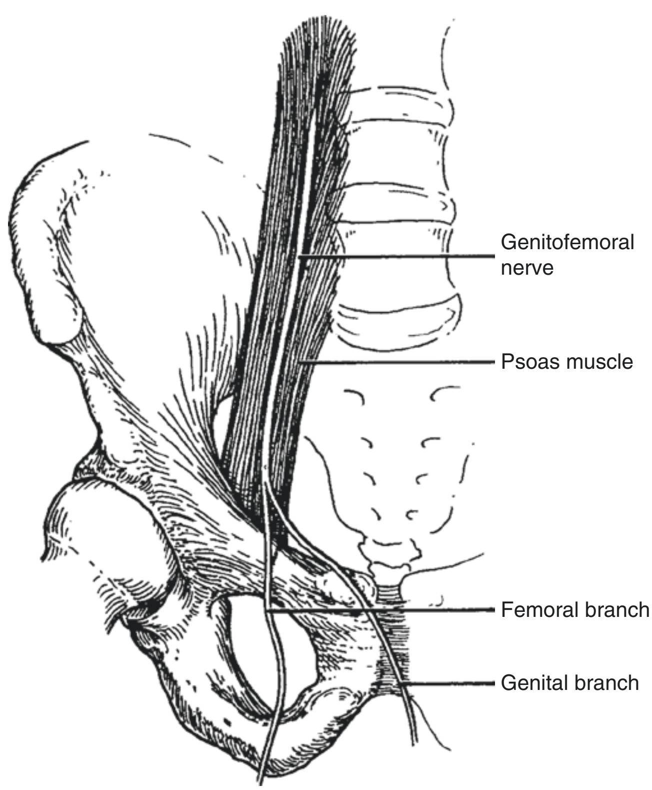

Fig. 2.8 The genitofemoral nerve, from L1 and L2, innervates the femoral sheath and the skin over it. It should be blocked prior to surgery for a femoral hernia under local anesthetic

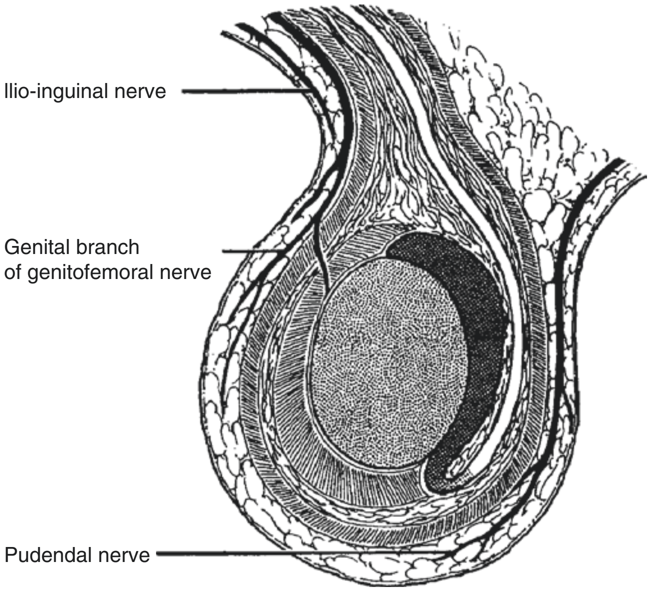

Fig. 2.9 The skin of the anterior scrotum is supplied by the ilioinguinal nerve, L1, and the genital branch of the genitofemoral nerve, L1. These nerves are often disrupted in hernioplasty

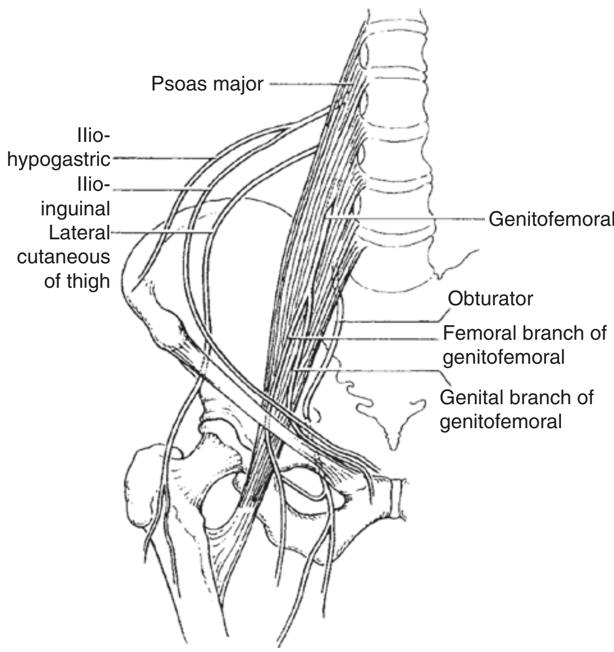

Fig. 2.10 The nerves of the lower abdomen, the groin and upper thigh. The lateral cutaneous nerve of the thigh and the femoral branch of the genitofemoral nerve are at special risk in extraperitoneal operations on groin hernia

ventral aspect of iliacus obliquely, running towards the anterior superior spine. It lies in the adipose tissue between the iliopsoas fascia and the peritoneum.

Usually the lateral cutaneous nerve of the thigh forms one single trunk, but it may divide into two branches at a variable distance proximal to the inguinal ligament (Figs. 2.10 and 2.11) [4]. The nerve then crosses into the anterior thigh by passing deep to the lateral portion of the inguinal ligament. It may then lie superficial to the sartorius muscle or may pass through the sartorius before becoming superficial to supply the skin of the lateral side of the thigh. The variability of the course of the nerve in the abdomen is considerable, and the distance between nerve and the deep inguinal ring also variable [5]. The nerve may traverse the anterior abdominal wall cranial to the inguinal ligament or through the attachment of the ligament to the anterior superior iliac spine (Fig. 2.11).

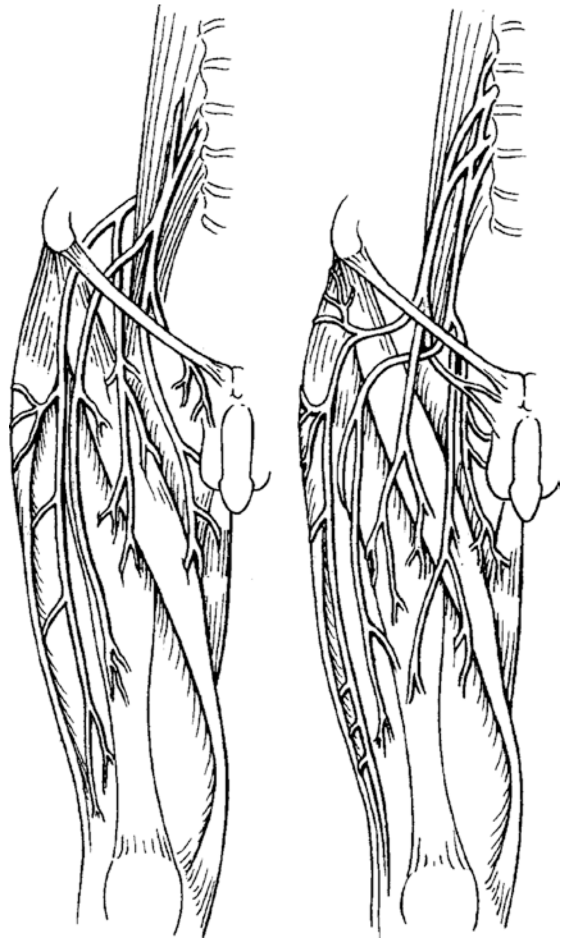

Fig. 2.11 The variable anatomy of the lateral cutaneous nerve of thigh and the femoral branch of the genitofemoral nerve. Both these nerves are in close proximity to the inguinal ligament as they progress to the thigh [4]

The scrotal nerve supply is complex [6]. The autonomic supply of the testis is from T10 to T12, via nerves which accompany the spermatic vessels. These autonomic nerves are motor to the vasculature and to the smooth muscle of the tunica albuginea. However, they also have free, sensory endings in the interstitial spaces of the testis and convey noxious stimuli which may present as referred pain in the lower abdomen (T10–T12 segments). The autonomic supply of the vas and epididymis is distinct from those of the testis; pain from these structures is felt in the L1 segment, lower than testicular pain, in the distributions of the genitofemoral nerve.

The somatic nerve supply is the genitofemoral nerve, L1 and L2, and the sacral nerve, S2 and S3. The genital branch of the genitofemoral nerve supplies the cord, the cremaster, the tunica vaginalis and, along with the L1 component of the ilioinguinal nerve, the anterior third of the scrotal skin.

When viewed from behind, as during endoscopic hernia surgery, the area lateral to the cord vessels and above the inguinal ligament where the femoral branch of genitofemoral nerve and lateral cutaneous nerve of the thigh lie, has been dubbed the ‘triangle of pain’ by laparoscopic surgeons because of the hazard of nerve injury by entrapment with staples. In this area thick globular adipose tissue can surround and conceal the nerves. On a deeper plane, the femoral nerve crosses this triangle with the genitofemoral and lateral cutaneous nerve superficial to it (Fig. 2.12). This entire area is spoken of as the ‘quadrangle of doom’. All of the nerves that can be injured during laparoscopic inguinal hernia repair are located in this anatomic region.

Musculoaponeurotic Plane

The musculoaponeurotic ‘plane’ is architecturally complex and composed of several layers.

A long and thick strap-like muscle, the rectus abdominis, lies on either side of the vertical midline. Lateral to the rectus abdominis on each side, the musculoaponeurotic plane comprises a three-ply arrangement of concentric muscular sheets. The largest and most superficial of the three is the external oblique muscle. The intermediate muscular sheet is the internal oblique muscle, while the deepest (innermost) sheet is the transversus abdominis. Of these three layers, the internal oblique and transversus abdominis curve posteriorly to attach to the lumbar fascia at the very lateral edge of the quadratus lumborum muscle on the posterior abdominal wall. The external and internal obliques and the transversus abdominis may be spoken of, collectively, as the anterolateral abdominal musculature.

Anteromedially, each of the abovementioned three muscular sheets becomes an aponeurosis (a flattened tendinous sheet). These aponeuroses envelop the ipsilateral rectus abdominis muscle in a highly specific and well-defined manner, and having done so, they interdigitate in the vertical midline with their counterpart aponeuroses from the contralateral side to form the linea alba. The aponeurotic envelope surrounding the rectus abdominis muscle is referred to as the rectus sheath.

A description of the rectus abdominis (and pyramidalis) muscles shall be followed by a detailed consideration of the three muscles which make up the anterolateral abdominal musculature.

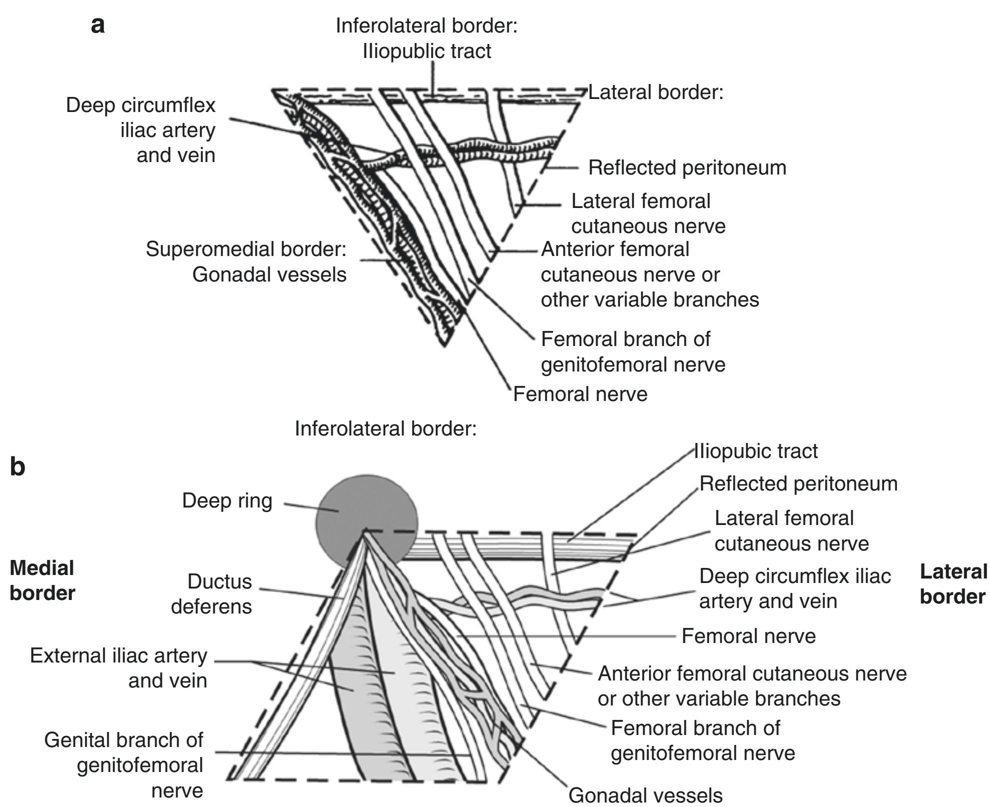

Fig. 2.12 (**a**) Laparoscopic view of the nerves immediately proximal to the inguinal ligament after reflection of the parietal peritoneum. These nerves lie in the adipose tissue just deep to the peritoneum and superficial to the iliopsoas muscle: the “triangle of pain.” (**b**) Laparoscopic view of the deep inguinal ring and adjacent structures, the “triangle of doom” [29]

The Rectus Abdominis Muscle

The rectus muscle is flat and strap-like and extends from the level of the pubis to the thorax. The muscle is separated from its fellow of the opposite side by the linea alba. Each rectus abdominis muscle arises by two short tendons: the larger and lateral tendon from the pubic crest and the smaller and medial tendon from the upper and anterior surfaces of the pubic symphysis (some of the fibres from the medial tendon mingle with those of the medial tendon of the other side). The two tendons, lateral and medial, unite a short distance above the pubis to give rise to a single muscle belly which broadens as it runs upwards and crosses the costal margin to attach to the anterior surfaces and inferior margins of the seventh, sixth and fifth costal cartilages and, by a small slip, to the xiphisternum.

The upper part of the muscle belly usually shows three transverse tendinous intersections: one at the level of the xiphisternum, one at the level of the umbilicus and one halfway between the other two. Sometimes a further incomplete intersection is present below the umbilical level. The intersections extend into the thickness of the muscle for a variable distance but never penetrate the entire thickness of the muscle. They are always intimately adherent to the anterior lamina of the sheath of the muscle but have no attachment to the posterior sheath.

The pyramidalis muscle is triangular in shape, arising by its base from the ligaments on the anterior surface of the symphysis pubis and being inserted into the lower linea alba 2–3 cm above the pubic symphysis. The muscle is absent in 10% of subjects (Fig. 2.13) and in any case is not thought to be of any functional consequence.

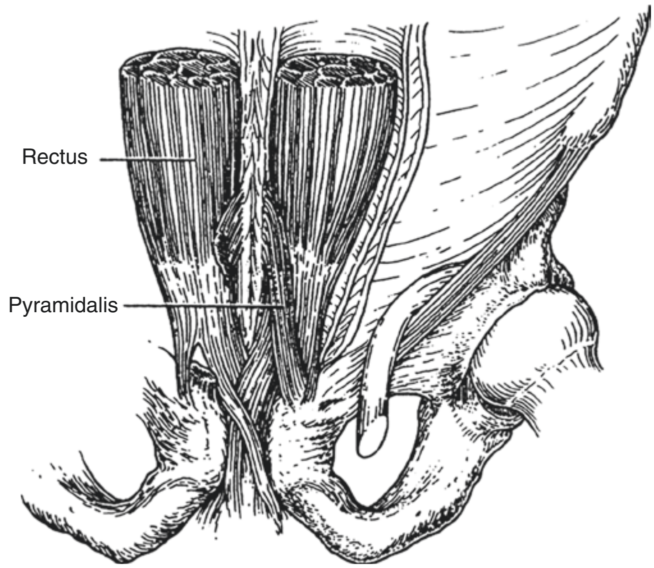

Fig. 2.13 The rectus muscle arises by two tendons—the larger and lateral from the crest of the pubis and the smaller and medial from the pubis of the opposite side and from the ligamentous fibers of the symphysis. The pyramidalis is variable; it arises from the ligamentous fibers of the symphysis and adjacent pubis and is inserted into the linea alba

The External Oblique Muscle

The external oblique muscle arises, typically, by eight slips: from the external surface and inferior border of each of the lower eight ribs. The upper four slips interdigitate with the slips of origin of the serratus anterior muscle. The lower four slips of the external oblique interdigitate with those of the latissimus dorsi muscle. The fibres pass downwards and forwards from their costal origins. The posterior fibres are nearly vertical and are inserted into the anterior half of the external lip of the iliac crest. The uppermost fibres run almost horizontally towards the ventral midline. The intervening fibres from above downwards display a progressively increasing obliquity as they run towards the ventral midline. All the superior and intermediate fibres end in the strong external oblique aponeurosis. The muscle may be said to have three borders: a posterior border which is muscular and upper and lower borders which are both aponeurotic.

The posterior border of the external oblique is free, so to speak, and forms the anterior boundary of the lumbar triangle (of Petit). The posterior boundary of the lumbar triangle is the anterolateral edge of the latissimus dorsi muscle, and the inferior boundary is the short length of iliac crest between the attachments of external oblique and latissimus dorsi. The 'floor' of this triangle is formed by the internal oblique and the underlying transversus abdominis. Both sheets are relatively thin at this level, and it is through this triangle that a lumbar hernia may present as a swelling in the flank.

Superiorly the external oblique aponeurosis is relatively thin and passes medially to be attached to the xiphoid process. Inferiorly the aponeurosis is very strong. The inferior margin of the aponeurosis forms the inguinal ligament. The latter is attached superolaterally to the anterior superior iliac spine and inferomedially to the pubic tubercle. Medially, the aponeurosis of the external oblique contributes to the anterior rectus sheath and thence interdigitates with its fellow of the opposite side at the linea alba. The external oblique aponeurosis is broadest inferiorly, narrowest at the umbilicus and broad again in the epigastrium.

The aponeurosis of the external oblique muscle fuses with the aponeurosis of the internal oblique in the anterior wall of the rectus sheath. This line of fusion which is considerably medial to the semilunar line has an oblique and somewhat curved trajectory, being more lateral above and more medial below. In fact, the external oblique aponeurosis contributes very little to the lower portion of the anterior rectus sheath. This latter point is of importance in inguinal hernioplasty (Fig. 2.14) [7].

There is a natural defect in the external oblique aponeurosis just above the pubis. This aperture known as the superfi-

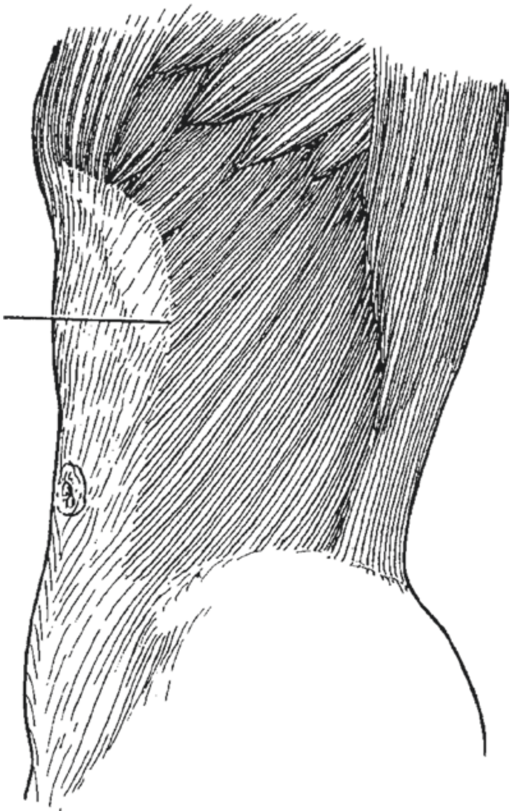

Fig. 2.14 The external oblique muscle and its aponeurosis invests the abdomen. The aponeurosis of this muscle forms the anterior wall of the rectus sheath by fusing with the underlying aponeurosis of the internal oblique. However, this line of fusion, in the lower abdomen especially, is considerably medial to the semilunar line. This is an anatomical point of importance in inguinal hernioplasty, as it allows a "slide operation" on the internal oblique without compromising the anterior rectus sheath

cial inguinal ring (external inguinal ring) is triangular in shape and in the male, transmits the spermatic cord from the abdomen to the scrotum. In the female the round ligament of the uterus emerges through this opening before blending with the subcutaneous tissue in the ipsilateral labium majus. The superficial inguinal ring is not a 'ring'; it is a triangular cleft with its long axis obliquely disposed in a superolateral direction from the pubic tubercle. It is approximately parallel to the inguinal ligament. The base of the triangle is formed by the crest of the pubis, and the apex is laterally directed towards the ASIS. The superficial inguinal ring represents the interval between that part of the external oblique aponeurosis which inserts into the pubic symphysis and pubic crest on the one hand and the inguinal ligament on the other hand, which inserts into the pubic tubercle. The aponeurotic margins of the ring are described as the superior and inferior crura. The spermatic cord, as it comes through the superficial inguinal ring, rests on the inferior crus which is a continuation of the floor of the inguinal canal (the enrolled inferomedial end of the inguinal ligament).

The dimensions of the superficial inguinal ring, or aponeurotic cleft, are of surgical importance and are far from being of standard size and predictable extent. It may sometimes fit snugly around the spermatic cord. At other times it may extend upwards and laterally beyond the anterior superior iliac spine. In 80% of cases, the cleft is confined to the lower half of the area between the midline and the anterior superior spine, but in the remaining 20%, it extends more laterally. In about 2% of individuals, one or more accessory clefts are seen. When present, they are usually superolateral to the main cleft. The accessory cleft may transmit the iliohypogastric nerve (Fig. 2.15) [8].

The relationship between the apex of the cleft and the inferior (deep) epigastric vessels (indicating the lateral margin of Hesselbach's triangle) is of crucial importance in closing the inguinal canal anteriorly and containing a potential direct inguinal hernia. Whereas the canal is usually described as closed anteriorly by the external oblique aponeurosis, in only 11% of cases does the apex of the cleft lie less than halfway along a line from the pubic tubercle to the inferior epigastric artery, in 52% the cleft extends to the level of the epigastric vessels and, most importantly, in 37% the apex of the cleft is lateral to the epigastric vessels (Fig. 2.16) [8].

The crura of the superficial ring are joined together by intercrural fibres derived from the outer investing fascia of the external oblique aponeurosis. The size and strength of these intercrural fibres vary. It has been estimated that in 27% of individuals these fibres do not cross from crus to crus and, therefore, do not reinforce the margins of the cleft [8].

The inferior border of the external oblique aponeurosis is rolled inwards to form a gutter. This enrolled edge is termed the inguinal ligament (Poupart's ligament). It is attached superolaterally to the anterior superior iliac spine and inferomedially to the pubic tubercle. Both bony landmarks are readily palpable. Reciprocal to the gutter-shaped, concave upper surface, the inguinal ligament presents a rounded inferior border towards the thigh. Attached to this rounded distal surface of the inguinal ligament is the deep fascia of the thigh, the fascia lata. The medial end of the inguinal ligament at the pubic tubercle gives rise to the lacunar ligament (Gimbernat's ligament) which extends upwards and backwards to reach the pectineal line on the superior ramus of the pubis. The crescentic, free, lateral edge of the lacunar ligament forms the medial boundary of the femoral ring. From its attachment on the pectineal line, the lacunar ligament sends a strong extension which runs superolaterally and has a firm attachment along the iliopectineal line. This extension is termed the pectineal ligament (of Astley Cooper). Finally, from the pubic tubercle, certain fibres of the inguinal ligament run superiorly and medially behind the spermatic cord to interdigitate at the linea alba with corresponding fibres from the contralateral side. This superomedial extension of the inguinal ligament is termed the reflected part of the inguinal ligament. The inguinal ligament shows a gentle curvature, with its concavity directed medially and upwards

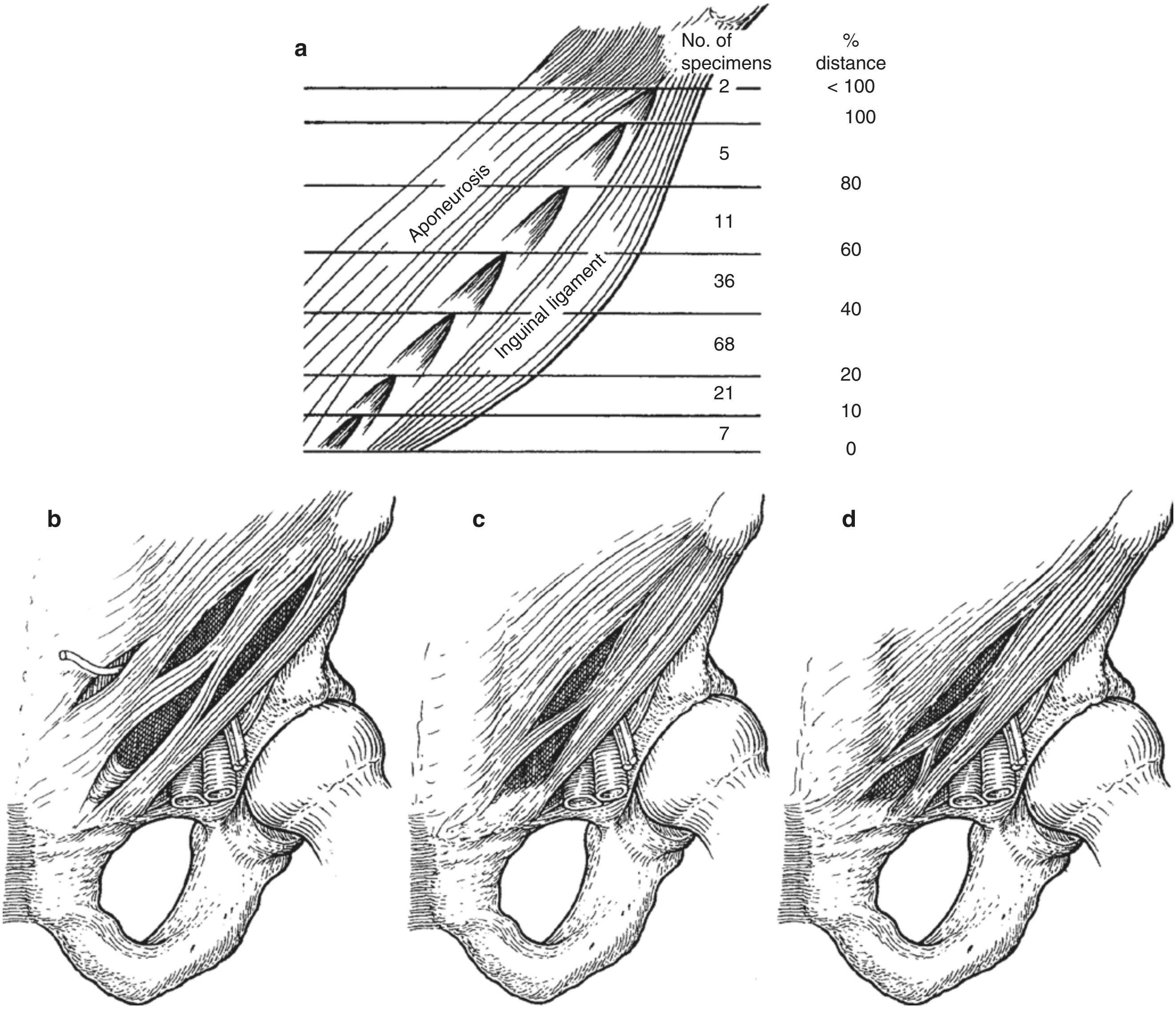

Fig. 2.15 The anatomy and dimensions of the superficial inguinal ring are very variable. The "ring" is a triangular cleft separating the insertions of the external oblique aponeurosis into the pubic crest and the pubic tubercle. Its base is medial and inferior and its apex superior and lateral. In 80% of subjects the apex lies in the medial half of the lower abdomen, but in the remaining 20% the apex approaches the anterior superior iliac spine (**a**). In 2% of subjects, there are accessory clefts superior to the main cleft (**b**–**d**). One of these clefts may transmit the iliohypogastric nerve (**b**) [8]

towards the (Fig. 2.17) abdomen and the reciprocal convexity directed inferolaterally towards the thigh.

The extensions from the medial end of the inguinal ligament as the lacunar (Gimbernat's) and the pectineal (Cooper's) ligament give a fan-like expansion of the inguinal ligament at its medial end. This expansion has important surgical implications.

The lacunar ligament is a triangular continuation of the medial end of the inguinal ligament. Its apex is at the pubic tubercle, its superior margin is continuous with the inguinal ligament and its posteromedial margin is attached to the iliopectineal line on the superior ramus of the pubis. Its lateral crescentic edge is free and is an important firm structure in the medial margin of the femoral ring (the proximal end of the femoral canal). The ligament lies in an oblique plane, with its upper (abdominal) surface facing superomedially and being crossed by the spermatic cord and its lower (femoral) surface looking inferolaterally. With the external oblique aponeurosis and the inguinal ligament, the superior surface forms a groove for the cord as it emerges from the inguinal canal (Fig. 2.18).

The reflected part of the inguinal ligament (Colles') is a broad band of rather thin fibres which arise from the crest of the pubis and the medial end of the iliopectineal line and pass anterosuperiorly behind the superior crus of the subcutaneous inguinal ring to the linea alba. The reflected part of the inguinal ligament is very variable in its extent, but it is an important structure closing the

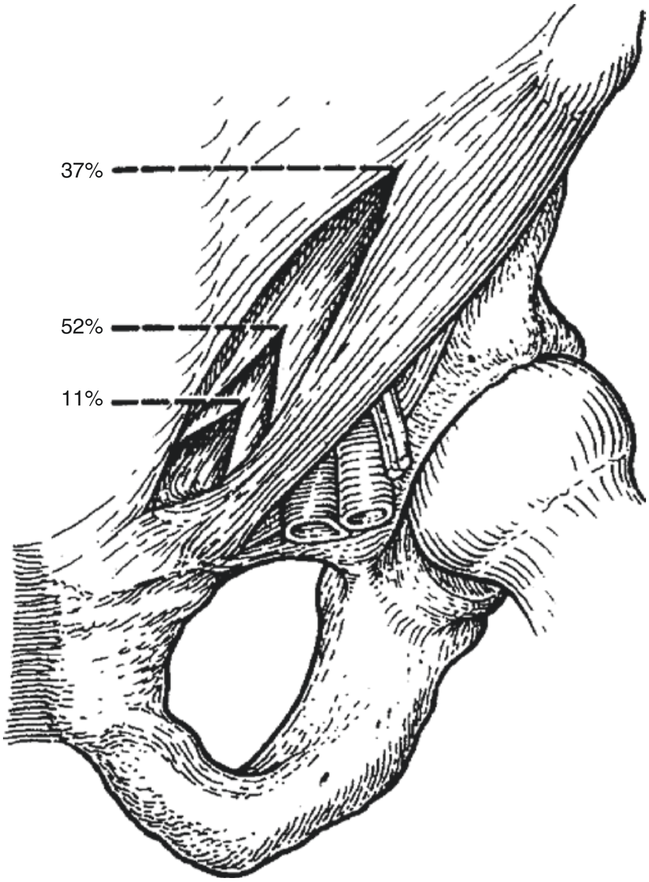

Fig. 2.16 The size of the superficial inguinal ring, the cleft in the external oblique, is crucial in closing the inguinal canal anteriorly. In 11% of subjects the cleft extends less than 50% of the length of the inguinal canal, in 52% it extends as far as the deep epigastric vessels, and in 37% the cleft extends lateral to the deep epigastric vessels [8]

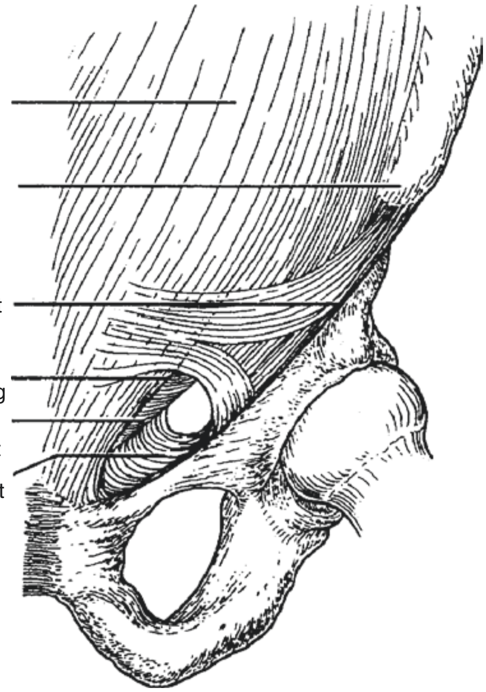

Fig. 2.17 The inguinal ligament is the lower margin of the external oblique muscle. Medially it is attached like a fan to the iliopectineal line (Cooper's ligament) and the tubercle of the pubis

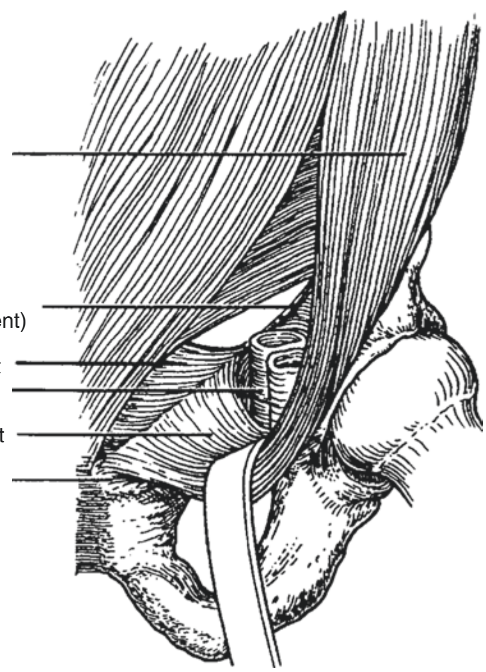

Fig. 2.18 The upper abdominal surface of the attachment of the inguinal ligament to the pubic tubercle is the floor of the inguinal canal which the cord rests on as it emerges from the canal

potential space in the posterior wall of the inguinal canal between the iliopectineal line and the lateral margin of the rectus muscle (Fig. 2.19).

The Internal Oblique Muscle

The internal oblique muscle arises from the lateral two-thirds of the abdominal surface of the inguinal ligament, the intermediate line on the anterior two-thirds of the iliac crest and from the whole length of the lumbar fascia. The general direction of the fibres (above the level of the anterior superior iliac spine) is upwards and medial. The posterior fibres are inserted into the inferior borders of the cartilages of the lower four ribs. The intermediate fibres pass upwards and medially and end in a strong aponeurosis which extends from the inferior borders of the seventh and eighth costal cartilages and the xiphisternum to the linea alba along the entire length of the latter. The lowermost fibres arise from the inguinal ligament and arch downwards and medially. These fibres along with the lowest fibres of the transversus muscle pass in front of the rectus abdominis muscle, contribute to the anterior rectus sheath and insert onto the pubic crest and the iliopectineal line behind the lacunar ligament and reflected part of the inguinal ligament (Fig. 2.20).

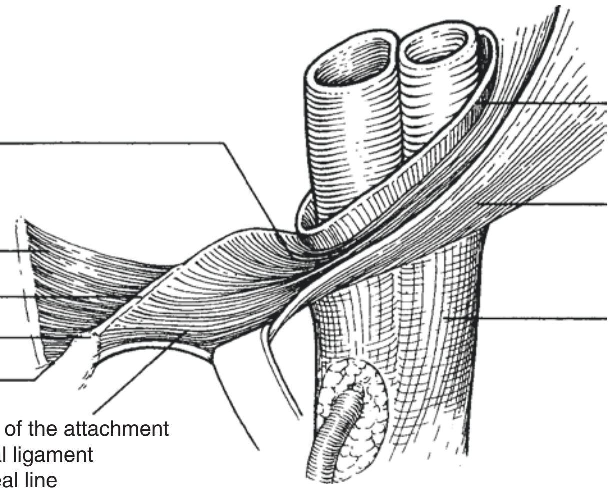

Fig. 2.19 Medially the posterior wall of the inguinal canal is reinforced by the reflected part of the inguinal ligament, a strong triangular fascia arising from the pubic crest anteriorly to the attachments of the internal oblique and transversus muscles and passing medially to the linea alba into which it is inserted

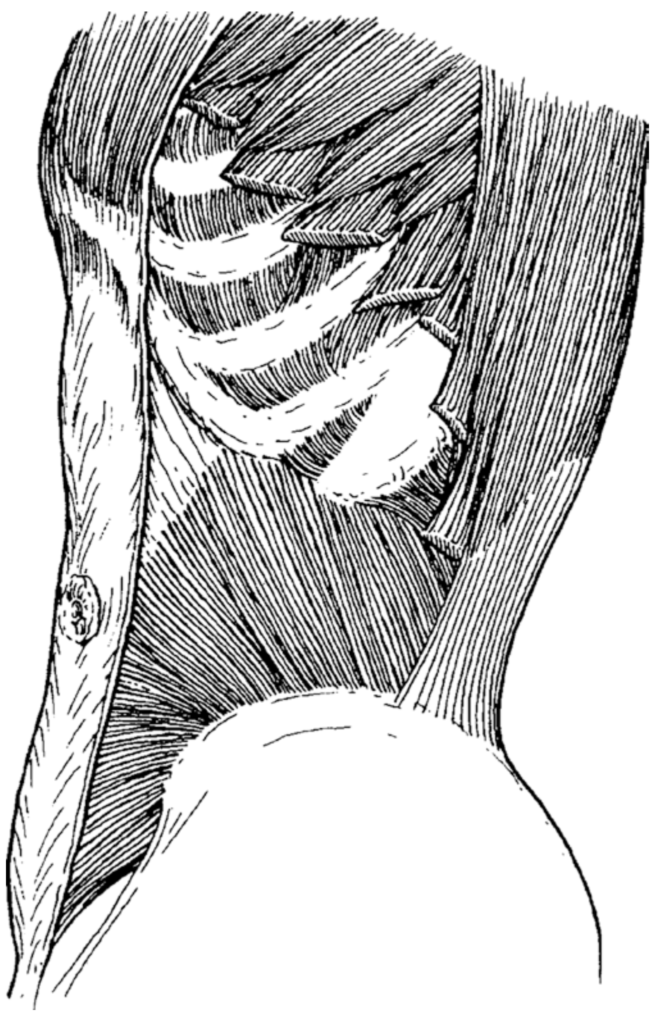

Fig. 2.20 The internal oblique muscle arising from the lateral half of the inguinal ligament and the iliac crest to be inserted into the lower costal cartilage and, via its aponeurosis, continuous with its fellow muscle contralaterally

A recent publication has questioned the traditional description of the lowest fibres of internal oblique (and transversus abdominis) arising from the upper surface of the inguinal ligament [9]. According to Acland, the lowest fibres of internal oblique and transversus abdominis arise not from the inguinal ligament but from a thickened ridge of iliopsoas fascia.

The internal oblique is not invariable in its anatomy in the inguinal region. Its origin may commence in front of the internal ring or at a variable distance lateral to the ring. The muscle may then insert either onto the pubic crest and tubercle or into the lateral margin of the rectus sheath a variable distance above the pubis. With regard to the behaviour of the internal oblique in the region of the groin, there are thus four possible combinations of origin and insertion. The contribution of the internal oblique to groin anatomy and in particular to the 'defences' of the inguinal canal is very variable. There are a number of well-recognized variations in the anatomy of the internal oblique in the groin (see p. 46) (Fig. 2.21).

The detailed anatomy of the semilunar line and rectus sheath, and that of the insertion of the lowermost fibres of the internal oblique into the pubic bone, is of surgical significance and warrants more detailed consideration.

At the lateral margin of the rectus muscle, the aponeurosis of the internal oblique splits into two lamellae—the superficial lamella passes anterior to the rectus, and the deep lamella goes posterior to the rectus. The superficial lamella fuses with the aponeurosis of the external oblique to form the anterior rectus sheath. The deep lamella fuses with the aponeurosis of the underlying transversus abdominis muscle. The detailed anatomy varies but has importance in the causation of umbilical and epigastric hernias. In the lower part of the abdomen, in an area inferior to a point about midway between the umbilicus and the pubis, the aponeurosis does not split into lamella but courses entirely in front of the rectus to fuse with the overlying aponeurosis of the external oblique (Fig. 2.22).

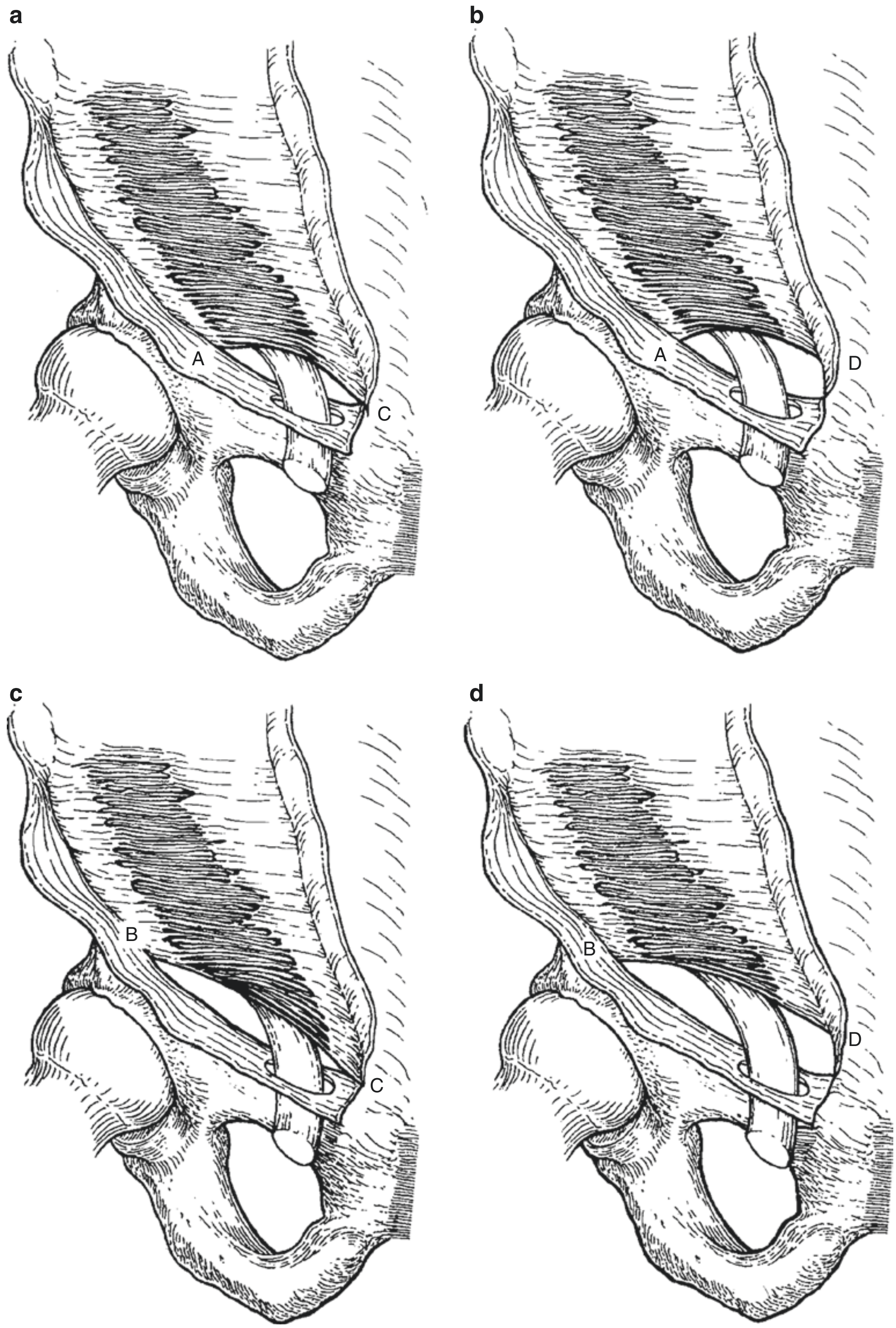

Fig. 2.21 The origin and insertions of the internal oblique muscle and aponeurosis in the inguinal region are variable. The origin of the red muscle fibers is from the lateral inguinal ligament; this origin may extend as far medially as the deep ring (**a**), or the muscle may arise more laterally (**b**). The insertion of the aponeurosis is also variable; it may be inserted into the pubic crest and pubic tubercle (**c**) or solely into the rectus sheath (**d**). This gives four variants of the lower margin of the internal oblique in the inguinal canal: A–C, A–D, B–C, and B–D

The internal oblique muscle in its lateral fleshy part is not uniform in structure; it is segmented or banded. The muscular bands terminate just lateral to the border of the rectus muscle and are most marked in the inguinal and lower abdominal region. The bands are generally arranged like 'the blades of a fan' with the interspaces increasing as the medial extremities are reached [10, 11]. The bands may be separable up to the point where they fuse with the aponeurosis lateral to the rectus muscle. In a fifth of cases, there are potential parietal deficits between these bands. Spigelian hernias occur through these defects in the region of the semilunar line, these defects being more pronounced in the lower abdomen.

At the lowermost part of the internal oblique muscle, adjacent to its origin from the inguinal ligament, the spermatic cord passes through or adjacent to the inferomedial margin of the muscle. Laterally the cord lies deep to the fleshy muscular fibres; then as it emerges alongside the muscle, it acquires a coat of cremaster muscle from the muscle.

The fascicles of the lower part of the internal oblique muscle follow a transverse or oblique direction. Medial to the cord, the muscle fibres are replaced with an aponeurosis which continues inferomedially to reach the pubis. There are variations both in the medial and the inferior extent of the muscle fibres of the internal oblique.

The fleshy muscle extends to the inferior margin in only 2% of cases; in 75% the extent is a centimetre or so above the margin, and in 20% there is a broad aponeurotic leaf superior to the spermatic cord. Likewise the fleshy muscle extends as far as the emergent cord in 20%, medial to the cord but not as far medially to the rectus margin in 75% and medial to the lateral margin of the rectus in 2%.

In clinical practice a direct inguinal hernia is never encountered when the lower margin of the internal oblique is fleshy *and* when the fleshy fibres extend medial to the superficial ring. Direct herniation is most frequently found at operation when the internal oblique muscle is replaced with flimsy aponeurosis in the roof of the inguinal canal (Fig. 2.23) [8].

In 52% of cases the lowermost arching fibres of the internal oblique are continuous above with the remainder of the internal oblique muscles, but in the remainder a variety of spaces between banding occur. In the medial and lower musculoaponeurotic part, defects superior to the spermatic cord may compromise the shutter mechanism of the canal and lead to direct inguinal herniation. Similarly, Spigelian hernia defects can develop between the muscle bands, enter the inguinal canal and present as direct inguinal hernia (Fig. 2.24) [12].

Rarely (0.15% of hernia cases), the spermatic cord is seen to come through the fleshy part of the lower muscle belly. In this rare situation, the muscle may be said to have an origin from the inguinal ligament medial to the emergent cord. In these cases there is prominent banding of the muscle in the lower abdomen; effectively, there is a band caudal to the cord (Fig. 2.25).

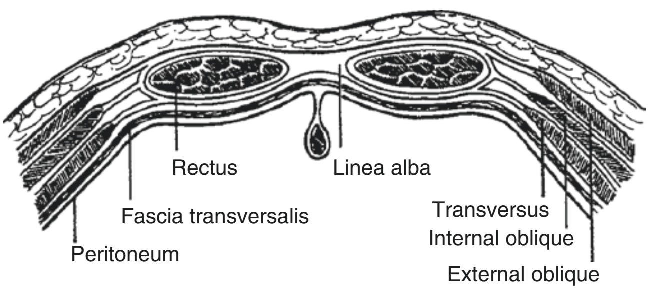

Fig. 2.22 Structure of the posterior rectus sheath in the upper abdomen. The internal oblique divides into two lamellae which enclose the rectus. The line of the fascia transversalis is deliberately emphasized

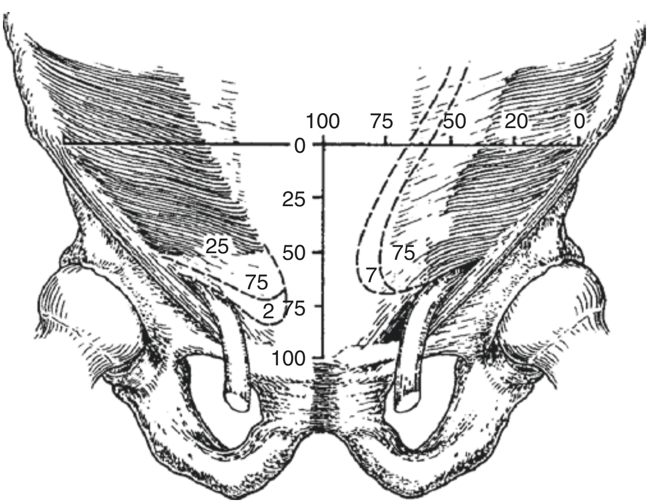

Fig. 2.23 Extent of the muscular fibers of the internal oblique. In only 2% of subjects the muscle extends inferiorly to the inguinal canal (*left* of diagram). Similarly the medial extent of the fleshy muscle fibers varies (*right* of diagram). The contribution of the internal oblique to the "defenses" of the inguinal canal is very variable [8] (from Anson et al.; with permission)

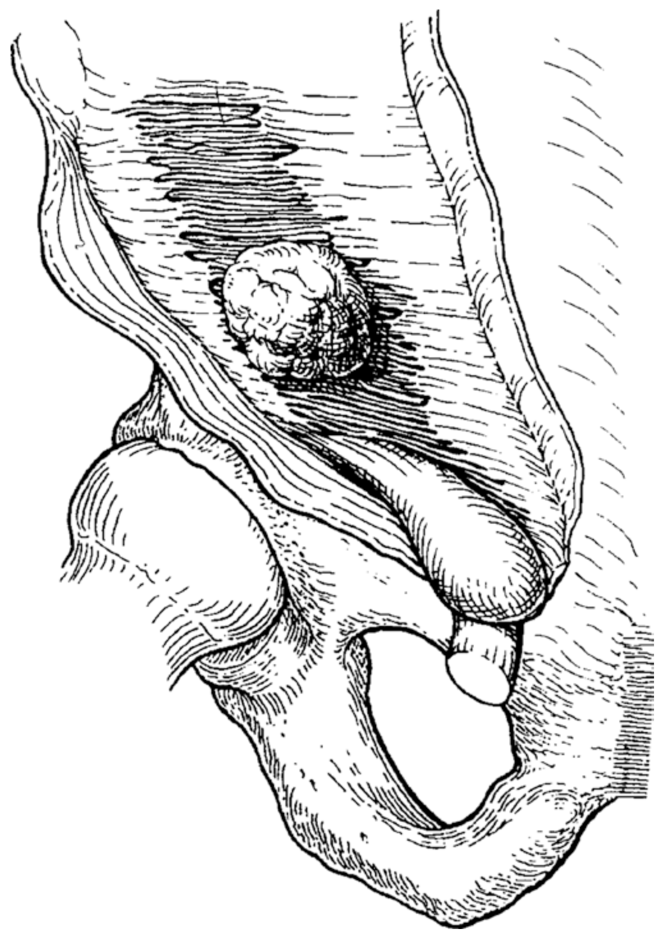

Fig. 2.24 A hernia can occur between bands of the internal oblique muscle. Although this hernia is in effect a variant Spigelian hernia, it presents as a direct hernia into the inguinal canal

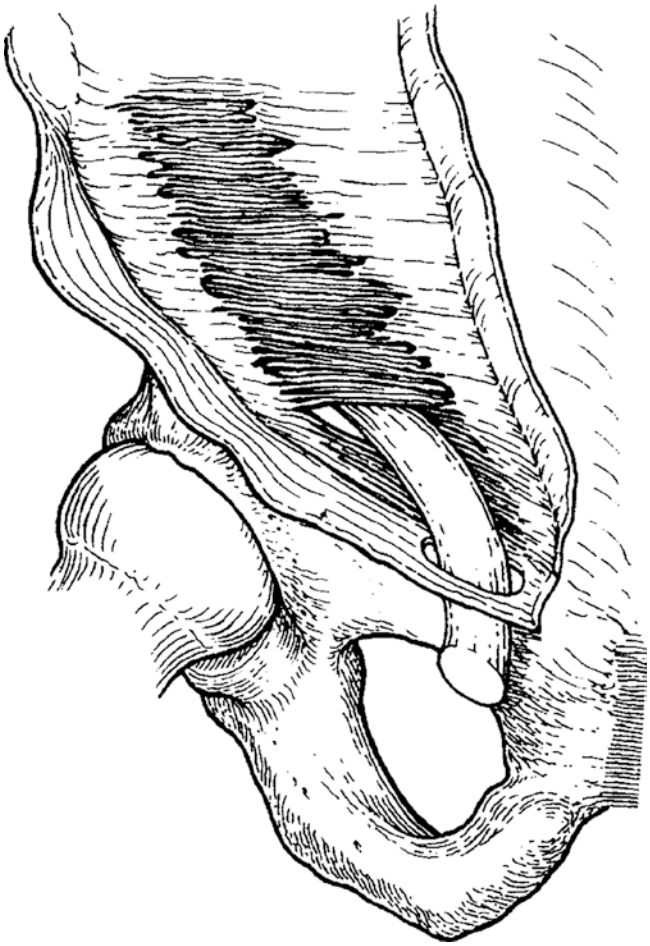

Fig. 2.25 Rarely fibers of the internal oblique muscle may extend medial to the deep ring, both above and below the ring, so that the cord is seen to pass between bands of the muscle

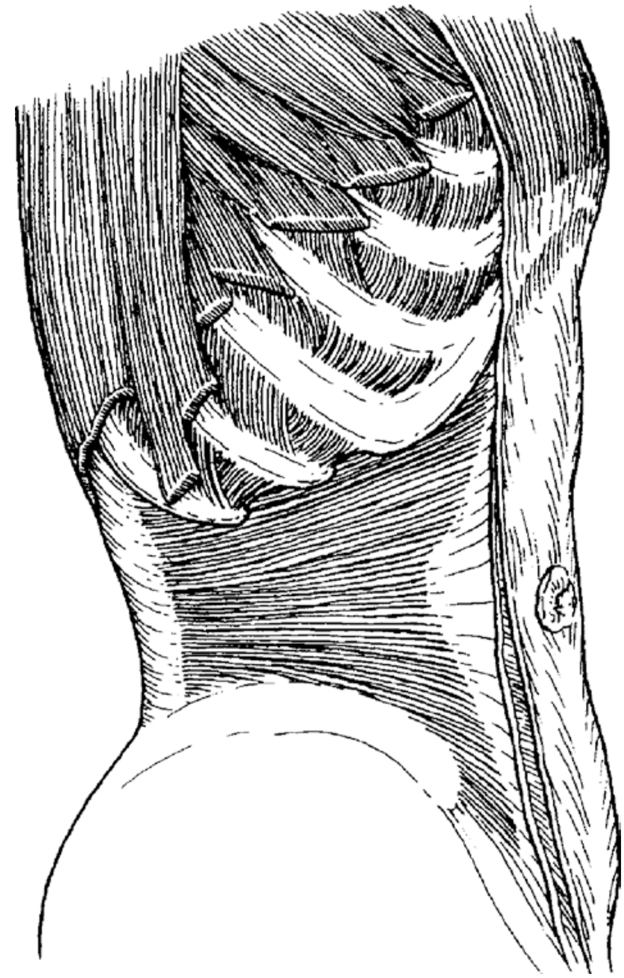

Fig. 2.26 The transversus muscle is the deepest of the anterolateral abdominal wall muscles; it arises from the iliopsoas fascia and inner lip of the iliac crest in its anterior two-thirds. The muscle extends to the inner surfaces of the lowest six costal cartilages, and its aponeurosis extends to the linea alba

The Transversus Abdominis Muscle

The transversus abdominis is the third and deepest of the three anterolateral abdominal muscle layers. The muscle arises in continuity from the inner surface of the costal margin, from the lumbar fascia, from the iliopsoas fascia along the internal lip of the anterior two-thirds of the iliac crest and from the lateral half or so of the superior surface of the inguinal ligament. The iliopsoas fascia is continuous posterosuperiorly with the anterior layer of the lumbar fascia, and the costal cartilages of the lower six ribs are interdigitating with the origin of the diaphragm (Fig. 2.26).

Traced anteromedially, the muscle fibres end in a strong aponeurosis which is inserted into the linea alba, the pubic crest and the iliopectineal line. For the most part, the muscle fibres run transversely, but the lowest of the muscle fibres take on a downward and medial curve so that the lower margin of the muscle forms an arch over the inguinal canal. The lower fibres of the muscle give way to the aponeurosis which gains insertion into the pubic crest and the iliopectineal line. The insertion of the transversus muscle is broader than that of the internal oblique, and consequently its aponeurosis extends further along the iliopectineal line (Fig. 2.27).

In the epigastrium and in the lower abdomen, down to a point midway between the umbilicus and the pubis, the transversus aponeurosis fuses with the posterior lamina of the aponeurosis of the internal oblique to form the posterior wall of the rectus sheath. In the lowermost abdomen, the aponeurosis passes in front of the rectus muscle and fuses with the deep surface of the aponeurosis of the internal oblique which in turn fuses with the deep aspect of the external oblique muscle to form the anterior wall of the rectus sheath (Fig. 2.28)

The transversus abdominis muscle is made up, proportionately, of more aponeurotic tissue and less muscle tissue than either the external or internal oblique muscles. In

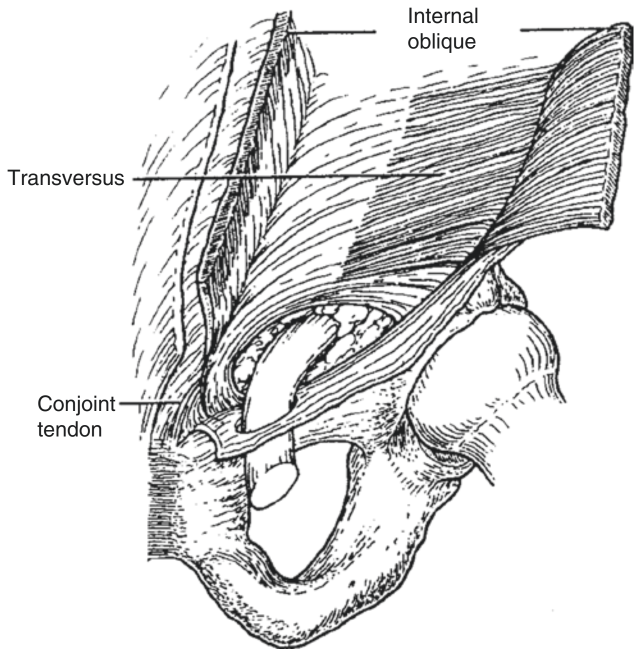

Fig. 2.27 The transversus muscle fibers run transversely, except in the lower abdomen where they form a strong aponeurosis (tendon) which is inserted to the pubic crest and the iliopectineal line. The insertion of the transversus tendon is broader than that of the internal oblique. The extent to which this tendon extends along the iliopectineal line determines its contribution to reinforcing the posterior wall of the inguinal canal. In surgical jargon the lowest fibers of the transversus aponeurosis cross over the cord to form the "roof" of the canal. These white aponeurotic fibers are referred to as the "arch" by some surgeons

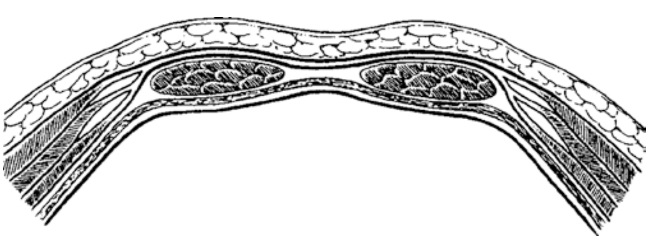

Fig. 2.28 Composition of the posterior rectus sheath in the lower abdomen. In the lower abdomen, inferior to the arcuate line of Douglas, the rectus sheath becomes deficient posteriorly. This is due to the fact that below the level of the arcuate line, all three aponeuroses (ext. oblique, int. oblique, and transversus abdominis) run in front of the rectus abdominis. The fascia transversalis, however, runs behind the rectus abdominis and in this location is denser and stronger than it is elsewhere

one study [8] it was observed that in 67% of cases fleshy muscle covered only the upper part of the inguinal region. In only 14% of cases were any fleshy fibres found in the lowermost fibres arching over the inguinal canal. Similarly, in 71% of subjects, the red fibres did not extend medial to the inferior epigastric vessels. The aponeurotic portion of the muscle shows its greatest anatomical variation in the inguinal region, where it is most important in hernia repair.

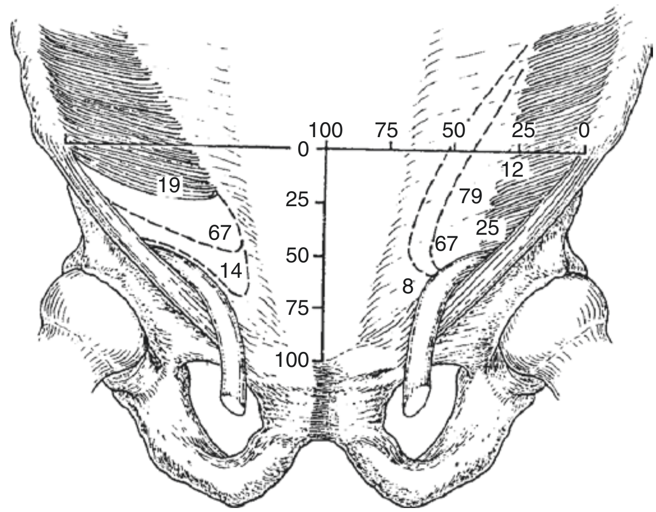

Fig. 2.29 The extent of fleshy red muscle in the transversus muscle is much less than in the internal oblique. Only in 14% of subjects is the lower margin of this muscle in the roof of the inguinal canal composed of red muscle (*left* of diagram). The medial extent of red fibers is similarly restricted; in 71% of subjects muscle fibers do not extend medially to the inferior epigastric vessels (*right* of diagram) [8] (from Anson et al.; with permission)

The lower border of the transversus abdominis aponeurosis is called the 'arch'. Above the arch the transversus aponeurosis forms a continuous strong sheet, with no spaces between its fibres. Below the arch the posterior wall of the inguinal canal is closed by transversalis fascia alone. This is a weak area through which direct herniation can occur. The aponeurotic arch is easily identifiable as a 'white line' of aponeurosis at operation (Figs. 2.27 and 2.29).

The Conjoint Tendon

The transverse fibres of the transversus muscle proceed horizontally to their insertion in the rectus sheath and the linea alba, while the lower fibres course downwards and medially—sometimes to fuse with the overlying fibres of the internal oblique as they insert onto the pubic crest and the iliopectineal line.

Only when the aponeuroses of the transversus and the internal oblique are fused some distance lateral to the rectus sheath is the term *conjoint tendon* appropriate and accurate. Thus the conjoint tendon represents the fused aponeuroses of the internal oblique and transversus muscles and which in turn is inserted onto the anteromedial 2 cm of the iliopectineal line. The transversus muscle contributes 80% of the substance of the conjoint tendon. The conjoint tendon is lateral to the rectus muscle and lies directly deep to the superficial inguinal ring. It passes down to its insertion on the pubis, deep to the inguinal and lacunar ligaments. The spermatic cord (or uterine round ligament) lies anterior to the conjoint tendon as it passes through the superficial inguinal ring.

The conjoint tendon has a very variable structure, and in 20% of subjects, it does not exist as a discrete anatomic structure. It may be totally absent or only partially developed, or it may be replaced by a lateral extension of the tendon of origin of the rectus muscle, or it may extend lateral to the deep inguinal ring so that no interval is present between the lower border of the transversus and the inguinal ligament. A shutter mechanism for the conjoint tendon can only be demonstrated when the lateral side of the tendon, that is, the transversus and internal oblique muscles, extends onto and is attached to the iliopectineal line [13]. The extent of this insertion is very variable. In 8% of cases, this attachment does not extend lateral to the rectus muscle, leaving the posterior wall of the inguinal canal (fascia transversalis) in such individuals unsupported. In 31% the attachment extends to the midpoint of the posterior wall between the pubic tubercle medially and the inferior epigastric vessels laterally; in 40% it extends as far laterally as the inferior epigastric vessels. In a minority of cases, bands of aponeurosis arise from the main aponeurotic arch and are inserted independently into the iliopectineal line. Sometimes, therefore, the lateral margin of the rectus sheath is formed only from the lowermost fibres of the transversus aponeurosis which curve inferiorly to become attached to the pubis—this is called the falx inguinalis.

A few fibres of the lowermost lateral margin of the rectus tendon may be fused with the fascia transversalis in their attachment to the iliopubic ligament—this has been called Henle's ligament (Fig. 2.30).

To understand the importance of the attachment of the internal oblique and transversus aponeuroses to the iliopectineal line, the posterior aspect of the inguinal canal must be visualized from inside the abdomen. If there is full attachment of the conjoint tendon to the iliopectineal line, the posterior wall of the inguinal canal may be said to be completely reinforced by aponeurosis. Absence of this attachment therefore renders the posterior wall devoid of reinforcement. In this situation there is clearly the potential for a direct hernia or a large indirect hernia to develop.

Of all the anatomic layers, the external oblique is the least variable; in the inguinal region, it is invariably aponeurotic. The internal oblique and transversus layers are very variable; they may be fleshy almost to the midline, aponeurotic or banded fan-like with the space between the musculoaponeurotic bands occupied only by the flimsiest fascia. If these local weaknesses in the internal oblique and transversus are superimposed, herniation is facilitated.

Zimmerman and colleagues have drawn attention to the frequency with which defects occur in the internal oblique and transversus muscles in this area. In 45% of their dissections, there was a defect in one or other of these two layers, and in 6% the defects were present in both layers and superimposed in the region of the lower linea semilunaris. These defects predispose to spontaneous ventral hernias either of preperitoneal fat or more extensive hernias with peritoneal sacs [13].

The Linea Alba and the Rectus Sheath

The linea alba is a longitudinally disposed, midline interdigitation (decussation) of the aponeuroses of the three-ply muscles of one side (external oblique, internal oblique and transversus abdominis) with those of the other. It is a pale band of dense fibrous tissue which extends from the xiphoid process above to the pubic symphysis, below. The linea alba is wide, thick and tough above the level of the umbilicus. It is broadest at the umbilicus, and below the umbilicus it becomes progressively narrower until it is little more than a narrow strip between the two rectus muscles at the suprapubic level. The linea alba is pierced by several small blood vessels and by the umbilical vessels in the foetus.

The anterior wall of the rectus sheath forms the most important portion of the abdominal wall aponeuroses. When the anterior wall of the sheath is gently dissected, during a paramedian incision, for example, it is seen to be made up of three laminae. The most superficial fibres of the anterior wall of the sheath are directed downwards and laterally; these are derived from the contralateral external oblique. The next layer is derived from the ipsilateral external oblique and has fibres which are oriented at right angles to those of the first layer, that is, they run downwards and medially. Finally, the third lamina of the anterior wall of the rectus sheath is formed from the anterior lamina of the ipsilateral internal oblique muscle, whose fibres generally run in the same direction as, and parallel to, the fibres of the external oblique of the opposite side. This gives the anterior rectus sheath a triple crisscross pattern similar to plywood [14, 15]. In the lower abdomen, the fusion of the external oblique aponeurosis to the internal oblique aponeurosis is very medial, an important anatomical arrangement that allows a tendon slide to be used to release the tension of the internal oblique in direct inguinal hernia repair without compromising the integrity of the anterior rectus sheath [14].

The most important feature from a surgical perspective is that the fibres of the rectus sheath run from side to side. Vertical incisions divide fibres, while horizontal incisions down closure with sutures encircling fibres rather than between fibres.

The posterior rectus sheath has a similar trilaminar crisscross pattern above the umbilicus, where it is composed of the posterior lamina of the internal oblique and the aponeurosis of the transversus abdominis muscle from either side.

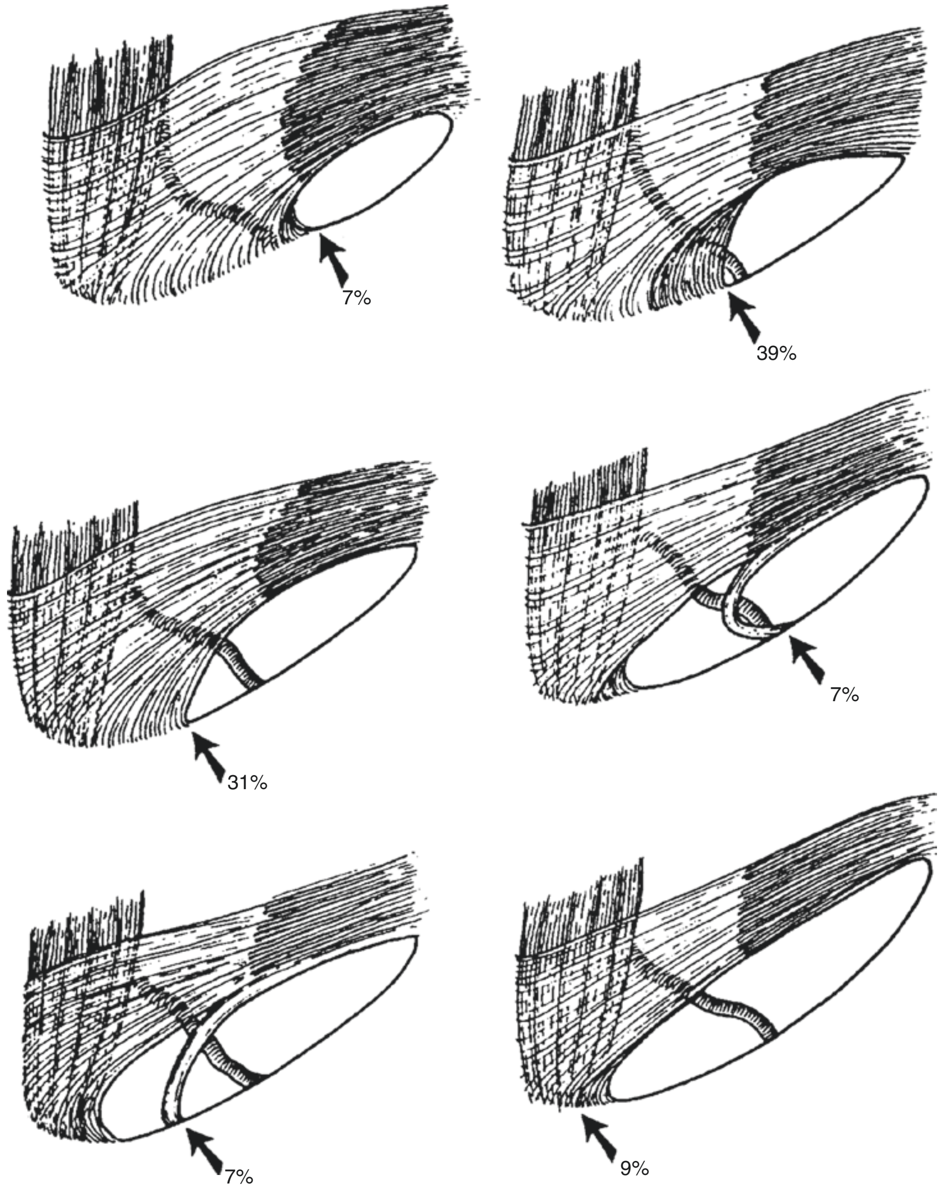

Fig. 2.30 The extent to which the tendon of transversus abdominis contributes to the posterior wall of the inguinal canal. In each illustration the *arrow* indicates the lateral most extension of the tendon and the corresponding percentage of subjects [8]

Within the rectus sheath are the rectus muscles, the pyramidalis muscle, the terminal portions of the lower six thoracic nerves and the superior and inferior epigastric vessels (Fig. 2.33).

Function of the Anterior Abdominal Wall

Although the anterior abdominal wall is composed of symmetrical halves, right and left, these halves function together in a coordinated and synergistic manner. The individual muscles cannot work separately and independently. The upper part of the anterior abdominal wall is the actively mobile respiratory zone, where the rectus sheath—the (anterolateral) flank muscles and the rectus muscle through its tendinous attachments to the rectus sheath—functions collectively as an accessory respiratory muscle. The lower part has no tendinous intersections and is a relatively fixed lower belly support zone. This anatomical and physiological configuration has been demonstrated using a transillumination silhouette technique by Askar [14].

The Fascia Transversalis: The Space of Bogros

The fascia transversalis lies immediately deep to the transversus abdominis muscle and, for the most part, is intimately adherent to the deep surface of the muscle. It is continuous from side to side and extends from the rib cage above to the pelvis inferiorly (Fig. 2.31).

In the upper abdominal wall, the fascia transversalis is thin, but in the lower abdomen and especially in the inguinofemoral region, the fascia is thicker and has specialized bands and folds within it. In the groin region, where the fascia transversalis is an important constituent of the posterior wall of the inguinal canal and where it forms the femoral sheath distal to the inguinal ligament, the anatomy and function of the fascia transversalis is of particular importance to the surgeon, as originally stated in his exquisite and detailed account of the fascia transversalis in the groin [16]. Sir Astley Cooper described the fascia transversalis as consisting of two layers. The anterior strong layer covers the deep aspect of the transversus abdominis muscle where it is intimately blended with the tendon of the transversus muscle. It then extends across the posterior wall of the inguinal canal medial to the deep ring and is attached to the inner margin of the medial end of the inguinal ligament. The posterior (deep) layer of fascia transversalis is a filmy, membranous layer and lies between the anterior substantial layer of fascia transversalis and the peritoneum. The extraperitoneal fat lies behind this filmy layer: between it and the peritoneum (Fig. 2.32). The (deep) inferior epigastric vessels run between the two layers of fascia transversalis.

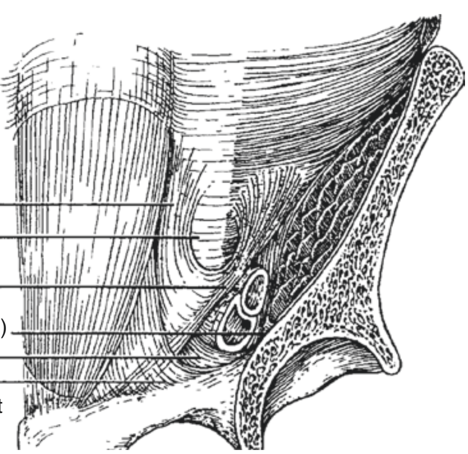

Fig. 2.31 The fascia transversalis, part of the endoabdominal fascia, lies on the deep surface of the transversus muscle. In the upper abdomen this fascia is thin and featureless; however, in the lower abdomen and pelvis the fascia transversalis has an important role. It is thickened and includes specialized bands and folds. It forms the posterior wall of the inguinal canal, and at the deep ring it has a condensation medial to the cord. This condensation is part of a U-shaped sling through which the cord passes. This sling hitches the cord up laterally when the transversus muscle contracts. Just above the inguinal ligament, the fascia transversalis is thickened as the iliopubic tract or Thomson's band [30]

These two distinct layers of fascia transversalis are readily identified laparoscopically and must be opened separately to allow access to the avascular preperitoneal space (of Bogros) when undertaking an extraperitoneal repair of a groin hernia either endoscopically or by open surgery. The deeper layer extends down behind the inguinal canal and fuses with the pectineal ligament (of Cooper) before continuing downwards into the pelvis. The deeper layer fuses with the spermatic cord at the deep ring and continues along the cord as part of the internal spermatic fascia [16–18]. The existence of the bilaminar structure of the fascia transversalis at the deep ring was confirmed by Lytle [19] and by Cleland et al. [20], but its nature was disputed by Anson et al. [8], and its relevance and importance were questioned by experienced surgeons [22].

The dissection of both layers of fascia transversalis from the cord structures at the deep inguinal ring is an important component of hernioplasty; it allows dissection of an indirect peritoneal sac and allows the divided peritoneal stump to retract at the deep ring in a classic Bassini and Shouldice operation for indirect hernias.

In the lower abdomen, it is attached laterally to the internal lip of the iliac crest, along which line it becomes continuous with the fascia over the iliacus and psoas muscles. From these lateral attachments, the fascia extends medially as a continuous curtain, which is interrupted only by the transit of the spermatic cord at the deep inguinal ring. The fascia transversalis invests the cord structures as they pass through it with a thin layer of fascia, the internal spermatic fascia. On the medial margin of the deep ring, the fascia transversalis is condensed into a U-shaped sling, with the cord supported in the concavity of the ring and the two limbs extending superiorly and laterally to be suspended from the posterior aspect of the transversus muscle. The curve of the 'U' lies at or just below the 'arched' lower border of the aponeurosis of the transversus muscle.

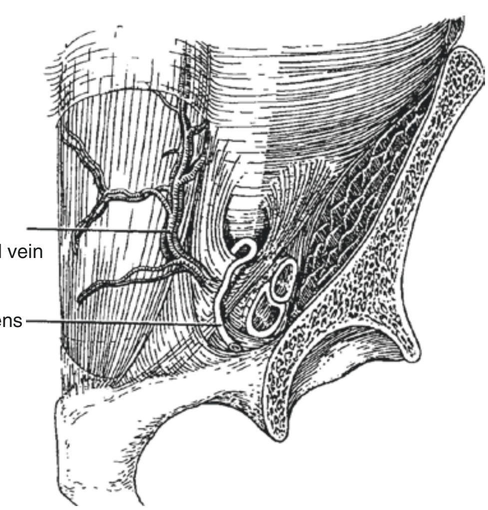

Fig. 2.32 Seen from behind, the view from within the abdomen, the inferior epigastric vessels are deep, on the abdominal side, of this curtain of fascia transversalis. The vas deferens and cord structures ascend to and hook over the sling of fascia transversalis at the deep ring

This U-shaped fold, the fascia transversalis sling, is the functional basis of the inguinal 'shutter' mechanism; as the transversus muscle contracts during coughing or straining, the column/pillars of the ring are pulled together and the entire sling drawn upwards and laterally. This motion increases the obliquity of exit of the spermatic cord structures through the ring and provides protection from forces tending to cause an indirect hernia (Figs. 2.33 and 2.34) [19, 30]. The reconstruction of this sling medially with preservation of the function of the ring laterally is the rationale of anterior inguinal hernioplasty. In front of the ring lies the lower border of the transversus muscle and the internal oblique muscle. Each of these structures supports the internal ring, and together they provide a very effective valve when the intra-abdominal pressure rises.

The 'shutter' action of the internal ring, the fascia transversalis sling, can be demonstrated readily at operation under local anaesthetic. If the patient is asked to cough, the ring is suddenly pulled upwards and laterally behind the lower margin of the transversus muscle. In the adult with an obliterated processus vaginalis, a flat lid of peritoneum covers the ring internally for the spermatic vessels, and the vas deferens lies extraperitoneally. The spermatic vessels pass down almost vertically retroperitoneally on the psoas muscle. As they enter the narrow gutter of the groin, they are joined by the vas deferens: the spermatic cord thus formed turns obligingly upwards and then hooks around the fascia transversalis sling to enter the deep ring, acquiring an investment of internal spermatic fascia as it traverses the ring (Fig. 2.35).

The inferior border of the internal ring abuts on a condensation of the fascia transversalis, the iliopubic tract or bandelette iliopubienne of Thomson. This narrow fascial band extends from the anterior superior iliac spine laterally to the pubis medially. The band is a condensation (and integral part) of the fascia transversalis; it lies on a plane somewhat deeper than the inguinal ligament which can be readily demonstrated as distinct from it, at operation. The iliopubic tract bridges the femoral canal medially and then curves inferiorly and posteriorly to spread out fanwise to its attachment to a broad area of the superior ramus of the pubis along the iliopectineal line just behind Cooper's ligament. The iliopubic tract thus forms the inferior margin of the defect in the fascia transversalis both in an indirect inguinal hernia and in a direct hernia [29, 31]. However, it is superior to the neck of the peritoneal sac of a femoral hernia (Figs. 2.31 and 2.36).

The fascia transversalis superior to the iliopubic tract extends over the posterior wall of the inguinal canal up to and posterior to the arch of the transversus muscle. Medially the fascia transversalis runs behind the aponeurosis of the transversus abdominis muscle and thereby blends with the posterior wall of the rectus sheath above the level of the arcuate line. Below the level of the arcuate line, it is directly related to the posterior surface of the rectus abdominis. Inferolaterally, it is directly posterior to the lowermost arch-

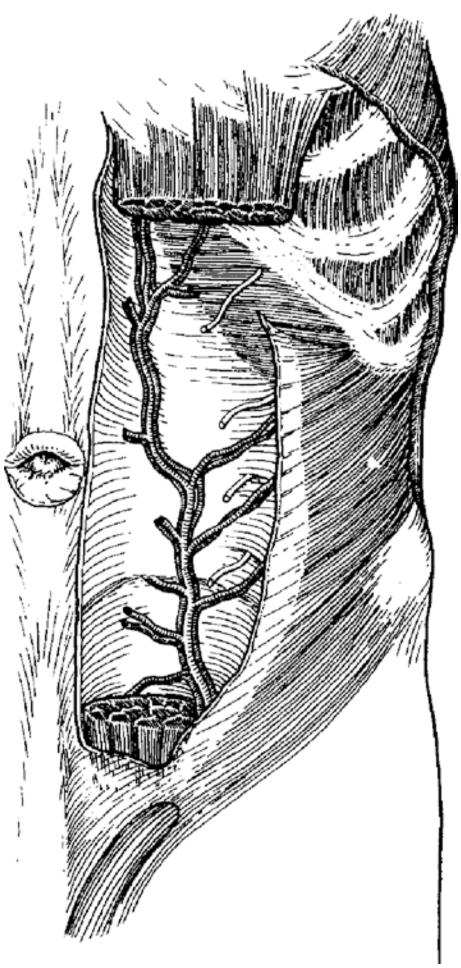

Fig. 2.33 Rectus sheath and linea alba. The contents of the rectus sheath are the rectus and pyramidalis muscles, the superior and inferior epigastric vessels, and the terminal branches of the lower six thoracic nerves

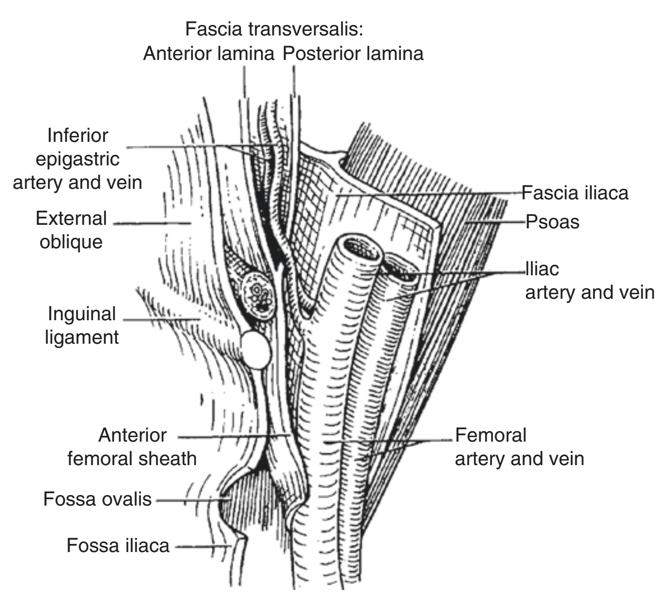

Fig. 2.34 The bilaminar fascia transversalis in the groin [18, 29]

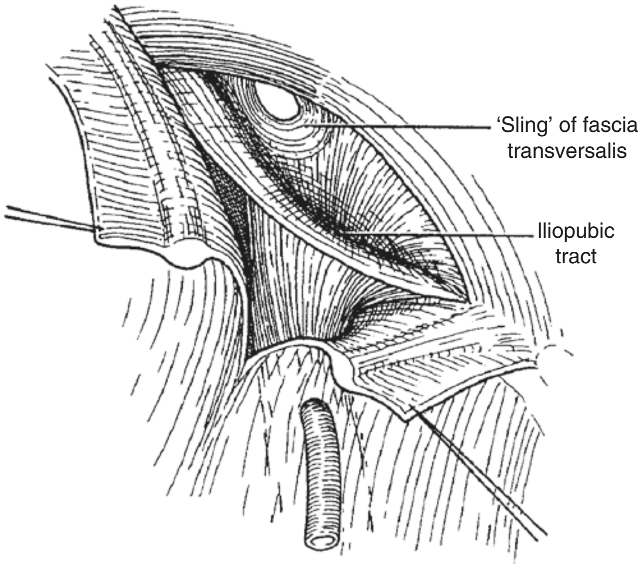

Fig. 2.35 Dissected further anteriorly, if the inguinal ligament is divided, the fascia transversalis can be seen to be continuous with the femoral sheath. The thickening at the junction of fascia transversalis with the femoral sheath is the iliopubic tract. The internal oblique muscle, which arises from the lateral inguinal ligament, acts as a shutter or "lid" on the deep inguinal ring

ing fibres of transversus abdominis muscle and conjoint tendon. The fascia transversalis in the posterior wall of the inguinal canal is supported to a variable extent by the aponeurosis of the transversus muscle as it arches down to its attachment to the pubis and iliopectineal line. Medial to the deep inguinal ring and deep to the fascia transversalis, lying in the extraperitoneal fat between the peritoneum and the fascia, the deep epigastric vessels follow an oblique course upwards and medially to the deep aspect of the rectus muscle. This triangular area, bounded by the deep epigastric vessels laterally, the lateral margin of the rectus muscle medially and the inguinal ligament below, is known to surgeons as Hesselbach's triangle; this is the area through which a direct inguinal hernia protrudes.

More exactly, a direct hernia explodes through the fascia transversalis in the area bounded by the iliopubic tract inferiorly, the medial limb of the fascia transversalis sling laterally and the lower margin of the arch of the transversus aponeurosis superiorly.

Condon [21, 22] has investigated the anatomy of the fascia transversalis using a technique of transillumination of fresh tissue. He clearly shows these anatomic details and defines the margins of the aponeurotic deficiency in the pos-

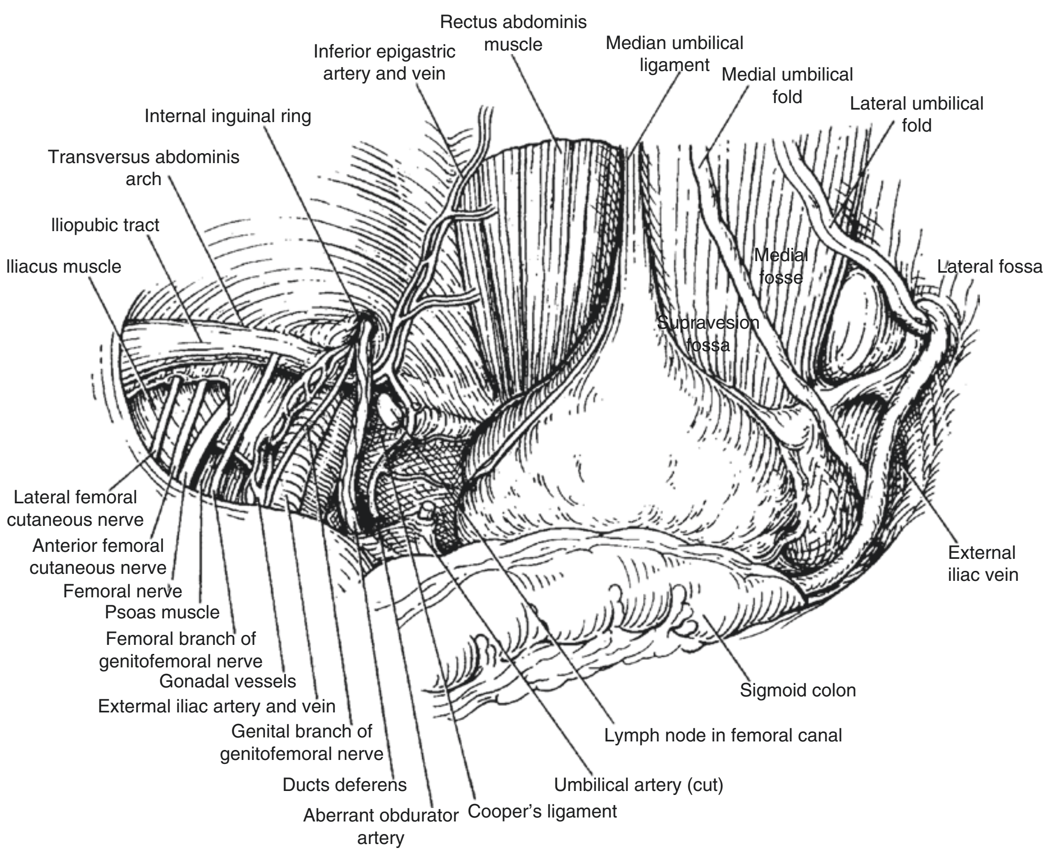

Fig. 2.36 The posterior view of the lower abdomen. The peritoneum is intact on the right side, illustrating the fossae demarcated by the umbilical ligaments. On the contralateral side the peritoneum has been removed to allow visualization of the extraperitoneal structures, the vessels and nerves [5, 31]

terior inguinal canal wall through which direct hernia protrudes. This area of fascia transversalis is buttressed anteriorly to a greater or lesser degree by the aponeurosis of the transversus muscle as it inserts to the iliopectineal line. At operation these features—the iliopubic tract, the deep ring and the 'line' of the arch of the transversus aponeurosis—are easily identifiable if the fascia transversalis is adequately dissected. Indeed, the identification of all these features is an essential prerequisite to adequate inguinal hernioplasty (Fig. 2.36) [22].

The fascia transversalis in the groin is but a part of the fascial continuum which surgical anatomists refer to as the endoabdominal fascia. This fascia is distinct in the lower abdomen but is fused into the fascia on the deep surface of the transversus abdominis muscle superiorly. This composite layer, the transversus muscle and its fascia (the fascia transversalis), is the most important of the abdominal wall strata in solving the problem of inguinofemoral hernia, as the integrity of this layer prevents herniation. Defects in it, congenital or acquired, are the aetiology of all groin hernias.

The fascia transversalis descends behind the inguinal ligament into the thigh as the sheath of the femoral vessels—this is a funnel-like sheath. Inferior to the inguinal ligament, the fascia transversalis attaches to the iliopectineal line medially and posteriorly to the femoral vessels. This funnel of fascia transversalis extends into the thigh as far as the fossa ovalis in the deep fascia. This anatomic arrangement allows for a small 'space' medial to the femoral vein through which some lymphatics pass. When a femoral hernia develops, this 'space' is expanded (Figs. 2.37 and 2.38).

What, then, is the anatomy of the peritoneum in relation to the layers of the abdominal wall we have considered previously? In the lower abdomen, the peritoneum is thrown up into five folds which converge as they pass upwards to the umbilicus. The median umbilical fold extends from the apex of the bladder to the umbilicus and contains the remnant of the urachus. To either lateral side, the medial umbilical fold contains the obliterated umbilical artery, and more laterally the inferior epigastric vessels raise the lateral umbilical fold. These folds create depressions or fossae in the anterior abdominal peritoneum: the supravesical fossae right and left and the medial and the lateral inguinal fossae right and left. A further depression on either side is below and medial to the lateral inguinal fossa and separated from it by the inguinal ligament. This overlies the femoral ring and is called the femoral fossa.

Hernias egress through these fossae—the femoral through the femoral fossa, the indirect inguinal through the lateral inguinal fossa and the direct through the medial fossa. Internal supravesical hernias can occur in the supravesical fossa (Fig. 2.36).

The landmarks are the peritoneal folds, particularly the medial umbilical ligament (containing the obliterated umbilical artery), and the lateral umbilical fold (containing the

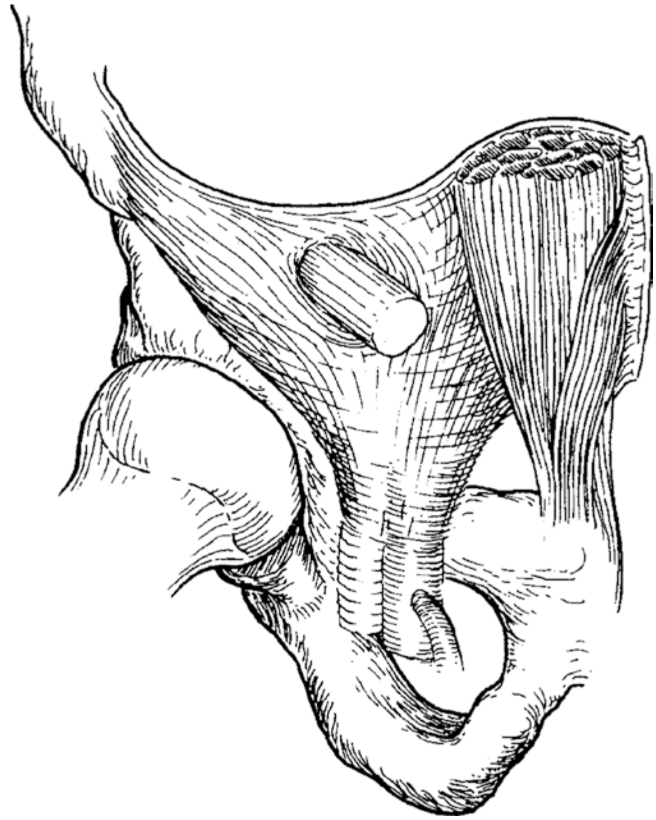

Fig. 2.37 From the front, as the surgeon visualizes the subject, the fascia transversalis in the groin resembles a funnel with a valved side vent. The femoral vessels come out of the funnel below and the cord structures out of the "side vent" which is "valved" by the sling of the fascia transversalis at the deep ring

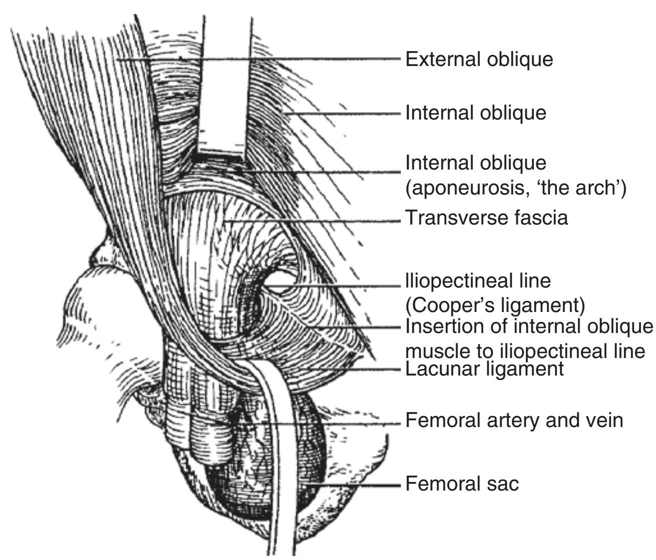

Fig. 2.38 A dissection to demonstrate the anatomy of a femoral hernia. The femoral cone of fascia transversalis is stretched on its medial aspect; the hernial sac extends within this cone of fascia transversalis medial to the femoral vein and lateral to the lacunar ligament

inferior epigastric vessels). The peritoneum overlying the deep inguinal ring is identified with the testicular vessels and vas deferens in the male, and the round ligament of the uterus in the female, all clearly visible beneath the peritoneum. The peritoneum is separated from the underlying fascia transversalis by adipose tissue except medial to the deep ring where the peritoneum is more firmly fixed to the overlying fascia transversalis. Below, posterior to, the inguinal ligament the genital branch of the genitofemoral nerve is seen joining the cord structures at the deep ring.

The lateral cutaneous nerve of the thigh and the femoral branch of the genitofemoral nerve lie rather deeper in the fatty tissue overlying the iliopsoas muscle. Blood vessels are also found in the adipose tissue beneath the peritoneum, in the extraperitoneal plane branches of the deep circumflex iliac vessels laterally and of the obturator vessels inferiorly and medially. There is an extensive venous circulation (anastomosis) in the extraperitoneal tissues between the inferior epigastric vein and obturator veins. This venous anastomosis lies between the two lamina of the fascia transversalis in the space of Bogros [17]. This space is continuous from side to side and with the pelvic space, the cave of Retzius. The space of Bogros is important for extraperitoneal repair of hernia and is the repository of bleeding in pelvic trauma.

The Peritoneum: The View from Within

Hernia sacs are composed of peritoneum, and they may contain intra-abdominal viscera. From within they consist of the peritoneum, then a loose layer of extraperitoneal fat, then the deep membranous lamina of fascia transversalis, then the vessels such as the epigastric vessels in the space of Bogros, then the stout anterior lamina of fascia transversalis and then the muscles and aponeuroses of the abdominal wall [23]. The preperitoneal space lies in the abdominal cavity between the peritoneum internally and transversalis fascia externally. Within this space lies a variable quantity of adipose tissue, loose connective tissue and membranous tissue and other anatomical entities such as arteries, veins, nerves and various organs such as the kidneys and ureters. The clinically significant parts of the preperitoneal space include the space associated with the structural elements related to the myopectineal orifice of Fruchaud, the prevesical space of Retzius, the space of Bogros and retroperitoneal periurinary space [24]. The myopectineal orifice of Fruchaud represents the potentially weak area in the abdominal wall, which permits inguinal and femoral hernias. The preperitoneal space that lies deep to the supravesical fossa and the medial inguinal fossa is the prevesical space of Retzius. The space of Retzius contains loose connective tissue and fat but more importantly vascular elements such as an abnormal obturator artery and vein. Bogros' space, which is a triangular area between the abdominal wall and peritoneum, can be entered by means of an incision through the roof and floor of the inguinal canal through which the posterior preperitoneal approach for hernia repair can be achieved. In the groin these muscles and aponeuroses are variously absent over the inguinal and crural canals. The myopectineal orifice of Fruchaud [25, 26] (Fig. 2.39) denotes a well-defined area through which all groin hernias present. Such a unifying concept of a single groin aperture is relevant for mesh repairs, whether repair is achieved by anterior open operation or by posterior endoscopic operation. The boundaries of the myopectineal orifice of Fruchaud are as follows: superiorly the 'arch' of the transversus muscle, laterally the iliopsoas muscle, medially, the lateral border of rectus abdominis muscle and inferiorly, the superior ramus of the pubis [27]. The space is utilized in both the transabdominal preperitoneal and the totally extraperitoneal laparoscopic approaches to the repair of inguinal and femoral repairs. A thorough understanding of the limits of this myopectineal orifice is necessary to accomplish an effective repair of the inguinal floor using laparoscopic methods.

Between the peritoneum and the fascia transversalis, there is a loose layer of extraperitoneal fat, used as an important landmark in many surgical operations. Hernial protrusions progress from within outwards through deficiencies in the musculoaponeurotic lamina of the abdominal wall; they carry this extraperitoneal fat with them along the track of the hernia sac. Abundance of this fat at the fundus of an indirect

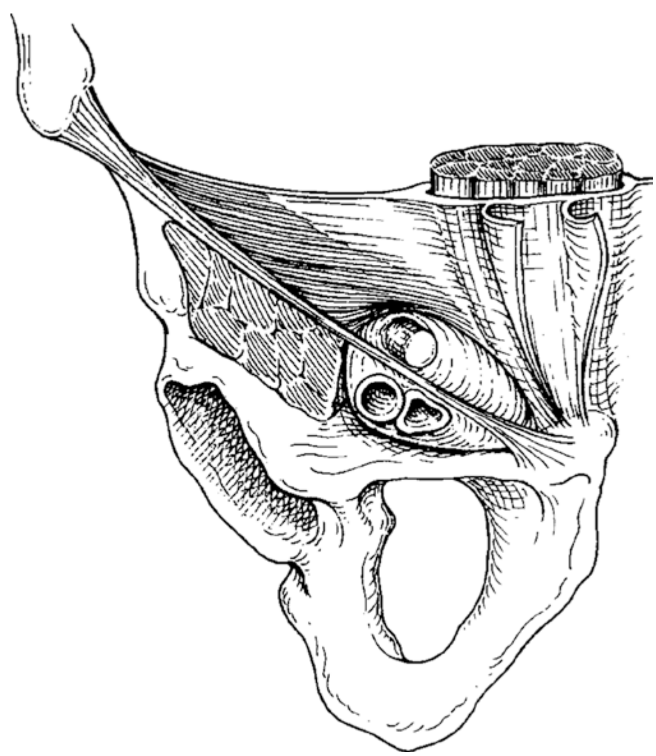

Fig. 2.39 The "myopectineal orifice of Fruchaud": the area of the groin limited above by the arching fibers of internal oblique and transversus abdominis, and below by the superior ramus of the pubis. It is crossed obliquely by the rigid inguinal ligament above which is the inguinal canal and below which lies the femoral canal [26]

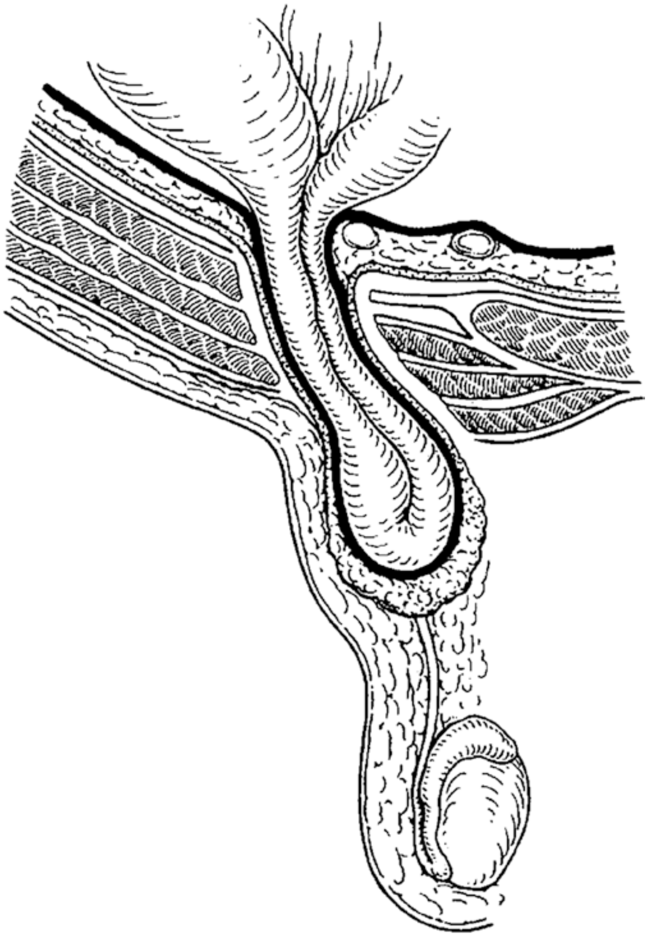

Fig. 2.40 As the peritoneum forms an indirect inguinal hernia it carries with it a covering of extraperitoneal fat. This extraperitoneal fat is referred to by many surgeons as "lipoma of the cord"

inguinal hernia gives rise to the surgical misnomer a 'lipoma of the cord'—in reality this is no more than extraperitoneal fat around the fundus of a peritoneal hernia sac (Fig. 2.40).

The Umbilicus

Between the sixth and tenth week of gestation the abdominal viscera enlarge rapidly and to such an extent that they can no longer be contained within the proportionately smaller coelomic cavity. Consequently, developing viscera (derived exclusively from the mid-gut) are temporarily extruded through the broad umbilical deficit into the exocoelom which occupies the base of the umbilical cord. At about the tenth week the abdominal cavity has enlarged sufficiently to reaccommodate the extruded viscera, and by the time of birth all the intestines are contained within the abdominal cavity proper. At birth the abdominal wall is complete except for the space occupied by the umbilical cord. Running in the cord are the urachus (from the apex of the urinary bladder), the umbilical arteries coursing up from the pelvis, and the umbilical vein directed to the liver. After the cord is ligated the stump sloughs off and the resultant granulating surface cicatrizes and epithelializes from its periphery.

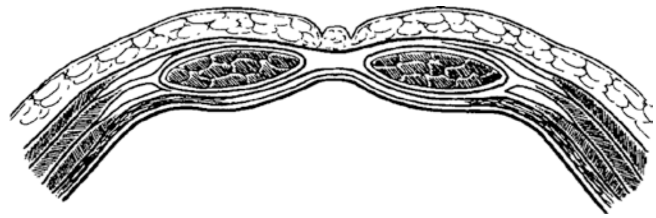

Fig. 2.41 Cross section through the umbilicus and adjacent anterior abdominal wall. The aponeuroses of the anterolateral abdominal muscles of the two sides are fused with each other in the umbilical cicatrix

In the normal umbilicus there is a single layer of fused fibrous tissue consisting of the superficial fascia, the medial edge of the rectus sheath and linea alba, and the fascia transversalis. The peritoneum is adherent to the deep aspect of this (Fig. 2.41).

The Spermatic Cord

The spermatic cord is composed of (a) arteries (the testicular artery, the artery to the vas deferens and the cremasteric artery), (b) veins (the testicular veins which arise from the pampiniform venous plexus within the spermatic cord), (c) lymphatics, (d) nerves (the genital branch of the genitofemoral nerve and autonomic nerves), (e) vas deferens and (f) the processus vaginalis.

The spermatic cord, as it emerges through the abdominal wall from the deep inguinal ring, receives investments of fascia. The fascia transversalis forms a thin, funicular coat called the internal spermatic fascia: the internal oblique invests it with a tracing of muscle fibres, the cremaster muscle, and most superficially it is coated with external spermatic fascia derived from the external oblique aponeurosis at the margins of the superficial inguinal ring. Each of these fascial layers requires opening to identify the processus vaginalis or sac of an indirect hernia. Until birth the processus vaginalis, although minute and narrow, is nevertheless an uninterrupted diverticulum from the abdominal peritoneum through the length of the cord to the testis, where it opens out to become the tunica vaginalis of the testis. Normally, the processus vaginalis becomes obliterated in most males soon after birth, except for the portion of the processus that surrounds the testis. This unobliterated part is known as the tunica vaginalis testis. More recently, the persistence of the processus vaginalis into adult life has been confirmed when hydrocele or hernia has complicated peritoneal dialysis in renal failure patients. The theories and mechanism of testicular descent and the development of the processus vaginalis (Fig. 2.42) are described in detail in Chap. 9.

An indirect inguinal hernia sac is a similar peritoneal diverticulum which extends into the spermatic cord and occupies the same position as the primitive processus vaginalis. Often indirect hernias also have extraperitoneal fat at their fundus.

Comparative Anatomy

A cool environment for spermatogenesis is a necessity in warm-blooded birds and mammals. Birds, which have high blood temperatures and are invariably cryptorchid, keep their testes cool by an air stream around the abdomen. In some sea-living mammals—whales and sea cows—the testes remain intra-abdominal, but presumably the constant contact with cold water is effective in keeping them cool.

The necessity to have the testes reside in a cooler temperature as prevails in the scrotum leads to problems, not only in humans but also in domestic and farm animals; the topic of hernia and undescended testicles appears in veterinary textbooks where it has a practical and economic importance of its own. Inguinal hernias are fairly common in pigs and horses but less common in bovine species. The economic consequence of an inguinal hernia in a stallion is considerable; the hernia may become incarcerated during mating, and this may hinder full consummation. A similar problem is documented in stud bulls. Hernias are relatively common in dogs but are rather rare in cats. Dogs, both male and female, may develop inguinal hernias, but the males are more likely to have intestine caught within the hernia sac. When a female dog develops a hernia, the usual content is one of the uterine horns and the broad ligament; this can present the danger of strangulation if the animal becomes pregnant (the content of a congenital hernia in a girl is most likely an ovary and/or fallopian tube). In the dog, most veterinary surgeons treat the hernia by orchidectomy (a proposition which is sometimes put forwards for dealing with the same situation in the elderly human).

Bats have testicles which are normally intra-abdominal and descend into the scrotum only at the time of mating. In these animals there is a low incidence of hernia and of a patent processus vaginalis. The testicles in bats descend to the scrotum and ascend to the abdomen, although there is no patent processus vaginalis. In small boys with retractile testicles which disappear up to the external inguinal ring, a hernia is rarely present.

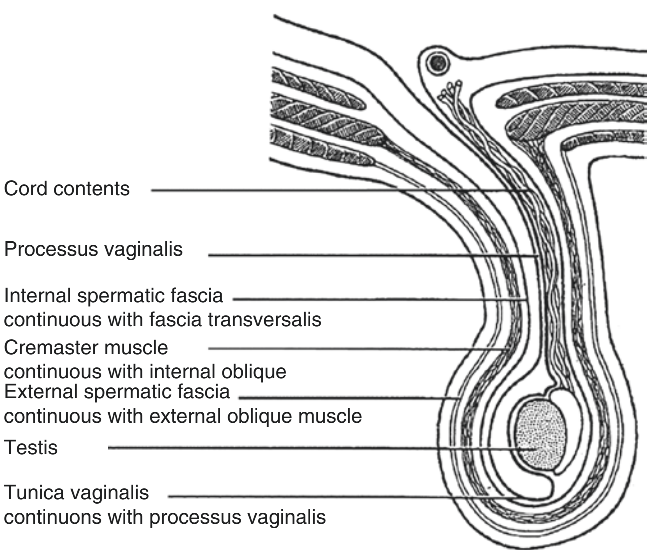

Fig. 2.42 Section through the spermatic cord and testis. The importance of the layers is demonstrated. The external spermatic fascia is derived from the fascia over the external oblique muscle at the superficial ring, the cremaster arises from the internal oblique muscle, and the internal spermatic fascia is the continuation of the fascia transversalis over the cord structures. Each of these layers needs division in inguinal hernia repair

Radiological Anatomy

Precise knowledge of the radiological anatomy is the key to success in the diagnosis and evaluation of groin masses which defy clinical diagnosis. Several diagnostic modalities are available including conventional radiography, ultrasound, CT and MRI scanning [28]. Herniography can be used in the diagnosis of hernia for patients with equivocal findings or those presenting with groin pain (see Chap. 11). The technique involves intraperitoneal administration of 50 ml of non-ionic contrast medium; a standard series of views of both groins is obtained during straining with the patient prone and in a slightly elevated position, as follows: posteroanterior, posteroanterior with caudocranial angulation of the tube (15°), two oblique views and a lateral view. A normal herniogram shows the median medial and lateral umbilical folds and the supravesical, medial inguinal and lateral inguinal fossae (Fig. 2.43). A disadvantage of her-

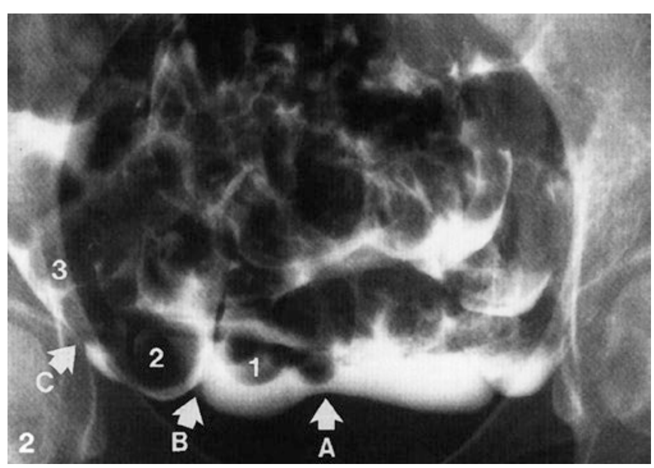

Fig. 2.43 Normal herniography. *A*, median umbilical fold; *B*, medial umbilical fold; *C*, lateral umbilical fold; *1*, supravesical fossa; *2*, medial inguinal fossa; *3*, lateral inguinal fossa

Fig. 2.44 Extended field-of-view ultrasound image demonstrating part of the anterior abdominal wall. *A*, external oblique muscle; *B*, internal oblique muscle; *C*, transversus muscle; *D*, rectus abdominis muscle

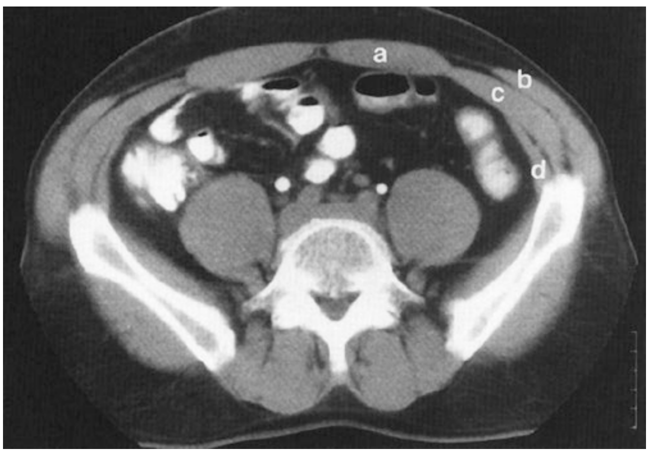

Fig. 2.45 A CT scan demonstrating normal anatomy of the muscles of the abdominal wall. *a*, Rectus abdominis muscle; *b*, external oblique muscle; *c*, internal oblique muscle; *d*, transversus muscle

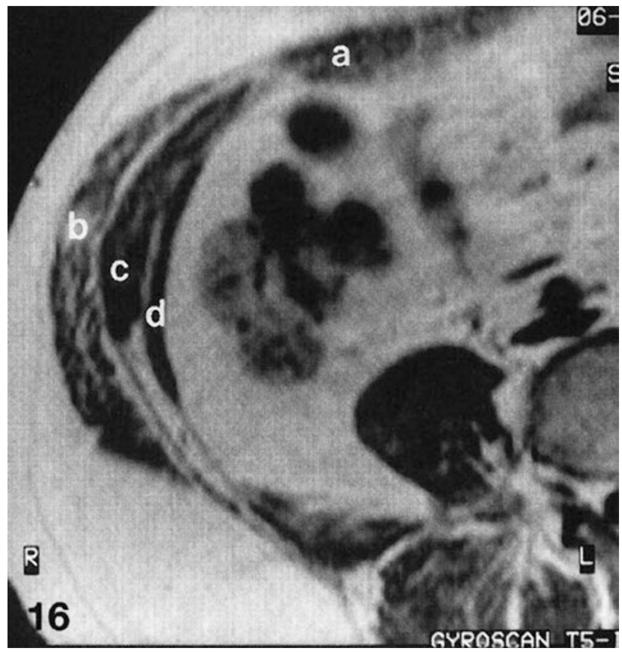

Fig. 2.46 Transverse T2-weighted MR image depicting the muscles of the anterior abdominal wall; *a*, rectus abdominis muscle; *b*, external oblique muscle; *c*, internal oblique muscle; *d*, transversus muscle; *R*, lateral; *L*, medial

niography is its invasiveness and its inability to depict pathological conditions other than hernias.

Ultrasonography with a high-frequency (7.5–10 MHz), short-focus transducer can depict the muscle and fascial layers of the abdominal wall and groin region. In these patients 5- or even 3.5-MHz transducers may be used which however result in low-resolution images. The entire anterior abdominal wall including the oblique muscles, transversus muscle, rectus abdominis and peritoneum can be visualized separately and clearly (Fig. 2.44). A major advantage is the ability to perform the examination in supine and upright positions as well as at rest and during straining, the so-called dynamic scanning technique. Yet another advantage is that ultrasound examination is non-invasive and allows comparison between the symptomatic and the asymptomatic side. The disadvantage however is its operator dependency and the considerable variation in imaging quality associated with the body habitus of the subject.

Computed tomography (CT) is usually performed in the inguinal region during breath-hold without straining. The anatomy of the anterior abdominal wall can be delineated clearly (Fig. 2.45). Because the inferior epigastric vessels forming the lateral umbilical folds can be clearly identified, CT is very reliable in helping differentiate between direct and indirect inguinal hernias.

Magnetic resonance imaging (MRI) has the advantage of being able to obtain images in any plane either by direct scanning in different planes or by making multiplanar reconstructions on a work station. MRI can also be performed during straining to gain dynamic images. The layers of the anterior abdominal wall (including transversalis fascia, extraperitoneal fat and peritoneum) can be delineated with precision using MRI (Fig. 2.46). CT scanning and MRI imaging have approximately the same order of sensitivity and specificity in diagnosing groin hernias.

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3 Epidemiology and Etiology of Primary Groin Hernias

Brian M. Stephenson

The population prevalence (the percentage of a population being studied that is affected with a particular disease at any given time) and the incidence (the rate of occurrence of new cases of a particular disease in a population being studied) of groin hernias have been studied extensively by a variety of authors in the last 100 years [1]. In developed countries the incidence of operations for groin hernia is approximately 2000 operations per million population per year [2]. Nationwide information on the relation between the number of procedures performed per year and the rates of incidence of groin hernia have been more difficult to establish. However, the 1981/1982 morbidity statistics from general practice (third national study) estimated that approximately the same number of *new* hernias was diagnosed annually by general practitioners as the number of patients consulting their doctors with *existing* hernias [3]. This clearly suggests that a large number of groin hernias are not referred for definitive surgical treatment and that the prevalence is far higher than the annual incidence of operation. A survey in Somerset and Avon Health Authority in the UK of a stratified random sample of 28,000 adults aged over 35 enquired about lumps in the groin and invited those indicating positive replies to attend for interview and examination. The results revealed that of the hernias discovered, one third of patients had not consulted their primary care physician and of the two thirds that had seen their primary care physician, less than half had been referred to a surgeon for a decision on definitive management. Interestingly of the third of patients who had not consulted their general practitioner, two thirds said they would accept an operation if this was advised. Of the patients who eventually reached a surgeon, 20% were advised that operation was not required. These findings suggest that there is an unmet need for groin hernia surgery with many patients being denied access by their family doctor. Once referred, surgeons seem to act as gatekeepers and may indeed "cherry-pick." Finally, there certainly appears to be a need for patient education in terms of the potential dangers of having a groin lump. Nevertheless, it is estimated that the number of groin herniorrhaphies done worldwide annually exceeds 20 million [4] and the lifetime risk of groin hernia is 27% for men and 3% for women [5].

Epidemiology

Prevalence and incidence data give no indication about the actual or potential demand for hernia surgery. Although incomplete and subject to many pitfalls in interpretation, UK data sources which relate to the need for hernia surgery include the English Hospital In-Patient Enquiry (HIPE) Data, 1975–1985; the English Hospital Episodes System (HES) Data, 1989/1990; and data on surgical activity in independent hospitals in the National Health Service (NHS) from local and national surveys [6].

There have been no true population or community-based studies of the incidence of groin hernia. The closest estimates for the true incidence of groin hernias (inguinal and femoral) can be obtained from the 1981/1982 morbidity statistics from general practice [3]. These figures are however probably an underestimate because of an unquantifiable proportion of patients who fail to seek medical advice. Nevertheless, based on these figures, the annual incidence of inguinal hernia in England will be of the order of 110,000/year.

The published evidence comes from three main sources. Firstly, population prevalence and incidence: there have been few community-based estimates of the prevalence of groin hernias. None have estimated the incidence. Each has been performed in communities where access to surgery was and often still remains limited, e.g., African populations. Further research defining the population incidence of groin hernias is required. Prevalence estimates are of local value only; they reflect not only the distribution and morbidity in the community but also the success of past local activity.

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Secondly, "demand" incidence rates are based on the number of people who seek medical advice for their problem. However, numerous factors may influence this decision and the data must therefore be treated with caution. Estimates of the incidence of inguinal and femoral hernias (Table 3.1) come from the 1981/1982 morbidity statistics from general practice ("third national study") based on consultations with 143 volunteer general practice principals caring for 332,000 patients [3]. Figures 3.1 and 3.2 show incidence rates for inguinal and femoral hernia, each of which denotes a consultation where the patient was seeking medical advice concerning a groin hernia for the first time during the study year. Again, these data must be interpreted with caution because neither the doctors nor the patients may be representative of the general population, and the diagnoses were not validated. The age-specific incidence rates are given with 95% confidence intervals.

Table 3.1 Incidence rates (95% confidence limits) of inguinal and femoral hernia per 10,000 persons at risk

Age (years)	Males	Females
Inguinal hernias		
0–4	58 (44.9, 74.8)	13 (6.9, 22.2)
5–14	7 (2.8, 14.4)	3 (0.6, 8.8)
15–24	7 (2.8, 14.4)	3 (0.6, 8.8)
25–44	20 (12.2, 30.9)	4 (1.1, 10.2)
45–64	70 (55.5, 88.2)	6 (2.2, 13.1)
65–74	88 (71.5, 108.2)	7 (2.8, 14.4)
75	150 (128.2, 175.5)	17 (9.9, 27.2)
Femoral hernias		
0–4		
5–14		
15–24		
25–44	1 (0.02, 5.6)	2 (0.2, 7.2)
45–64	1 (0.02, 5.6)	2 (0.2, 7.2)
65–74	1 (0.02, 5.6)	2 (0.2, 7.2)
75	9 (4.1, 17.1)	7 (2.8, 14.4)

Data from Royal College of General Practitioners [3]

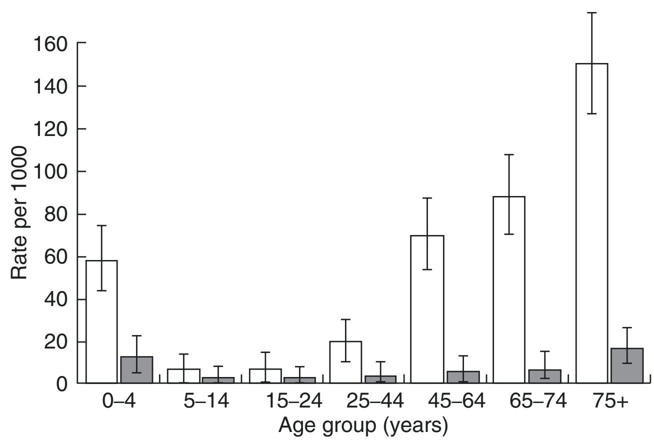

Fig. 3.1 Incidence rates of inguinal hernia per 10,000 persons at risk. *White* males; *shaded* females. Data from Royal College of General Practitioners [3]

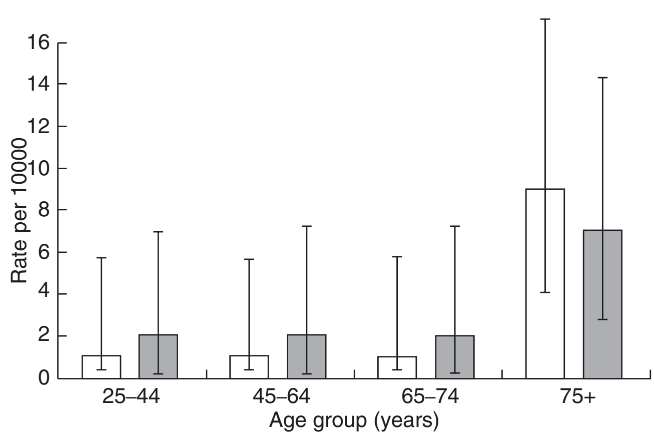

Fig. 3.2 Incidence rates of femoral hernia per 10,000 persons at risk. *White* males; *shaded* females. Data from Royal College of General Practitioners [3]

Demand for Groin Hernia Surgery in Adults

The overall rates for inguinal hernia repair (primary and recurrent) performed in NHS hospitals in England have not changed in the 15 years between 1975 and 1990 (Fig. 3.3). The total numbers for 1989/1990 were 64,998 primary inguinal hernia repairs and 3480 recurrent inguinal hernia repairs (Table 3.2). Age-specific hernia rates have altered considerably since 1975 with a significant increase in the surgical rates for older men. For instance, the age-specific inguinal repair rate for the 65- to 74-year age group rose from 40/10,000 in 1975 to 70/100,000 in 1990. This probably reflects improvements in anesthetic delivery, including the wider use of locoregional anesthesia and monitored recovery programs. A more detailed analysis of age-specific inguinal hernia repair rates for males and females is shown in Fig. 3.4, which indicates the high rates in infants and men over the age of 55.

Of the approximately 65,000 inguinal and 6000 femoral hernia repairs performed in NHS hospitals in England each year, 10% are emergency operations; these have remained constant for two decades. There has been an expansion in the private sector, which now accounts for 14% of all elective groin operations. Referring to the data in Figs. 3.4 and 3.5, it cannot be assumed that these repair rates approximate to the population incidence of inguinal and femoral hernias, because only 60% of groin hernias are referred to specialists for operation [3]. The implications for the English population will be 112,700 new cases per annum for inguinal hernias and 6900 for femoral hernias. Because a considerable proportion of patients are not undergoing groin hernia surgery, this may account for the surprisingly high number of trusses (40,000) sold annually [7, 8].

There is considerable variation in surgical rates for populations of health districts in England, and the weak correlations between these rates and supply factors (e.g., consultants

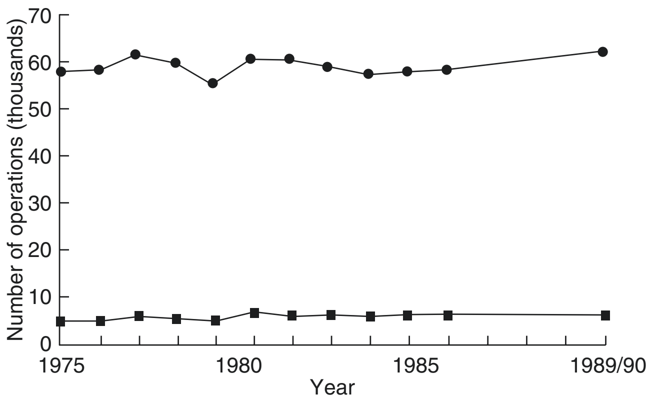

Fig. 3.3 Trends in number of inguinal hernia repairs, NHS hospitals in England, 1975–1989/1990. *Filled circle* males; *filled square* females. Data from Williams et al. [9]

Table 3.2 Number and percentage of single procedure inguinal hernia operations performed in NHS hospitals, England, 1989/1990

Inguinal hernia	Total no. of operations	No. (%) done as single procedure
Primary	64,998	54,090 [80]
Recurrent	3480	2790 [77]

Data from Williams et al. [9]

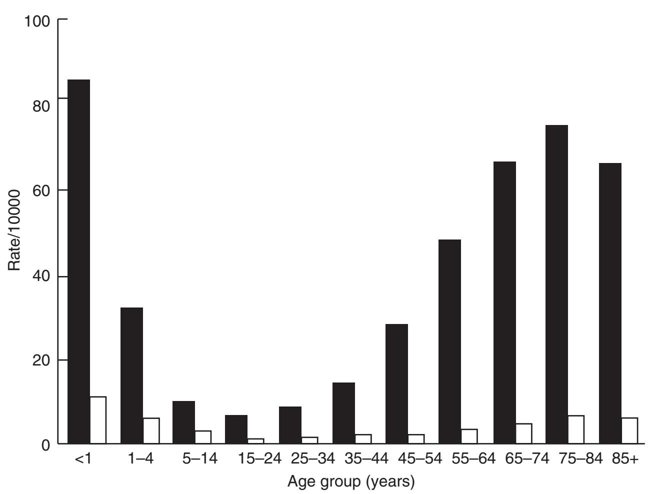

Fig. 3.4 Age-specific primary inguinal hernia repair rates, NHS hospitals, England, 1989/1990. *Shaded* males; *white* females. Data from Williams et al. [9]

per 1000 population) and demand factors (e.g., waiting lists) suggest that a considerable proportion of the variation is accounted for by differences in medical decision making [9].

Demand incidence is based on surgical procedures. In a stable catchment population, the number of people who seek surgery during a defined period can be established.

Of more importance is the demographic structure of the population being studied, which may vary widely between

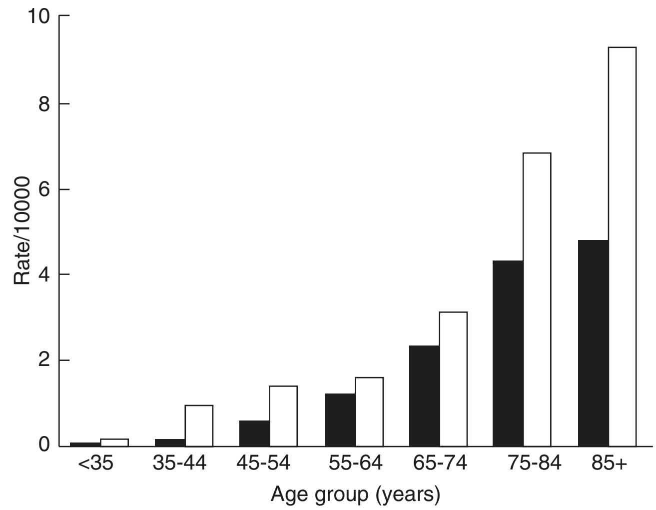

Fig. 3.5 Age-specific surgery rates for femoral hernia per 10,000 for males and females, NHS hospitals, England, 1989/1990. *Shaded* males; *white* females. Data from Williams et al. [9]

regional populations. The demand for emergency treatment of strangulated inguinal hernia is better defined, being estimated at 3.25–7.16/100,000/annum, in Western Europe [10, 11]. However, deficiencies of available data arise from three facts: firstly, they are based on health service use rather than healthcare needs; secondly, patterns of morbidity have an uncertain relationship to indications for treatment; and thirdly, patients will seek treatment only if they are fully informed of the significance of potential morbidity and the consequences of treatment as opposed to nontreatment.

Inguinal hernias are more common than femoral hernias, occurring in ratios of 8:1 or 20:1 depending on the surgical series, and are more common in males, where the inguinal to femoral ratio may be up to 35:1. Seventy percent of inguinal hernias are indirect and 30% direct. Inguinal and femoral hernias may also coexist: 2% of males with inguinal hernias also have a femoral hernia and 50% of men with femoral hernias have a coexisting inguinal hernia. This distribution of groin hernias is illustrated by Fig. 3.6 taken from a large series of 4173 hernias operated on in Truro, England by Barwell between 1974 and 1992 [9, 12]. Nilsson from Sweden reports similar figures [13].

Age-standardized hernia surgery rates vary considerably throughout the world. For instance, the hernia surgery rate per 100,000 population per year in England and Wales is 200, Norway 200, the USA 280, and Australia 180. The actual approximate number of operations performed per year in respective countries is 5500 in Scotland, 10,000 in Finland, 25,000 in Belgium, 30,000 in Holland, 100,000 in England and France, and 180,000 in Germany [14–17]. In the USA, where at least 550,000 inguinal hernia operations are carried out per year, the annual costs estimated in 1987 were 2.8 billion US dollars or 3% of the total healthcare budget! These figures are obtained from the National Center for Health

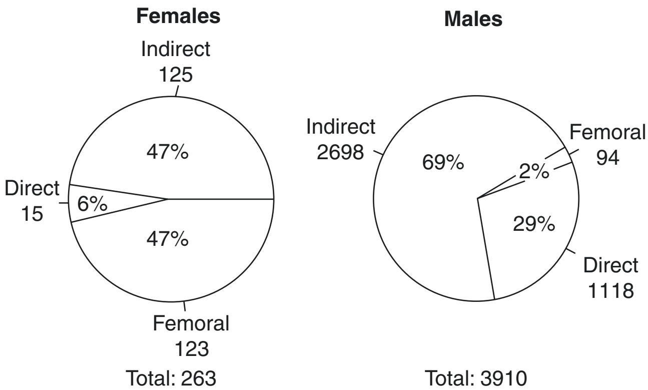

Fig. 3.6 Groin hernia diagnoses in males and females (Truro 1974–1992). Data from Williams et al. [9]

Statistics (NCHS) through its National Hospital Discharge Survey, which has compiled data on the number of operations performed annually in the USA, from a 5 to 8% sample of patient records [18]. In the UK hernia surgery rates peak in the 55- to 85-year age group, at 600 operations per 100,000 population per year, and the incidence of strangulated hernia is 13/100,000 population, with a peak in the 80-year-old group. A graphical analysis of hospital discharge data and demographic information guided by three hypotheses on urgency of surgery, age, and evidence of discordance between population prevalence of disease and rates of surgery has suggested that in the last 10 years in Scotland, the rates of operation have increased in over 65-year-olds but the rate of elective surgery has decreased in the more socioeconomically deprived areas [19]. It could be concluded from this data that more hernia surgery is being carried out in an aging population and the need for patient education is of particular importance, in terms of health gains, in lower socioeconomic or uninsured population groups. Certainly in developing countries large, hernias in the younger population place a significant economic burden on society that is difficult to quantify [20].

In the USA the high rates of hernia surgery may have contributed to the reduction in mortality associated with strangulation. For instance, the mortality for hernia and intestinal obstruction obtained by analysis of statistics data from the NCHS shows a fall in the number of deaths per year per 100,000 population in patients over the age of 15 years, from 5 in 1968 to 3.1 in 1978, and stabilizing at 3.0 in 1988. This was in spite of the fact that hernia patients with intestinal obstruction were on average 15 years older in 1988 than in 1968. In 1971 Medicare discharges for inguinal hernia without intestinal obstruction showed 94% of patients having surgery, with a probability of death at 0.005 (5/100,000 population) [21]. Despite this low figure, uninsured patients still seem five times more likely to present with complicated hernias implying preventative measures still need to be addressed even in well-developed countries [22].

Inguinal Hernias in Adults

Inguinal hernias are more common in males than females, in a ratio of 8:1 or 20:1 in different series. However, there is considerable incidence of under-reporting of inguinal hernia, as illustrated by two validity checks in the US National Health Surveys. In both studies half the hernias recorded during the previous year were unreported on interview, and in another study in Baltimore, positive reports were received from only 21% of men found to have hernias on clinical examination.

Incidence estimates in the literature vary widely and depend on the source of the data. Approximately 94% of hernias among males are estimated to be in the inguinal region. Ninety-five percent of inguinal hernia operations are on males. Three times more females undergo femoral hernia operations than males. By the age of 75 years, 10–15% of males have already received inguinal hernia surgery. In the period 1975–1990, mortality from inguinal hernia surgery in the UK fell by 22% and for femoral hernia by 55%. In the USA, for inguinal hernia with obstruction, 88% underwent surgery with a mortality rate of 0.05% [21].

In a study of World War I British recruits, aged between 18 and 41 years, there was a marked variation in the reported incidence of inguinal hernia. In Scotland 31/1000 were found, whereas in London and the southeast of England, it was 17–56/1000. In men aged 16–30 years, the rate was 6/1000, and in older men (aged 40–50), it was 24/1000. In contrast, the overall rate in Stockport and Manchester was 125/1000. Sir Arthur Keith, in 1924, estimated the prevalence at 25/1000 males [23]. The figures for World War II recruits are equally mystifying: the prevalence was about 26/1000 but ranged from 6 to 80/1000 men. Despite these variations the overall incidence is probably much higher given that these figures were recorded in young fit servicemen [24].

Sixty-five percent of inguinal hernias in adult European males are indirect in type. Right-sided inguinal hernias in adult males are slightly more frequent than left sided, 55% occurring on the right, regardless of whether the hernia is indirect or direct. Bilateral hernias are four times more often direct than indirect. In Western series the peak incidence of groin hernias is in the sixth decade [25].

A possible genetic link has been postulated in the Inuit living in the western Arctic of Greenland. Hernia is common in males and thought to be due to a high prevalence of disorders associated with instability of mesenchymal tissues, such as spondylolisthesis, arthritis, and heart block. The Inuit have been living in almost complete genetic isolation for 150–200 generations and have a high incidence and frequency of the HLA-B27 allele. Such polymorphism could result in the observed frequency of hernia in this closed knit population [26].

Table 3.3 Percentage of age group with inguinal hernia

Age (years)							
	25–34	35–44	45–54	55–64	65–74	75	Total
No. examined	620	438	300	322	156	47	1883
Current prevalence (excluding successful repairs)	11.9	15.1	19.7	26.1	29.5	34.1	18.3
"Obvious" hernias[a]	1.0	4.8	9.0	14.3	19.2	29.8	7.6
Unoperated swellings	0.7	3.7	5.7	10.9	13.5	23.4	5.5
Recurrences	0.3	1.4	3.7	3.4	5.8	6.4	2.2
Palpable impulse only	11.0	10.3	10.7	11.8	10.3	4.3	10.7
Lifetime prevalence (including successful repairs)	15.2	19.4	28.0	34.5	39.7	46.8	24.3
"Obvious" hernias[a]	4.7	9.6	18.3	24.2	30.8	44.7	14.5

Data from Abramson et al. [28]

[a]"Obvious" hernias included swellings and repaired hernias and excluded those presenting with a palpable impulse only. The current prevalence of obvious hernias may be less than the combined prevalences of unoperated swellings and recurrences, since a person may have for example an unoperated swelling in one groin and a recurrence in the other

The difference between the ratios of indirect to direct inguinal hernia in different geographical locations supports a polygenic predisposition to herniation. In Japan hernias are seen twice as frequent in twins. In Ghana, West Africa, one in every five live births is a twin (twice the rate seen in non-Africans), a fact that may account for the higher incidence of hernias recorded in Ghanaian men [27]. Comparing the age structure of the patients with inguinal hernia operated in Accra (the capital of Ghana) with the age structure found in a field study shows that all age groups are equally represented in the Accra hospital population, whereas in rural Ghana the prevalence of groin hernia rises with increasing age [27].

It is impossible to compare these findings. Clearly the results of the two large-scale surveys of fit uncomplaining males, drawn from recruits of the British and American forces in two world wars, do not represent fair and unbiased sampling. The only field study is from southern Ghana and confirms that inguinal hernias are at least three times more common in Africans than Europeans.

The true prevalence of inguinal hernias can be estimated only by community-based epidemiological studies, the validity of which will depend on the diagnostic criteria used. The presence of a visible, palpable lump may be supplemented by such diagnostic criteria as cough impulse at the internal or external ring and the presence of an incision in the groin. The latter, of course, may represent another form of surgery, such as orchidopexy, rather than hernia. Moreover, recurrent inguinal hernias may not be adequately ascertained. These drawbacks are well illustrated by the two studies alluded to above, carried out on British Army recruits in the first and second world wars. The prevalence of groin hernias in recruits aged 30–40 years in World War I was 1.6% as compared to 11% in World War II [9, 23].

Perhaps the most rigorous epidemiological study carried out was that of Abramson in Western Jerusalem between 1969 and 1971 [28]. Males from differing ethnic and social backgrounds were studied, although young males were largely excluded because of national service. The study involved interviewing subjects in their own homes where the response rate approached 90%. Of these, 91% participated in the second stage of the study, that is, of a physical examination. Both interviewers and examiners had been trained in the use of questionnaires and diagnostic criteria. The results are shown in Table 3.3. The prevalence increased with age in all cohorts studied with the majority diagnosed on the basis of a visible swelling. An important finding from the Abramson study was the concordance between interview and examination findings: only 50% of men reported a swelling in the groin on interview, which is in close agreement with the 50% under-reporting revealed from validity checks by the US National Health Surveys [29]. It is obvious from these studies that questionnaire-based data must be augmented by clinical examination if the true prevalence is to be ascertained, although this may be confounded by problems with diagnostic criteria. Clearly data regarding the incidence statistics of hernia patients are difficult to ascertain accurately and are probably all underestimates.

Femoral Hernias in Adults

The prevalence and incidence of femoral hernias in the population cannot be determined accurately for a number of reasons. However, the demand incidence can be estimated from the general practitioner morbidity survey of 1981/1982, which is summarized in Table 3.1. An incidence figure for England derived from these data is approximately 7000/year [3], but the 95% confidence intervals are very wide indeed (1500–24,000).

Femoral hernias are less common than inguinal and account for only 10% of all groin hernias. They are more frequent in females than males with an average ratio of 2.5:1, but this is also age dependent (see Figs. 3.1 and 3.2). However, there is other data that disputes this statistic (see Chap. 20). Maingot states that femoral hernias in women are eight times more common than in men [30]. Glassow, from the Shouldice Clinic in Toronto Canada, reports more males than females in his series, at a ratio of 5:3 [31]. However, it must be remembered that Glassow's large series is of patients undergoing elective operation for inguinal hernia and many of the cases were found as *concomitant* femoral hernias in men undergoing elective inguinal hernia repair. Clearly this series, or similar ones, does not fairly represent everyday general surgical practice.

Over 30 years ago, approximately 40% of femoral hernias in the UK were admitted acutely with complications such as strangulation or incarceration [32]. This is also still unfortunately true in many other developed countries at the time of writing [33, 34]. Women still however undergo three times as many inguinal as opposed to femoral hernia repairs. Femoral hernias are rare in those under 35 and are most common in multiparous women and surprisingly as common in men as in multiparous women. The ratio of inguinal to femoral hernias is between 10:1 and 8:1. In Accra, Ghana, femoral hernias are rare, accounting for only 1.2% of groin hernias, with an inguinal to femoral ratio of 77:1. In Kampala, Uganda, the ratio is very different, 22:1. It is interesting to observe that indirect inguinal hernias outnumber direct inguinal hernias in Accra and in Zaria, Nigeria, whereas in Kampala direct hernias are more frequent. In Kampala there are nine women with femoral hernias to one man, whereas in West African Hausa the male to female ratio of femoral hernias is 1.2:1 [35–39].

The surgical volume for rates of femoral hernia repair in NHS hospitals in England has remained stable between 1975 and 1990, with 5083 primary femoral hernia repairs and 299 recurrent femoral hernia repairs being performed in 1989/1990 (Table 3.1). The age-specific data indicate an increasing rate of repair through the decades with a peak in our elderly female population (Fig. 3.5).

There is also considerable variation in surgical rates for both inguinal and femoral hernia repair in the districts of English Regional Health Authorities. The range for primary inguinal hernia repair is 0.57–24/10,000 and for primary femoral hernia repair 0.16–2.3/10,000. Such unexplainable wide variations reflect the diversity of clinical practice and the "demand and supply" of treatment options already noted [9].

Etiology of Primary Groin Hernia

The pathogenesis of groin herniation is multifactorial. Sir Astley Cooper's "predispositions" to hernia, in 1827, and the subsequent addition of chronic cough, obesity, constipation, pregnancy, ascites, and prostatic hypertrophy are now only of historic interest. These factors may reveal a hernia but certainly did not cause it ab initio.

As indirect inguinal hernias are so common in infancy, the first surgical speculation was that they were due to a developmental defect. Indirect inguinal hernia arises from incomplete obliteration of the processus vaginalis, the embryological out pocketing of peritoneum that precedes testicular descent into the scrotum. The testes originate along the urogenital line in the retroperitoneum and migrate caudally during the second trimester of pregnancy to arrive at the internal inguinal ring at about 6 months of intrauterine life. During the last trimester, they proceed through the abdominal wall via the inguinal canal and descend into the scrotum, the right slightly later than the left. The processus vaginalis then normally obliterates postnatally except for the portion surrounding and serving as a covering for the testes. Failure of this obliterative process results in congenital indirect inguinal hernia. The modern epidemiological support for this hypothesis has already been reviewed, while the differing familial and tribal incidences, and the coincidence of hernias in twins, are supportive.

John Hunter, in the late eighteenth century, researched the development and descent of the testis in men and domestic animals. He showed that in some inguinal hernias the sac was continuous with the processus vaginalis [40]. The Parisian surgeon Cloquet, of nodal fame, observed that the processus vaginalis was frequently not closed at birth [41]. Indeed a complete (or scrotal) indirect hernia in an adult man has the same anatomy as that of the neonate—it is invested by all the three layers of the spermatic cord as it transverses the inguinal canal, and its sac is continuous with the tunica vaginalis of the testis. Additional support for the congenital theory of indirect inguinal herniation is the finding at autopsy that 15–30% of adult males without clinically apparent inguinal hernias have a patent processus vaginalis at death [42]. In a Bedouin mother and her four daughters with indirect inguinal hernia in whom there was no evidence of collagen diseases, normal hormone profile and normal pelvic anatomy suggest that in adult females as well, there is genetic heterogeneity [43]. Such an occurrence in females may be associated with an alteration in the anatomy of the round ligament, which normally terminates in a hernia sac and is attached to the mid portion of the fallopian tube near the ovary [44].

Review of the contralateral side in infantile inguinal hernias reveals a patent processus vaginalis in 60% of neonates and a contralateral hernia in 10–20%. In slightly older children (say 2 years or so), the rate of developing a metachronous contralateral inguinal hernia is of the order of 5–7% with those children having a left-sided one at a higher risk of later herniation than had the first hernia been on the other side [45, 46]. In addition, at 20 years of follow-up after an infantile hernia repair, 22% of men will develop a contralateral inguinal hernia, of which 41% occur if the initial hernia was on the left and 14% if the initial hernia was on the right.

The introduction of continuous ambulatory peritoneal dialysis (CAPD) in the management of renal failure has demonstrated that a persistent processus vaginalis, if subjected to intra-abdominal pressure, will dilate to give a hydrocele or hernia [47–49]. Indeed this has been documented as late as 2 years after commencing CAPD. In addition the development of an inguinal hernia in female CAPD patients adds further support to this premise [49–51].

Russell, an Australian pediatric surgeon, in 1906 advanced the "saccular theory" of the formation of hernia, a theory that "rejects the view that any hernia can ever be "acquired" in the pathological sense and maintains that the presence of a developmental peritoneal diverticulum is a necessary antecedent condition in every case … We may have an open funicular peritoneum and we may have them separately or together in infinitely variable gradations" [52]. In recent years, with the increasing use of "diagnostic" laparoscopy, some light has been shed on this debate. When the inguinal anatomy of 600 patients undergoing diagnostic laparoscopy for other reasons was carefully recorded, the prevalence of a sac or remnant of a patent processus vaginalis did not seem to increase with age [53]. However and interestingly, when these patients were followed for over 5 years, those in whom an asymptomatic patent processus vaginalis had been noted were four times more likely to have undergone a later hernia repair [54].

It would be apparent from the above that the problem of indirect inguinal hernia may not simply be one of a congenital defect, i.e., there is more to the story than just a persistent patent processus vaginalis. The high frequency of indirect inguinal hernia in middle-aged and older people suggests a pathological change in connective tissue of the abdominal wall to be a contributory factor. Indeed, simple removal of the sac in adults results in an unacceptably high recurrence rate and clearly is inappropriate. Thus the susceptibility to herniation is based on both the presence of a congenital sac and failure of the transversalis fascia. In direct inguinal hernia, there is no peritoneal sac and the prevalence parallels aging and other factors including smoking [55, 56]. Furthermore the absence of an adequate musculoaponeurotic support for the fascia transversalis and the medial half of the inguinal canal has been described in about a quarter of individuals [24]. In these men there is deficiency of the lower aponeurotic fibers of the internal oblique muscle, coupled with a narrow insertion of the transversus abdominis onto the superior pubic ramus [57, 58]. Because such a congenital anomaly would be symmetric, this explanation is consistent with the clinical finding that direct hernias are frequently bilateral and often surprisingly asymptomatic.

The anatomic disposition of the pelvis, and particularly the height of the pubic arch, may also be a significant and possibly ethnic characteristic predisposing to inguinal hernia formation. The height of the pubic arch is measured as the distance of the pubic tubercle from the bispinous line between the innermost parts of the two anterior superior iliac spines. African (Negro) peoples have lower pubic arches than Europeans and a higher incidence of inguinal hernia. In West and East Africa, the "lowness" of the pubic arch is greater than 7.5 cm in 65% of males; in Europeans and in Arabs, the arch is less low, 65% of males having a height of between 5 and 7.5 cm (Fig. 3.7). In European females 80% have an arch between 5 and 7.5 cm, and they have the lowest incidence of groin hernias [39, 59, 60].

This "low" arch is associated with a narrower pelvis and with a narrower origin of the external oblique muscle from the lateral inguinal ligament. With these anatomic variations, the inguinal canal is shorter with the deep inguinal ring left uncovered by the internal oblique. The canal may then be so short that no significant muscular "shutter mechanism" is apparent [59] as illustrated in Fig. 3.8. There is another much rarer form of direct hernia where a narrow peritoneal diver-

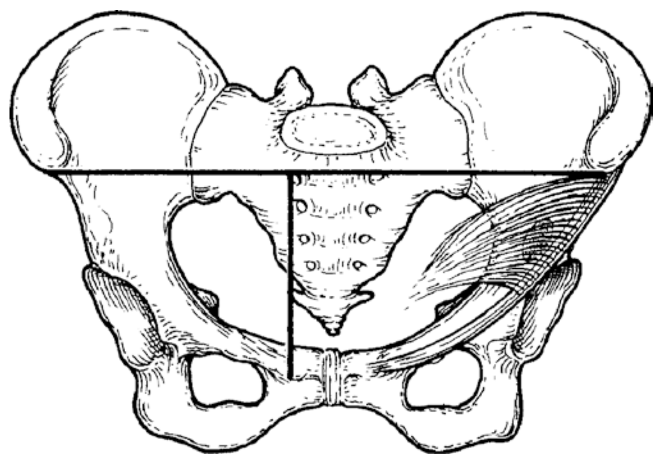

Fig. 3.7 The European pelvis is relatively wide with a less deep arch than the Negro pelvis. This ensures that the internal oblique muscle origin from the lateral inguinal ligament is broad, so that the internal oblique muscle "protects" the deep ring

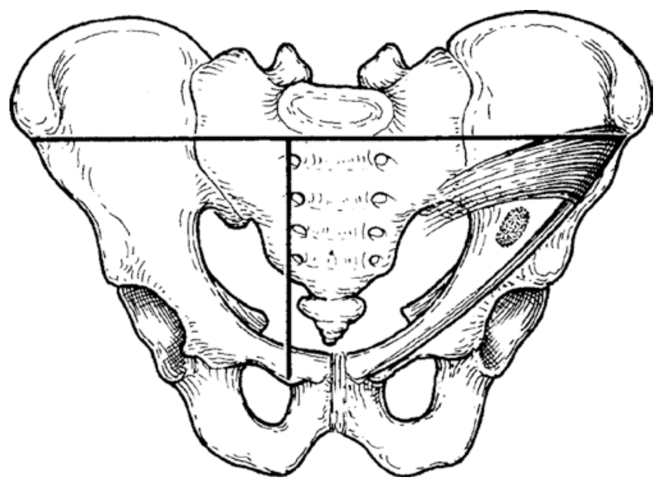

Fig. 3.8 The Negro pelvis is narrower than the European, which means that the lowness of the arch of the pelvis is greater in the Negro and the origin of the internal oblique relatively narrower. Hence the internal oblique will not cover the deep ring during straining, and the "shutter mechanism" of the inguinal canal is de fi cient. Negroes have a ten times greater incidence of indirect inguinal hernia than Europeans

ticulum comes directly through the conjoint tendon lateral to the rectus and pyramidal muscles to project at the superficial inguinal ring. In addition there are numerous unusual types of interparietal hernias where the sac may be mono- or bilocular and associated or not with a patent indirect sac.

It must be concluded that there are congenital, anatomical, and genetic factors that render individuals more likely to manifest direct as opposed to indirect inguinal hernias.

Over 80 years ago, Sir Arthur Keith, a Scottish anatomist and anthropologist, observed: “There is one other matter, which requires further observation. We are so apt to look on tendons, fascial structures and connective tissues as dead passive structures. They are certainly alive, and the fact that hernias are so often multiple in middle aged and old people leads one to suspect that a pathological change in the connective tissues of the belly wall may render certain individuals particularly liable to hernia.” He concluded his argument with a statement regarding “the importance of a right understanding of the etiology of hernia … If they occur only in those who have hernial sacs already formed during fetal life then we must either excise the sacs at birth or stand by and do nothing but trust to luck. But if … the occurrence of hernia is due to circumstances over which we have control then the prevention of hernia is a matter worthy of our serious study” [23].

Some 50 years later, Read, an American surgeon, made a crucial clinical observation which further advanced our thoughts as to the etiology of inguinal hernia. In 1970 he noted, when using an open preperitoneal approach to the inguinal region, that the rectus sheath is thinner and has a “greasy” feel in those patients who turned out to have direct inguinal defects. This observation was confirmed by weighing samples of a constant cross-sectional area; specimens from controls weighed significantly more than those from patients with indirect, pantaloon, and direct hernias (in that order). Bilateral hernias were associated with more severe atrophy. Adjustments for age and muscle mass confirmed the validity of this observation [56]. Further evidence in support of a collagen derangement in the transversalis fascia was presented by Peacock and Madden in 1974, who observed that satisfactory repair of adult inguinal herniation depended on the local extent of any collagen deficiency. And, if surgical technical failure can be excluded, the logical treatment of recurrent herniation is a fascial graft or prosthetic repair [61]. This concept was enthusiastically promoted by Irving Lichtenstein, one of the earliest pioneers of prosthetic repair for primary inguinal hernia [62]. We now all know how this revolutionized modern hernia practice [17].

Hernias “Under the Microscope”

Let us start with some basic science that we may have forgotten! Surgical wound healing is a controlled cascade in which there are sequential cellular and molecular events allowing ordered tissue repair. After the initial wound, there is a phase of healing characterized by hemostasis and inflammation followed by one of proliferation, which is predominantly one of increased fibroblastic activity with extracellular deposition and increased angiogenesis. Collagen is the end product of fibroblast activity, and while there are many types of collagen, types I and III are those most implicated in wound healing. Subsequent remodeling involves collagen bundle organization to give rise to a mature scar. Now, before moving on, let us remind ourselves that the inguinal canal and transversalis fascia comprise tissues made up of collagen, elastic fibers consisting of elastin and microfibrils, and the glycosaminoglycan component of the extracellular matrix.

Following the earlier observations regarding the “greasy” feel of the rectus sheath [56], Read and coworkers showed that hydroxyproline, which comprises 80% of the dry weight of collagen, was strikingly decreased in the rectus sheath of inguinal hernia patients especially if the hernia was of a direct type [63, 64]. The extracted collagen revealed a reduced hydroxyproline to proline ratio. Intermolecular cross-linking is unaffected, but synthesis of hydroxyproline is inhibited, and there is variability in the diameter of the collagen fibrils in hernia patients [65]. Similar electron microscopic findings are also present in pericardial and skin biopsies from these patients [65] and have also been described in connective tissue tumors [66], pulmonary emphysema [67], and scurvy [68]. Based upon these observations and the results of later similar studies, the prosthetic repair of inguinal hernias was promoted as the new “gold standard” of surgery. These findings also changed the approach to the repair of ventral (including incisional) hernias such that the vast majority are now also augmented with prosthetic biomaterials.

The above observations led Read, in 1978, to postulate that inguinal herniation is not a localized defect of the groin fascia but is in fact a manifestation of a generalized connective tissue disorder similar to emphysema, α1-antitrypsin deficiency, osteogenesis imperfecta, scurvy, varicose veins, and experimental nicotine deficiency [67]. This hypothesis was then tested with a computerized suction device to assess the biomechanical properties of the transversalis fascia and rectus abdominis so as to measure any functional connective tissue abnormalities in the groin [69]. The study was unable to demonstrate any differences in the properties of aponeurosis between hernia patients and controls. There was, however, a difference in collagen ultrastructure when it was examined under an electron microscope and in its physicochemical properties as observed by altered perceptibility and deficiency in hydroxyproline content. It appears thus that the fundamental problem in the aponeurosis of men with direct inguinal herniation is failure of hydroxylation of the collagen molecule.

Berliner in 1984 confirmed these findings by studying biopsies from three sites in patients with inguinal hernia [70]. Degenerative changes in the musculoaponeurotic fibers were found not only in the transversalis fascia/transversus abdominis of patients with direct inguinal hernias but also in the transversalis fascia at the superior aspect of the internal ring in patients with indirect inguinal hernia and also distant from the hernia site in grossly normal transversus abdominis aponeurosis. The main changes observed were reduction in elastic tissue with a paucity and fragmentation of elastic fiber similar to that seen in Marfan and Ehlers–Danlos syndrome. The implication from these findings is that collagen malsynthesis and enzymolysis mutually but not necessarily equally play a major role in the etiology of both direct and indirect inguinal hernia. Indeed, this was supported when the in-vitro synthesis of types I and III collagens (and their procollagen mRNAs) were studied from isolated skin fibroblasts in patients with inguinal hernia. Fibroblasts incubated with radiolabeled tritiated proline secreted increased amounts of type III procollagen, suggesting that an altered fibroblast phenotype in patients with inguinal hernia could result in reduced collagen fibril assembly and defective connective tissue formation [71]. Further support for this suggestion comes from a case control (fresh cadavers) study where both the total and type I collagen were decreased in fit young men with indirect inguinal hernias [72]. In addition when patients who had had at least three previous hernia repairs were compared to controls, venous biomarkers of collagen turnover ("synthesis," P4NP and P5CP; "breakdown," C4M and CM5) were significantly different [73].

Could an uninhibited elastolytic enzyme system cause groin herniation—a similar mechanism to low serum levels of the protease inhibitor α1-antitrypsin globulin allowing endogenous enzymes to destroy the alveoli [74]? Experimental evidence certainly supports the biochemical hypothesis that the pulmonary connective tissue disorder in emphysema is an imbalance between proteolytic enzyme levels and their inhibitors. Evidence of raised elastolytic enzyme has been found in smokers, and in smokers with inguinal herniation, there is a close association between raised elastolytic levels and raised white counts. Neutrophils carry proteolytic and elastolytic enzymes and are actively involved in the lung inflammatory response to cigarette smoke. Could they not also deliver the same proteolytic insult to the transversalis fascia? The neutrophil-derived enzyme metalloproteinase (MMP-2 and MMP-9) has been identified as one that breaks down collagen, elastin, and other components of the extracellular matrix. They have been found in transversus abdominis biopsies of patients with direct but not indirect inguinal hernias. MMP-2 overexpression has been measured in fibroblasts of patients with direct hernias and MMP-13 overexpression detected in recurrent inguinal hernias [75, 76]. While these studies are best described as observational, they are important indicators of the pathological process at the cellular level. Although it is unclear whether a deteriorating groin expresses increased MMP levels, it is of interest to see that transforming growth factor beta1 (TGFβ1) is overexpressed in the transversalis fascia of young patients with direct hernias [77]. Such growth factors are known to play a role in tissue remodeling and are presumably doing so or attempting to counterbalance the microscopic problems of a failing groin.

On a "macroscopic" or clinical scale, is there evidence that collagen is at fault? The prevalence of inguinal hernia (41%) in 119 patients with infrarenal aortic aneurysms was significantly higher when compared with 81 patients with aortic–iliac occlusive disease (18.5%) and 293 patients with coronary artery disease (18.1%). In addition, the number of patients who had undergone a recent hernia repair (16%) or were still waiting for repair (19%) was very high [78]. Also following elective aortic reconstruction for aneurysmal or occlusive aortic disease, at 1-year follow-up, incisional hernias were found in 31% of patients with aneurysm and 12% with occlusive disease, and inguinal hernias were found in 19% of patients with aneurysm and 5% with occlusive disease further supporting the concept of a biochemical abnormality [79]. The smoking habits of the three groups were not different, and again the findings support the concept of systemic fiber degeneration [80]. Although the enzymatic elastase content of the wall of abdominal aortic aneurysms has been shown to be increased, the concept of high levels of circulating elastase has not been confirmed. Nevertheless, overall patients with aneurysmal disease have a fourfold increased risk of inguinal and incisional herniation [81, 82]. Similar findings have been found in patients examined by a magnetic resonance imaging of the abdominal wall following aortic surgery [83]. These findings indicate that 50% or more of patients with nonocclusive infrarenal aortic aneurysm suffer from inguinal hernia. Indeed, it has been suggested that an inguinal hernia in certain high-risk age groups be used as an index for ultrasonic screening for aneurysmal disease [84]. However as the ultrasonography would have to be performed and repeated over a substantial period of time, the results of a small ($n = 70$) prospective study goes some way to point out this is not going to be a useful screening tool [85].

A number of years ago, the term "metastatic emphysema" was coined by Cannon and Read [67] for the concept of a generalized connective tissue disorder, which was maybe due to a leakage of proteases from the lungs of heavy smokers [86]. Read emphasized that the data indicate that more than one factor can cause systemic metabolic disease of collagen leading to abdominal herniation including the imbalanced expression of different collagens. Subsequent results have confirmed this in the transversalis fascia of patients with inguinal hernia by direct measurement of the important collagens (types I and III) [72, 87]. Nevertheless we must be cautious in interpreting the experimental data about a proteolytic defect in inguinal hernia patients and then relating it to the proven association with abdominal aortic aneurysm. It is however tempting to relate this "metastatic emphysema theory of inguinal herniation" to Hunt's and Tilson's ideas that aortic aneurysm is a copper transport collagen disorder enhanced by cigarette smoking [88, 89].

With all the available data [90–92], it seems probable and indeed highly likely that primary inguinal hernias are a connective tissue disorder as opposed to recurrent ones, which are due to a combination of this underlying innate problem and a technical failure of wound healing/repair. This further supports the need for a well-dissected prosthetic repair in the first instance. Whether biological meshes will play a part in the elective repair of primary inguinal hernias, other than in a few very selected cases, remains debatable [93]. Indeed a recent meta-analysis of nearly 400 patients from five randomized controlled trials showed no superiority of biologic mesh over a prosthetic one in terms of either recurrence or chronic pain [94]. They are more expensive and lead to a longer operating time, and such repairs are more often complicated by seroma formation.

Fig. 3.9 Persistent herniation in Ehlers–Danlos syndrome. Note the unusual skin appearance

A Curious Case of Recurrent Recurrence

A 45-year-old otherwise asymptomatic man developed an incisional hernia following a lower midline laparotomy for peritonitis from a perforated appendix. This was repaired but recurred and did so again when this recurrence was repaired with preperitoneal mesh. Wound healing seemed attenuated and the hernia unmanageable. After a further repair using the component separation technique (again augmented with onlay mesh) failed, a diagnosis of Ehlers–Danlos syndrome (EDS) was contemplated and later established (Fig. 3.9).

This unusual inherited connective tissue disorder, also known as "cutis hyperelastica," is caused by a defect in the synthesis of collagen (type III). There are numerous recognized types of Ehlers–Danlos syndrome [95] with the genetic mutations (autosomal dominant mode of inheritance) altering the structure, production, or processing of collagen or the proteins that interact with collagen to varying degrees. Even in established EDS, now known to be more prevalent than previously thought, the symptoms and presentation vary widely. Treatment is generally supportive and the prognosis dependent on the type of EDS.

Could "milder" defects in collagen synthesis/metabolism be even more prevalent in the population than otherwise contemplated with other factors such as smoking accelerating the general wear and tear process that we subject ourselves too? Interestingly inguinal hernia occurs more frequently in patients with milder EDS phenotypes.

Genetics in Pediatric Surgical Practice

Inguinal hernia may be associated with many different genetic syndromes including single gene and chromosomal disorders. Given the known constituents of the inguinal canal and transversalis fascia, one would expect such disorders to be associated with a higher risk of inguinal hernia [96]. Indeed genetic diseases of the microfibril (Marfan syndrome), elastin (Costello syndrome and Menkes disease), and collagen (Ehlers–Danlos syndrome and osteogenesis imperfecta) are all associated with an increased risk of inguinal hernia.

While the vast majority of childhood inguinal hernias do not have a genetic basis, warning signs that a hernia may have a genetic basis include a direct hernia, a recurrent hernia, or a hernia in girls as well as the more commonly recognized features associated with genetic disorders such as developmental delay.

The Genetics of Inheritance of the "Common" Indirect Inguinal Hernia

Although there is considerable evidence suggesting the role of genetic factors in the etiology of inguinal hernia, its mode of inheritance remains controversial [97]. A number of hypotheses have been suggested:

1. Autosomal dominant inheritance with incomplete penetrance [98]
2. Autosomal dominant inheritance with sex influence [99, 100]
3. X-linked dominant inheritance [101]
4. Polygenic inheritance [102, 103]

In a study from Budapest [102], the parents of 707 index patients with operated indirect congenital inguinal hernia born during the years 1962–1966 were studied for their frequency of indirect inguinal hernia. There was a 2 and 5.6 times higher incidence, respectively, in the fathers and mothers than in the general population, and the rate of affected siblings was higher than that of parents but was generally dependent on the sex of the index patient. In twins the hereditability was 0.77. These data suggested a multifactorial threshold model involving dominant variance.

A study of 280 families with congenital indirect inguinal hernia in the Shandong Province of China has indicated that the mode of transmission in these families is autosomal dominant with incomplete penetrance and sex influence. There is preferential paternal transmission of the gene, suggesting a role for genomic imprinting in the etiology of indirect inguinal hernias [104]. In this study the probands (index cases) had all been operated on by 5 years of age, with the hernia occurring on the right side in 138 and on the left side in 84. This is consistent with the known embryological facts that the right testis descends later than the left and that the processus vaginalis is therefore obliterated later on the right side than on the left side; hence hernia is more frequent on the right than on the left side.

In a record linkage study from the UK reported in 1998, of the risk of congenital inguinal hernia in siblings, 1921 male and 347 female cases born during 1970–1986 and who were operated on for inguinal hernia at the ages of 0–5 years were matched against 12,886 male and 2534 female controls [105]. The relative risk for inguinal hernia was found to be 5.8 for brothers of male cases and 4.3 for brothers of female cases, while the relative risk was 3.7 for sisters of male cases and 17.8 for sisters of female cases. This pattern of sex-dependent risk suggests a multifactorial threshold model for the disease. In essence as girls have a much lower incidence of inguinal hernia, those girls who do develop the disease might have a potentially larger contribution to susceptibility from genetic or intrauterine risk factors unrelated to their sex.

More recently a study from Hong Kong has examined the strength of a positive family history as a risk factor for developing an inguinal hernia [106]. As compared to controls and using multivariate logistic regression analyses, a positive family history was the only truly independent predictor for a hernia; indeed a man with a positive family history is eight times more likely to develop a primary inguinal hernia.

Indirect inguinal hernia arises from incomplete obliteration of the processus vaginalis, the embryological protrusion of peritoneum that precedes testicular descent into the scrotum. The testes originate along the urogenital line in the retroperitoneum and migrate caudally during the second trimester of pregnancy to arrive at the internal inguinal ring at about 6 months of intrauterine life. During the last trimester, they proceed through the abdominal wall via the inguinal canal and descend into the scrotum, the right slightly later than the left. The processus vaginalis then normally obliterates postnatally except for the portion surrounding and serving as a covering for the testes. Failure of this obliterative process results in congenital indirect inguinal hernia.

It is plausible to speculate that morphogenesis may be determined by single genes and complicated by environmental factors. In the case of indirect inguinal hernia, an autosomally dominantly inherited gene with reduced penetrance and sex influence would therefore be susceptible to environmental factors influencing its expression as a clinical inguinal hernia. In most families, however, a monogenic mode of inheritance is not apparent. Therefore the maternal allele (of a/the gene?) may protect against failure of closure of the patent processus vaginalis.

In conclusion, the fact that most affected males have inherited an indirect inguinal hernia gene(s) from their father implicates a role of genomic imprinting (i.e., the paternal allele) in the etiology of the indirect inguinal hernia phenotype. Finally it may be of interest to note that certain chromosomal loci were identified as genetic susceptibility targets in pigs at known "high risk" of developing inguinoscrotal hernias [107]. All geneticists have to start somewhere, but subsequently four chromosomal loci have been identified when comparing 15,000 cases and 150,000 controls [108]. These loci appear to be associated with both direct and indirect inguinal hernias. Their proteins are expressed in mouse connective tissue, and two of them (WT1 and EFEMP1) are thought to play roles in connective tissue maintenance through their action on extracellular matrix enzymes including metalloproteinases that are known to degrade both collagen and elastin.

Intra-abdominal Diseases Causing Hernias

Ascites due to liver and heart disease (failure) and more rarely abdominal or peritoneal carcinomatosis can present as recent onset groin and umbilical herniation. The mechanism is similar to that already described in CAPD patients, with increasing hydrostatic pressure dilating a preexisting sac irrespective of its earlier size. Intra-abdominal contents may then follow into this enlarged space. Clearly the sudden onset of a hernia in middle-aged or elderly patients should thus arouse diagnostic suspicion. It is a sound policy to subject hernial sacs to histological examination, especially in older patients, where ascites (blood stained or not) is found or when the sac is thickened or indurated. However, the routine histological examination of "normal" hernial sacs is not justified. Indeed the chance of unexpected "pathology" in an otherwise normal hernial sac has been estimated (!) to be 0.00098% [109]. Routine histology is certainly *unnecessary* and obviously uneconomical.

Interestingly the histological examination of sacs obtained from children with hernia, hydrocele, or undescended testis revealed that in the inguinal hernia patients during childhood, smooth muscle was found within the wall of the sac but not in sacs associated with undescended testis. This suggests that this smooth muscle may have played a role in the prevention of obliteration and clinical outcome [110].

Thickening of a hernial sac per se is not necessarily due to significant pathology; peritoneum is an active tissue and particularly in children and young adults can exhibit overexuberant tumor-like reaction to mechanical injury. This so-called mesothelial hyperplasia may follow wearing a truss or occur simply after repeated attacks of near incarceration. Microscopically there are atypical mesothelial cells that are either free or attached to the wall of the sac. Mitoses and multinucleated cells are frequently seen but despite this mesothelial hyperplasia is reactive and certainly not neoplastic [111].

The development of an abdominal wall hernia may be a rare but initial sign of decompensated heart or liver disease. Whereas good surgical practice is to repair an uncomplicated hernia, the question of repair in cirrhotics raises other issues. Leonetti et al. [112] reported that repair of umbilical hernias in uncontrolled unshunted cirrhotics led to a mortality of 8.3%, a morbidity of 16.6%, and a recurrence rate of 16.6%. However umbilical herniorrhaphy in patients with a functioning peritoneovenous shunt was associated with minimal morbidity (7%). The authors suggested that peritoneovenous shunting should be a prerequisite to hernia repair [112]. While this may not now always be necessary, these patients clearly need medical optimization before surgery [113]. There is now little doubt that elective surgery has significantly [114, 115] improved the quality of life of these patients with mesh repairs well tolerated and outcomes similar to patients without cirrhosis [116].

Intra-abdominal pus can also collect in and distend an empty hernial sac, as with any peritoneal recess, at the initial peritonitis. It may also collect in a long-standing hernia even after successful emergency surgery (Fig. 3.10). In a review of 32 examples of this phenomenon, 19 were right inguinal, 5 right femoral, 3 left inguinal, 1 epigastric, and 1 umbilical. Acute appendicitis accounted for 16 examples, perforated peptic ulcers for three, one followed pneumococcal peritonitis in a 2-week-old male child, one an acute pyosalpinx, and one followed a biliary leak after removal of a common bile duct drain [117]. Every patient with this complication was originally diagnosed as having a strangulated hernia, which is not surprising. If pus is found in a hernial sac, abdominal exploration is usually mandatory with acute appendicitis being the commonest diagnosis, especially in right-sided hernias [118]. When confronted with a tender incarcerated hernia, the diagnosis remains primarily a clinical one but appropriate, and recently more immediately available radiological investigations can usefully augment one's suspicions allowing a tailored minimally invasive staged approach when appropriate [119, 120]. A tender inguinal mass may not represent a hernia as demonstrated in Fig. 3.11!

Fig. 3.10 Residual collection in a large long-standing hernia after emergency surgery for gastric perforation

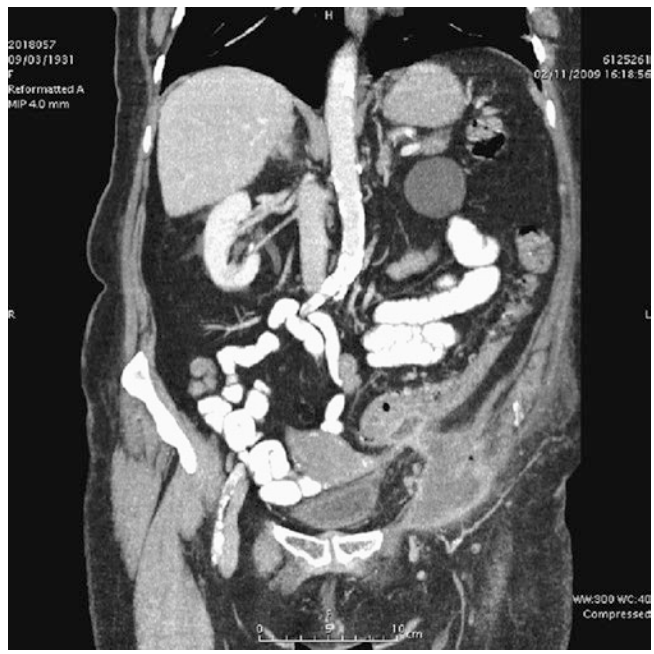

Fig. 3.11 A diverticular abscess presenting as a hernia. Fortunately a colocutaneous fistula did not develop in this frail 78-year-old lady

Inguinal Hernia and Appendectomy

Over a hundred years ago, Hoguet first reported the development of inguinal hernia in patients who had undergone previous appendicectomy [121]. He found eight right inguinal hernias in a series of 190 patients who had undergone appendectomy and suggested a causal relationship. Other authors have supported this contention [122–124].

Right inguinal hernias are more frequent when appendectomy is performed through a lower, "more cosmetic" incision, which is placed below the anterior superior iliac spine and in which the iliohypogastric nerve is injured. Electromyographic studies have shown conflicting results. While some investigators [124] have shown that denervation of the transversus abdominis muscle in the groin does occur and could therefore interfere with the shutter mechanism of the deep ring and be a factor in the subsequent development of inguinal hernia, other investigators have failed to detect any significant denervation of the musculature in and around the right groin [125].

Using the *standard* McBurney (introduced by Charles McBurney in 1894) appendectomy incision (at right angles to a line from the umbilicus to the anterior superior iliac spine, at a point at the junction of its lateral third and medial two-thirds and parallel to the iliohypogastric nerve which is rarely injured if the flank muscles are opened by splitting in their fiber line), there is no evidence that inguinal herniation is a consequence of appendectomy. In a series of 549 patients who had undergone inguinal hernia repair, the percentage incidence of previous appendectomy in right-sided hernias was 8.9 ± 1.7% and in left-sided inguinal hernias 11.2 ± 2.1% [126].

It is the *lower* and "more cosmetic" incisions, which carry a particular hazard to the iliohypogastric nerve and a propensity to subsequent inguinal herniation. The introduction of effective antibiotics and the consequent reduction in wound complications are also clearly important. Only when laparoscopic appendectomy is fully embraced as a standard approach (with reasons for and with durable follow-up of converted cases) will we know if this technique also contributes to a later lower incidence of subsequent inguinal herniation. The debate regarding open or laparoscopic appendectomy will no doubt continue before this becomes universal surgical practice even in the developed world [127, 128].

Inguinal Hernia and Prostatic Surgery

It is not really surprising that men being investigated and/or treated for prostate cancer are found to have an inguinal hernia given the incidence of this disease with increasing age. The majority of these are asymptomatic or at most minimally symptomatic. However it is of interest to note that patients undergoing treatment for prostate cancer (retropubic prostatectomy, minimally invasive approaches, or radiotherapy alone) in Sweden had an almost fourfold increase in later groin hernia repair as compared to over 100,000 controls [129]. The findings of this nationwide, population-based study are not particularly new but illustrate the frequency of the problem and the dilemma facing surgeons.

Clearly prostatic surgery, whichever operative approach is used, leads to a further weakening of the anatomy of this area. Symptomatic inguinal hernias are justifiably repaired, but what of those found incidentally at preoperative workups? Are there any identifiable risk factors that might be useful in predicting which patients would benefit from prophylactic surgery? The answer seems to be yes. The presence of a processus vaginalis, either patent or not, on dissecting the preperitoneal space is an important risk factor for the later development of an inguinal hernia [130].

Now that we may have identified those at later risk, how should these be managed? Is there just a theoretical risk or are concerns about prosthetic mesh infection, close to a neobladder-urethral anastomosis, valid? Certainly there are a number of reports suggesting that repairs can be safely accomplished with and without mesh [130–133], but should incidental hernias be repaired with prosthetics? In view of the concerns about infection, absorbable meshes have been used, but the results have been poor. Another approach that seems worthy of consideration is a concerted dissection, isolation, and transection of any identified processus vaginalis off the vas deferens and spermatic vessels [134, 135]. When the processus was formally transected, less than 1% of patients developed herniation at a median follow-up of 42 months. Although to date there are no randomized trials comparing these different approaches, we will have to wait to see if exploiting anatomy is indeed better than augmenting it.

Hernias Related to Trauma and Pelvic Fracture

Abdominal hernias related to trauma and blunt injuries are rare and are only reported following lower abdominal and pelvic injuries. To diagnose a traumatic hernia, there must be immediate signs of local soft-tissue injury, bruising, hematoma, etc., and then there must be the early presentation of the symptoms of the hernia. The aponeuroses close to their pelvic attachments are most at risk.

Disruption of the inguinal canal and complete ruptures of the conjoint tendon are recorded but are very rare [136]. Ryan, from the Shouldice Clinic, reported only five hernias related to pelvic fractures in 8000 hernia repairs [137]. Figure 3.12 illustrates an unusual case of a patient whose hernia was related to a pelvic fracture: a 40-year-old man

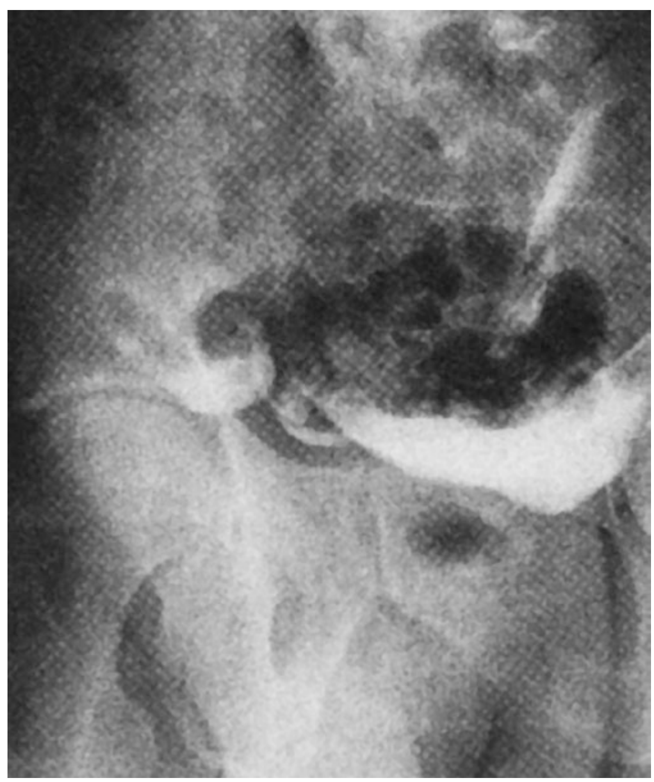

Fig. 3.12 Herniography on a 40-year-old man who had sustained a fracture of both pubic rami. The patient developed a "pantaloon" inguinal hernia

developed a "pantaloon" hernia after fracture of both rami of the pubis in a traffic accident. Such "traumatic" hernias are also recognized after pelvic diastasis in the absence of fracture and often present late and may contain the bladder or small bowel alone (supravesical).

Hernias related to iatrogenic pelvic fractures, for example, an osteotomy for congenital dislocation of the hip, are well described in the literature. Ryan classifies these fracture-related hernias according to the mechanism of the fracture [137].

1. Due to acute anteroposterior forces acting on the pelvis: In these instances there is tearing of the rectus abdominis origin from the pubic crest. The tearing is maximal on the side opposite to that on which maximum bony displacement had occurred. The damage to the muscle is usually more severe medially than laterally, leading to the development of a broad-necked sac just suprapubically from the midline extending laterally across the attachment of the rectus to the pubic crest.
2. Due to lateral or lateral/vertical forces: These fractures involve the superior pubic ramus with consequent tearing of the fascial and aponeurotic attachments of the inguinofemoral region. In these circumstances a direct inguinal hernia develops through the fascia transversalis immediately above the bony fracture line. A repair of the direct hernia corrects the situation.
3. Due to surgical innominate osteotomy: This hernia occurs in children with congenital dislocated hips. The hernia following innominate osteotomy is either a direct inguinal hernia, a prevascular femoral (Narath's) hernia, or a combination of the two [138].

Following innominate or Salter's osteotomy, there is a downward lateral and forward displacement of the lower fragment of the pelvis produced by a combination of hinging and rotation at the symphysis pubis [139]. This procedure leads to an increase in the distance between the edge of the rectus abdominis muscle and the inguinal and pectineal ligaments. There is a consequent weakening in the posterior wall of the inguinal canal. The angle between the midline (and, therefore, the lateral edge of the rectus muscle) and the superior ramus of the pubis is increased by a minimum of 5° when compared to the opposite side, and there is also an increase in the distance from the pubic tubercle to the anterior superior iliac spine. These changes alter the anatomy of the inguinofemoral region predisposing to hernia. It must be stressed that a consequent hernia is rare, and undoubtedly compensatory remodeling of the soft tissues occurs as the child develops after the traumatic procedure (Fig. 3.13). Any earlier musculoskeletal surgery, iatrogenic or not, in the region of the groin can lead to the later unusual groin herniation (Fig. 3.14).

The use of autologous bone grafts from the iliac crest is also troublesome. When full-thickness grafts are taken from the posterior iliac crest, the inferior lumbar triangle is enlarged predisposing to herniation. These "iatrogenic" lumbar hernias cause backache, can be complicated by irreducibility and strangulation, and should be repaired [140]. Bone grafts from the anterior iliac crest are similarly complicated by later herniation and require corrective surgery (Fig. 3.15).

Truly blunt traumatic abdominal wall hernias may occur after both low (falls) or high (motor vehicle accidents) "energy" impact injuries. Despite the use of early CT scanning, the mechanism of injury is vitally important and a high index of suspicion is necessary when managing such patients. High-energy trauma cases may need urgent laparotomy for concomitant intra-abdominal injuries, whereas in low impact

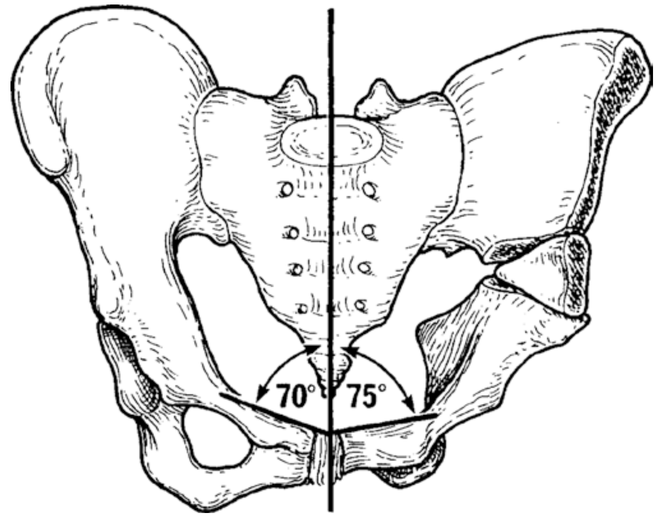

Fig. 3.13 Diagram to show how innominate osteotomy predisposes to inguinal herniation

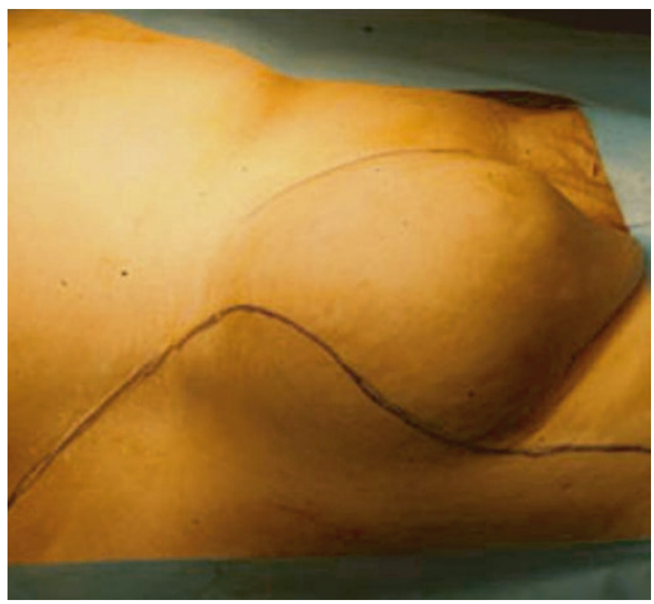

Fig. 3.14 An external femoral hernia (Hesselbach's) passing deep into the thigh below the inguinal ligament lateral to the femoral vessels. Note the previous incision for corrective hip surgery of uncertain nature

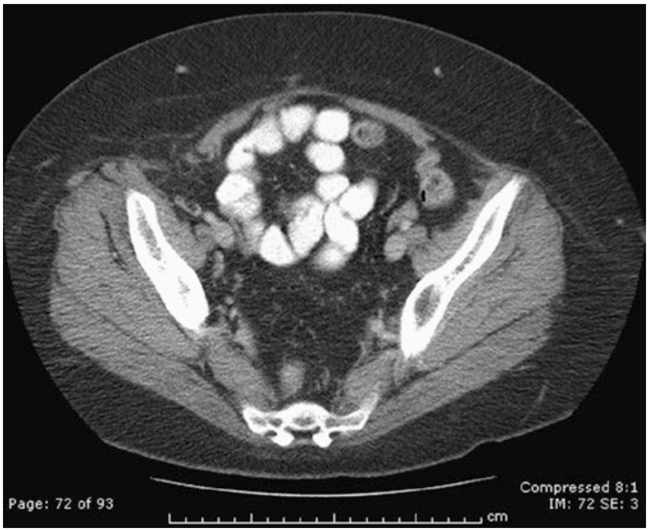

Fig. 3.15 An earlier anterior bone graft site complicated by groin herniation. The sac contained incarcerated omentum

Table 3.4 Severity of abdominal wall injury

Description	Grade	Incidence (%)
Tissue bruising/contusion	I	54
Muscle(s) hematoma	II	28
Single-layer disruption	III	8
Complete-layer disruption	IV	8
IV with herniation	V	2
IV with evisceration	VI	0

Data from Dennis et al. [141] based on CT scans in 1549 patients with blunt trauma

injuries, local wound toilet, debridement, and immediate repair may suffice. In a review of 1549 CT scans from a level I trauma center, abdominal wall injuries were graded as to their severity with respect to the documented disruption of the layers of the abdominal wall [141]. Overall abdominal wall injuries occurred in 9% of cases (Table 3.4) with those at risk of later herniation (not necessarily in the groin) estimated to be 16%. The role of subsequent follow-up CT scanning may well define the place of "early vs late" repair of these injuries. To date the later repairs of such hernias should probably be undertaken through a preperitoneal approach so that the anatomy, or lack of it, can be best appreciated.

Exertion and Groin Herniation

There is no firm evidence that strong muscular or strenuous athletic exertion causes inguinal hernia in the absence of a fascial and/or muscular abnormality—either acquired connective tissue disease or congenital anomaly of the abdominal wall. Indeed, inguinal hernias (as opposed to sliding hiatal hernias) are rare in weight lifters [142]. However, in a study of inguinal hernia and a "single strenuous event," in which 129 patients with a total of 145 inguinal hernias were included, in 7% the hernia was subjectively attributable to a single muscular strain [143]. Indeed these authors suggested guidelines to assist in assessing "causation" in work-related compensation claims in such patients, which included the following four recommendations:

1. The patient should have made an official report of the incident of muscular strain.
2. Severe groin pain must have been experienced at the time of the strain.
3. The diagnosis of hernia should preferably have been made within 3 days of the incident (or certainly within 30 days).
4. There should be no previous history of inguinal hernia.

Interestingly, a recent similar study, using structured postal questionnaires suggested that inguinal herniation may be attributed to a single event in a similar proportion of patients [144], but another report questions the appearance of a hernia (of any type) after such an event [145]. Furthermore "hazard ratios" for reoperation, after a previous inguinal hernia repair where you might think the area is already weakened, showed no correlation with different types of heavy manual work [146].

At the moment the relative importance of genetic, anatomic, and environmental (smoking and heavy manual work) factors cannot be construed in each case. Manual work or strain is never, or very rarely, the *sole* cause of inguinal herniation; it may however reveal an underlying previously asymptomatic one, of which our patient was "clearly" unaware of.

Recent research suggests that persistent straining and heavy work are relevant (but not causal) to the development of groin hernia. Recent European research has stressed these environmental factors rather than congenital defects in hernia development [147, 148]. In man and many mammalian quadrupeds, there is an abstinence of the posterior rectus sheath below the arcuate line (of Douglas) and an "ineffectual" transversalis fascia in the groin. Gravitational stresses, while in the erect posture, amplify this hindrance of weakness, which is an evolved anatomical defect [149]. The etiology of groin hernia also has importance in terms of prevention; smoking is a causal agent but possibly less so in women [150].

In medicolegal terms, the situation remains somewhat confused—an accident or heavy strain at work is generally construed as a causal factor in the onset of a hernia, and in British courts damages are usually awarded. Our current understanding of the etiology of inguinal hernias casts doubt on judicial reasoning in many cases. The legal foundation for compensating a workman who develops a hernia after an accident at his workplace is the commission of a tort or breach of contract by his employer. The heads of damages awarded are for pain or suffering, loss of amenities (usually sex life), pecuniary loss, medical expenses, and loss of later earning capacity. The role of a preexisting disability, patent processus vaginalis or metastatic emphysema, will need offsetting against these "damages." This is definitely a task for the judiciary, being largely unrelated to the observations of natural science [151]. Nevertheless in preparing a medicolegal report, surgeons and other medical experts must carefully examine all the contemporaneous medical records to support a claim. If there is insufficient evidence to support a claim, they have a duty to the court to nullify the plaintiff's claim and associated litigation [145, 152]. Finally the risk of a "work-related" hernia causes many patients to seek surgical correction of a hernia that is discovered in a preemployment physical examination (especially in the USA). These hernias must be repaired regardless of the paucity of symptoms due to the medicolegal risks to both employer *and* surgeon.

Conclusions

The incidence of primary groin hernia varies in different communities. The exact incidence in adult males is very difficult to estimate, but 16% of adult males will undergo operation. The incidence of inguinal hernia is higher in African people, who tend to have a narrower male pelvis than Europeans. Of interest is that the incidence of herniation varies considerably even between different African tribes.

Genetic and acquired factors clearly interact to allow a hernia to develop. However, we are forced to the conclusion that it is the failure of the fascia transversalis to withstand the stresses and strains of an upright posture that is crucial to the development of an inguinal hernia. A preformed, congenital, peritoneal processus or sac is an important prerequisite of indirect hernias in children and of an indirect sac in adults.

Connective tissue defects and imbalances are demonstrated in adult males with inguinal herniation and are causally related to smoking. Persistently heavy labor is also associated with herniation.

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4 Incisional and Parastomal Hernia Prevention

Sofiane El Djouzi and J. Scott Roth

Introduction

Incisional hernias (IH) are arguably the most common complication of abdominal surgery with many presentations and timelines. The incidence of IH repair likely represents only a fraction of the number of patients who have developed IH, as many are occult [1] or asymptomatic. Most commonly, patients will develop a noticeable protuberance within an abdominal incision with or without associated symptoms. Patients requiring operative repair of their IH occur costs that significantly increase overall healthcare costs relative to those who do not develop hernias [2]. Fortunately, only a small minority of patients will present with urgent or life-threatening problems necessitating more urgent hernia repair with or without bowel resection related to incarcerated or strangulated viscera. Historically, the presence of an IH was deemed an indication for repair due to concerns for incarceration and strangulation when nonoperative strategies are employed [3]. However, IHs present emergently in fewer than 5% of all cases [4].

Accordingly, strategies to identify patients at greatest risk for the development of IH have evolved to reduce the incidence of this common condition.

Recent decades have been marked with innovations in surgery resulting in more precise procedures through smaller incisions with reduced morbidity [5]. Technologic advancements have enabled surgeons to broaden the net of pathology that can be safely and effectively managed, resulting in enhanced overall procedural outcomes and quality of life [2, 6, 7]. More specifically, laparoscopic surgery has dramatically impacted the overall number of open abdominal operations performed in the United States with significant adoption for many common conditions. However, the use of open surgical techniques for abdominal surgery remains a reality today for many procedures due to challenges related to training, equipment, and patient complexity. Accordingly, open abdominal operations will likely remain within the scope of surgery for the foreseeable future. Having said that, abdominal incisions are associated with not infrequent complications, and the optimal means of abdominal closure has yet to be elucidated. Despite technical improvement and adherence to principles [8], the overall incidence of IH following laparotomy is reported to be as high as 20% [9] with significantly higher rates after postoperative wound infection and other wound complications [10]. It is also expectedly higher in patients with genetic predispositions or comorbidities favoring abnormal tissue healing. In a 10-year prospective study by Mudge and Hughes [10], fewer than 50% of IHs occur in the first year after surgery. Suffice it to say, patient follow-up in excess of 1 year is needed to adequately assess the true incidence of hernia. Gallup et al. [11] concluded that a 10-year follow-up of such patients is probably needed to determine the actual incidence of IH. The associated costs attributed to the long-term incidence of IH formation result in significant economic [12] and health management burdens [13–15] which are likely further compounded considering the not insignificant rate of recurrence following IH repair (despite the widespread use of mesh as reinforcement) [16]. Significant medical comorbidities, advanced preoperative wound class, and postoperative complications further increase costs of ventral hernia repair [17].

Patient risk factors and the mechanism behind IH are well studied [16, 18, 19]. Although not inclusive, obesity [20], connective tissue disorders, chronic obstructive pulmonary disease, tobacco use, malnourishment, corticosteroid dependency, and prostatism are among the most notable [21]. In light of the risks associated with IH repair [22] and the impact upon quality of life, the prevention of IH should be the primary goal at every instance an abdominal incision is created.

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More than 2 million open abdominal operations are performed annually in the United States with approximately 100,000 patients undergoing IH repair annually [23]. The technique of abdominal wall closure is one of the most important factors in the prevention of IHs [24]. It is arguably the only risk factor that is entirely within the control of the surgeon. Aponeurotic tissue needs a considerably longer time to heal than, for example, skin and mucosa. A normally healed wound will obtain 50% of its original strength after approximately 6 weeks [25], and the aponeurosis may never completely regain its original strength (only 60–90% after 1 year) [26]. During the period of wound healing, the technique for closure and suture material will greatly impact overall the strength of incision. Numerous studies have been conducted in an attempt to identify the optimal fascial closure, evaluating suture materials [27] and suturing technique [28]. The short stitch technique for wound closure utilizing a 2-0 slowly resorbing suture has emerged as a technique with a lower incidence of IH rates compared to a traditional running closure utilizing a looped suture in prospective studies [29]. While dramatic and significant reductions in IH rates (38%) have been demonstrated by altering the technique for suture placement, rates of IH remain in excess of 10% in this study. As a result, the development of additional strategies to further reduce the incidence of IH formation continues to evolve.

In an effort to decrease occurrence of IHs, investigators have pioneered techniques for mesh reinforcement of abdominal wall closure following elective laparotomy for patients deemed to be at increased risk for hernia formation. These "high-risk" patients often demonstrate comorbidities including obesity, smoking, immunosuppression, steroid use, and abdominal aortic aneurysm. Numerous mesh materials and techniques for mesh placement have been evaluated. By choosing to use mesh as an adjunct to the abdominal wall closure, surgeons must consider not only the incidence of IH formation but also cost-effectiveness, risk for mesh complications, impact upon future operations, and quality of life.

Mesh Prophylaxis Use at the Time of Midline Laparotomy Closure

The earliest descriptions of the use of prophylactic mesh as an adjunct to laparotomy closure were in the 1990s at the time of open weight loss surgery [30]. The authors studied the IH outcome on 288 morbidly obese patients randomly assigned to polyglactin mesh (21.5 × 26.5 cm) reinforcement (144 patients) compared to sutured midline laparotomy wound closure (144 patients). They excluded patients with any history of prior midline incisions from their series. Interestingly, the intraperitoneal mesh was not secured, but care was taken to spread it as far as possible into the flanks. With a follow-up averaging 30 months, 83% of the patients were evaluated through physical examinations, while the remaining were assessed through phone and mail communication. Eighty-seven percent of the hernias were observed during the first 18 postoperative months, and the incidence of IH was similar between mesh (23%) and non-mesh group (28%). The authors concluded that intraperitoneal absorbable prosthetic mesh was not successful in reducing IH rates in the morbidly obese population, although the study demonstrated risk factors for hernia formation including advanced age, male gender, and high BMI. Although not successful in reducing IH rates, from this study was born the concept of mesh prophylaxis for IH prevention.

The use of a permanent synthetic mesh offers some potential advantages over a rapidly absorbed mesh in the prevention of hernia by buttressing the abdominal wall in the event of early fascial dehiscence. In the event of small fascial separations, the permanent prosthetic remains in position, stabilizes the fascia, and prevents herniation. As many IHs begin as an occult fascial dehiscence, reinforcement of the incision with a permanent mesh serves to protect the incision from the postoperative problems (suture failure, knot failure, fascial tears, etc.) that may result in fascial separation. While the use of reinforcing synthetic mesh has appeal, safety concerns related to potential for mesh complications require address. Furthermore, an appreciation of the cost-effectiveness of mesh prophylaxis is required in order to appreciate not only the savings associated with a reduction in IH rates but also to appreciate any increased costs associated with the management of complications related to the use of mesh as prophylaxis. In light of the potential for morbidity associated with implanting a permanent synthetic mesh prophylactically, most studies to date have evaluated the use of prophylactic mesh in patients at greatest risk for incisional hernia formation.

Synthetic polypropylene mesh has been studied in the prophylaxis of IH repair following gastric bypass [31, 32]. In a prospective randomized trial, 36 gastric bypass patients undergoing abdominal closure with a retrorectus polypropylene mesh (8 cm width with extension 2 cm beyond incision cranially and caudally) were compared to 38 patients who underwent mass closure of the abdominal wall with 2-0 polypropylene suture. With follow-up ranging from 6 to 38 months, there was no difference in adverse events or major complications related to either the mesh placement or the gastric bypass between groups. The incidence of seromas and minor wound complications was similar in both groups. The incidence of hernia formation was 21% in the suture group and 3% in the mesh group. Although this study was not blinded, these results reinforce the results of a prior non-randomized study by the same author [32] in which hernia rates were dramatically reduced with mesh prophylaxis. In these studies, the polypropylene mesh was placed in an onlay location (reportedly to minimize the risk of bowel fistula of intraperitoneal mesh location) and used on morbidly obese patients who were considered at the greatest risk of postoperative hernia or evisceration (BMI of 45 kg/m^2 or higher, history of abdominal hernias, and liver function tests suggesting profound liver damage or cirrhosis).

Abo-Ryia et al. [33] replicated similar outcomes in a randomized controlled trial of morbidly obese patients undergoing prophylactic preperitoneal mesh placement following weight loss surgery. The polypropylene mesh was approximately 4–5 cm longer than the wound length and 10–12 cm wider. Postoperative wound-related complications (seroma, infection, and partial dehiscence) were similar between groups and were all managed conservatively. Over a mean follow-up of 4 years, the incidence of IH in the prophylactic mesh group (3.1%) compared favorably to the non-mesh group (28.1%) $p < 0.01$. Among advantages of mesh placement in the retrorectus space, the authors felt it would not hinder any aesthetic abdominal surgery planned following maximum weight reduction.

In contrast, others have reported favorable outcomes with placement of a prophylactic mesh in the intraperitoneal position [34]. In this study, 40 high-risk patients at risk for the development of IH were randomized into matched groups of 20 patients, with patients undergoing closure with either polypropylene suture or an intraperitoneal polypropylene with 2 cm overlap secured with only 4 corner sutures. The incidence of seroma, surgical site infection, and partial wound disruption was similarly low in both groups. With a follow-up averaging 3 years, only one patient (5%) in the mesh group and three patients (15%) in the non-mesh group developed IHs. However, chronic wound pain was only seen in the mesh group (three patients) but was not statistically significant. While not significant, the potential for mesh-related complications associated with prophylactic mesh placement requires further consideration. This study sheds some insight into the potential for chronic pain associated with prophylactic mesh. Larger studies with attention to quality of life metrics, including pain, are needed to appreciate all potential impacts, both intended and unintended of the use of prophylactic mesh to prevent IH.

A larger prospective randomized study of 100 high-risk patients compared standard fascial closure with and without the onlay placement of a heavyweight (82 g/m^2) knitted polypropylene mesh with 3 cm overlap [34, 35]. With 3-year follow-up in 88 of the patients (44 in each group), the mesh group experienced no IHs, whereas 5 hernias (11.3%) occurred in the non-mesh group. Postoperative pain was noticed in the mesh group and persisted beyond 3 months in 2 patients. A decade later, Caro-Tarrago et al. [36] studied onlay mesh use with 3 cm overlap to reinforce abdominal wall closures at the time of elective supra- and infraumbilical laparotomies. This study utilized a macroporous lightweight (40 g/m^2) polypropylene mesh and included high- and low-risk patients and patients with all degrees of wound contamination; exclusion criteria included patients with ASA score greater than 3, patients with prior herniorrhaphy or ostomy, and patients on steroid therapy. Eighty patients in each arm underwent oncologic or gastrointestinal operations with 1-year follow-up. A significantly higher rate of seroma was encountered in the mesh group (28.8%) compared to the standard abdominal wall closure (11.3%). Although most (73.8%) of the mesh group cases were contaminated, there was no impact on the rate of either superficial (6.3%) or deep (3.8%) wound infection rates. No mesh explants were reported. This study suggests safety in using prosthetic mesh in contaminated wounds as have other series [37]. The lightweight mesh dramatically decreased the rate of IH (1.5%) in comparison to the non-mesh group (35.9%), and no patient experienced chronic pain. The differences in lightweight and heavyweight polypropylene mesh are often debated. Lightweight mesh was popularized as a material with reduced mass of polypropylene often with greater porosity allowing for rapid integration into the abdominal wall. In a meta-analysis comparing lightweight mesh to standard polypropylene in hernia repair, the former has been associated with less chronic pain [38, 39]. Others have reported the use of lightweight polypropylene mesh in contaminated hernia repair with incidences of mesh removal less than 5%. However, the incidence of hernia recurrence is higher with lightweight polypropylene relative to other non-lightweight materials. It is not clear as of now whether the use of lightweight mesh for IH prophylaxis will result in improved outcomes relative to heavyweight polypropylene. Although speculative, there may be patient populations that are best served with different mesh types when performing IH prophylaxis.

The ideal technique for mesh fixation in IH requires investigation. Mesh placement strategies include absorbable and permanent suture, tacking devices (i.e., tackers, staplers), glues, self-adhering mesh, or fixation-free placement. Timmermans et al. [39] published short-term outcomes of an ongoing randomized controlled trial (RCT) comparing standard suture with glued onlay mesh and glued sublay mesh augmentation. The onlay mesh group experienced a greater incidence of wound seroma (18.1%) than the sublay group (7%) with an odds ratio of 2.9, while the non-mesh group showed the lowest rate of wound seroma (4.7%). Increased seroma rates with the onlay approach may be explained by the dead space following the creation of the suprafascial flaps and the inherent characteristics of the mesh use. However, a large proportion of postoperative seromas are clinically innocuous and resolve without intervention. Nevertheless, an appreciation of the implications of each mesh position is important in determining the ideal strategy for mesh placement in prophylaxis.

Abdominal Aortic Aneurysm Incisional Hernia Prophylaxis

Aneurysmal disease of the aorta has been associated with a fivefold [40] increased risk of IH development compared with those patients undergoing surgery for aortic occlusive disease with rates as high as 38% [41]. Bevis et al. [42] reported an excellent outcome of their RCT with the use of preperitoneal polypropylene mesh as a reinforcement of the laparotomy closure at the time of open elective abdominal aortic aneurysm (AAA) repair. In this study, there were no exclusion criteria, and patients were not stratified. Among 85 randomized patients, 40 patients had a 15 × 15 cm polypropylene mesh placed preperitoneally before fascial closure, and 45 patients underwent standard fascial closure. With a follow-up ranging from 35 to 1510 days, the incidence of IH was significantly lower in the mesh group (13.5%) than in the non-mesh group (37.2%). Two infectious events in each group were recorded without any mesh infection. Two cases of seroma were recorded in the mesh group that did not have any significant consequences. A 2016 study of 120 AAA patients prospectively undergoing IH prophylaxis with a large-pore lightweight polypropylene mesh in the preperitoneal space performed at 8 centers demonstrated a reduction of IH rates from 28% to 0% with no mesh infections or increase in wound complications, although operative time was increased by 16 min [29].

In 2013, a task force group was created with the goal to investigate and elaborate guidelines for "the prevention of IH" [43]. The group reviewed the previously detailed six randomized controlled trials covering the 2003–2014 period, all of which studied different variants of polypropylene mesh in different anatomical locations. Despite the favorable and consistent data for prophylactic mesh augmentation, the Guidelines Development Group decided that larger trials are needed to make a strong recommendation to perform prophylactic mesh augmentation for all patients within certain risk groups.

At this time, there appears to be a benefit to IH prophylaxis with synthetic mesh in the studied patient populations. However, many unanswered questions remain regarding mesh type, mesh location, and mesh fixation. While all techniques appear safe and beneficial relative to sutured closure alone, it is unclear which strategy is most efficacious with the lowest incidence of adverse events.

Biologic Mesh IH Prophylaxis

Biologic meshes represent a heterogeneous group of materials derived from different biologic sources and have in common the valuable inherent property of being resistant to infection [44]. Despite their expense, their efficacy in complex and contaminated surgical environments is well established. Synthetic meshes have demonstrated efficacy in hernia repair, but their use is more frequently associated with wound infection compared to suture repair [45]. This fact has prompted some authors to investigate the use of the alternative biologic mesh as a reinforcement material to the laparotomy closure at the time of contaminated surgical operations (i.e., open bariatric surgery, etc.) or to prevent future prosthetic graft infection (i.e., open AAA repair, etc.). Sarr et al. [46] conducted a RCT targeting the outcome of porcine small intestinal submucosa mesh in the reinforcement of the midline incision after primary and revision Roux-en-Y gastric bypass surgery. A total of 380 morbidly obese patients with BMI averaging 48 kg/m^2 (range: 35–79) were selected excluding patients with pre-existing IH, known connective tissue disorder (i.e., Ehlers-Danlos syndrome), diastasis recti, umbilical hernia >2.5 cm in diameter, or active infection at the time of operation. The technique involved placement of the mesh with 4 cm lateral and 2 cm cranial/caudal overlap in a preperitoneal location with peripheral transfascial stitches and no associated drains. Two-year prospective follow-up was achieved in 75% of the 139 patients randomized to mesh reinforcement and in 72% of the 141 patients with standard fascial closure. There was no difference in IH rates between groups (17.3% mesh vs. 19.5% suture) in this study.

A study of gastric bypass patients undergoing hernia prophylaxis with a human acellular dermal matrix demonstrated a benefit compared to sutured closure alone [47]. This study utilized an intraperitoneal mesh placement using a 16 × 6 cm mesh. Significantly, more seromas (13.6%) were seen in association with mesh use compared to 1.6% in the non-mesh group. The incidence of IH at mean follow-up of 17 months was 2% in the mesh group compared with 18% in concomitant nonrandomized controls, suggesting a benefit to IH prophylaxis with a human acellular dermal matrix.

A study of 40 patients using bovine pericardium mesh [48] as a reinforcement of the midline laparotomy closure at the time of AAA repair utilized an onlay mesh with 4 cm overlap secured with a running nonabsorbable suture compared to sutured closure. Patients underwent annual physical examination and CT scan. With a 3-year follow-up of 95%, there were two seromas in the mesh group and one in the sutured closure. No other wound complications were recorded in either of the groups. The non-mesh group IH incidence was 31.6%, whereas no patients in the mesh group developed hernias.

The mixed results seen with IH prophylaxis utilizing biologic meshes are unable to clearly demonstrate a benefit. The overall small study sizes and heterogeneity in patient population and technique limit applicability. Appealing to the use of biologic mesh in IH prophylaxis is the inherent properties of biologic mesh resulting in infection resistance. The infection resistance of biologic mesh may be advantageous when performing IH prophylaxis in clean-contaminated and contaminated surgical wounds. However, the relative cost of biologic mesh relative to synthetic mesh may represent a further constraint. As of the present time, we feel that the current evidence is not capable of supporting the use of biologic mesh for IH prophylaxis, but future investigations are warranted.

Parastomal Hernia Prophylaxis

Parastomal hernia (PSH) or enterostomy-associated hernia is by definition an IH created by a weakened abdominal wall traversed by an ostomy [49]. According to Israelsson [50], PSH is any palpable defect or bulge adjacent to the stoma detected when the patient is supine with legs elevated or while coughing or straining when the patient is erect and/or CT scan showing the protrusion of any intra-abdominal content along the ostomy. Enterostomies exist in different configurations and shapes that include temporary and permanent, end and loop, as well as ileostomy and colostomy. Ostomy types, variability in clinical and radiographic detection methods, heterogeneous patient groups, and heterogeneous follow-up periods are all contributing factors in the uncertainty of the true incidence of PSH. Nonetheless, it is widely accepted that the overall incidence approaches 50% [51].

It is important to distinguish PSH from similar yet different phenomena. In a Cochrane report on loop stomas, PSH was defined as the formation of a hernia beside the stoma; stoma prolapse was defined as eversion of the stoma [52]. Such differentiation is of great importance considering that the mechanism and the management of each are different. Mesh prophylaxis offers no benefit in the prophylaxis of stoma prolapse.

Any stoma through the abdominal wall results in a risk for subsequent parastomal herniation, which in turn may negatively affect quality of life and increase healthcare expenditures. Such hernias are common to the point where some degree of parastomal herniation has even been considered to be an almost inevitable complication of colostomy formation [50]. Carne et al. [51] wrote in 2003 a review discussing the available standardized means of decreasing the rate of PH. Although authors did not touch on the use of mesh as a means of lowering the rate of such hernias, they acknowledged the limitations of the armamentarium of tools available to surgeons in constructing enterostomies.

Considering the lowest recurrence rates for parastomal hernia repair are demonstrated with the use of mesh, some authors have investigated the use of prophylactic mesh at the time of stoma creation as a mean to decrease the incidence of parastomal herniation. This concept is in congruence with the repair of an IH with a mesh. Constructing a stoma essentially creates an IH, since it is characterized by abdominal contents protruding through a defect in the abdominal wall [53].

Parastomal Hernia Prophylaxis with Synthetic Mesh

Numerous case series, prospective trials, and systematic reviews have emerged since the first reported experience with the use of prosthetic mesh as a mean of reinforcing enterostomy sites at the time of stoma creation. In one of the largest RCTs to date by Jänes et al. [54, 55], reinforcement of permanent end colostomies with a 10 × 10 cm lightweight polypropylene and partially absorbable mesh was studied. The RCT included a total of 54 patients, half of which received prophylactic mesh. The investigators standardized their technique with the passage of the colostomy limb through an opening in the rectus muscle and the placement of the mesh in the retrorectus space. A cross cut of 2.5 × 2.5 cm in the center of mesh allowed the colostomy limb to traverse. The mesh was anchored to the posterior rectus sheath with absorbable stitches placed in its lateral corners. The authors included few emergency laparotomies (4 in the control group and 1 in the mesh group) and mostly elective colectomies with malignant pathology representing more than 80% the indications for surgery in both groups. With a follow-up averaging 24 months (12–38 months), only 1 IH was diagnosed in the mesh group in comparison to 13 in the control group. No wound complications or chronic pain were reported. With overwhelmingly favorable results, the trial was halted due to ethical concerns related to not routinely offering mesh prophylaxis. In a follow-up report, the authors published outcomes up to 5 years following initial operation [56]. The control group was reduced to 21 surviving patients with 17 cases of PSHs compared to 2 PSHs among the remaining 15 alive patients with prophylactic mesh. The control group witnessed a rate of PSH of 50% at 12 months and 81% at 5 years. Of the 2 patients from the mesh group found to have PSH, 1 was diagnosed after 12 months and another after 5-year follow-up. The wound complication rates remained unchanged for the entire duration of the follow-up and no mesh explantation was recorded. The authors concluded on the safety and efficacy of the prophylactic mesh use and they attributed such favorable results to two main factors: the lightweight nature of the partially absorbable mesh and its location in the retrorectus space away from the bowel. Although the quality of the study was good, the authors did not record the extra time required to place the mesh, and no final conclusions were drawn as the study was not blinded.

In the interim of this trial's long-term follow-up, other authors followed the lead and investigated the application of different types of prosthetic meshes at the time of enterostomy creation. Berger [57] prospectively evaluated the outcome of 25 enterostomies subjected to the placement of an intraperitoneal mesh utilizing the modified Sugarbaker technique. In this study, a mesh made of a polyvinylidene fluoride (PVDF) with a small amount of polypropylene on the parietal side was utilized. The patient sample was a mix of laparoscopic and open cases and included 24 colostomies and 1 ileostomy. With a median of 11-month follow-up, the author reported no PSHs or wound complications on physical examination or CT scan obtained 6 months post-surgery on 12 patients.

Gogenur et al. [58] described an onlay approach with a laser cut polypropylene mesh with six arms to reinforce permanent end colostomies at the time of elective colorectal resection. A total of 25 patients were selected and prospectively followed for 1 year with clinical examination and abdominal wall ultrasounds at 6 and 12 months. Only two PSHs were documented on ultrasounds, and no wound/mesh complications were reported. A keyhole approach was studied by Marimuthu et al. [59] utilizing a polypropylene mesh placed preperitoneally at the time of 18 elective end colostomy creations. With a follow-up reaching up to 28 months, they reported no PSHs or any other direct complications.

As proven by experience, there is frequently discrepancy between the rate of hernias diagnosed with abdominal wall imaging (i.e., ultrasounds, CT scan, etc.) and those reported clinically. This is to say that some subclinical PSHs may have been missed in the few reported studies. Despite this weakness in the current literature, we do not feel this should significantly affect the overall perception of the benefits of prophylactic mesh use.

Shabbir et al. [60] reported the first systematic review investigating the outcomes with the use of prosthetic mesh at the time of primary stoma creation. The study evaluated publications between 1980 and 2010 including English and foreign language written series but did not differentiate between synthetic and biologic meshes. The meta-analysis selected 3 RCTs with a total of 128 patients of which 50% had mesh placed at the time of the index surgery.

Although methodological flaws exist within the three RCTs and the overall patient population was small, this systematic review demonstrated that the use of a prophylactic mesh at the primary operation reduces the incidence of PSH with a hernia incidence of 12.5% in the mesh group compared to 53% in the control group (risk ratio, 95%, CI, 0.25 (0.13, 0.48), $p < 0.0001$) with a follow-up period of 7–83 months. This study did not identify the optimal mesh type or anatomic location but further reinforced the benefits of prophylaxis while acknowledging the need for a large randomized, double-blind clinical trial with long-term follow-up before advocating mesh use as a standardized approach.

Among the RCTs identified in the meta-analysis was a trial evaluating the use of prophylactic mesh reinforcement at the time of temporary ileostomy creation. This prospective randomized trial evaluated 20 patients utilizing a cross-linked porcine dermal matrix for parastomal prevention [61]. After an average follow-up of approximately 6 months, fewer hernias were seen in the mesh group than in controls (0% vs. 30%). Despite the results of this small study, we question the value of mesh prophylaxis at the time of temporary fecal diversion. The added cost, potential for mesh complications, and potential for increased difficulty of a subsequent operation related to adhesions are not clear. And accordingly we would not recommend prophylaxis in this situation.

Lopez-Cano et al. reported two successive RCTs in the years of 2012 [62] and 2016 [63]. A large-pore lightweight composite mesh was used in both trials (12 × 12 cm polypropylene/oxidized regenerated cellulose and 15 × 15 cm polypropylene/poliglecaprone 25 mesh, respectively). A sublay keyhole technique was adopted in the first study and the Sugarbaker technique in the later trial. In both RCTs, the studied groups were homogeneous, without statistically significant differences in all epidemiological characteristics and risk factors. The first trial included 36 patients with lower rectal cancer of which 19 were randomized to the mesh group and 17 to the control group, excluding patients with prior hernia repair with mesh or life expectancy less than 1 year. At 12 months, a CT scan was obtained demonstrating 9 (50%) PSHs among 18 patients in the mesh group and in 15 of 16 (93.8%) patients in the control group ($p = 0.008$). Further hernia repair was required on three patients from the control group and on one in the mesh group. The latter RCT recruited 52 patients comprised of a group of 28 mesh prophylaxis colostomy patients and 24 controls. Follow-up CT scans were again obtained at 12 months. In this study, 6 of 24 patients (25%) were observed in the mesh group compared with 18 of 28 (64.3%) in the non-mesh group (odds ratio 0.39, 95% confidence interval 0.18–0.82; $p = 0.04$). The authors did not experience any mesh-related complications in either of the RCTs. The rate of PSH was reduced by 50% between trials and between the mesh groups. Plausible explanations for outcome differences between these two studies include difference in the surgical technique in placing the mesh within the peritoneal cavity or the inherent characteristics of the mesh. The finding of noticeable difference between the rates of PSH between the non-mesh groups is of unknown significance considering that the technique of ostomy construction was similar.

A systematic review of RCTs between 1980 and March of 2016 evaluated eight RCTs comparing mesh prophylaxis and non-reinforced stomas (522 patients) [64]. The mesh group was found to have significantly lower risk ratio, 0.2 (95% confidence interval 0.13–0.38; $p < 0.00001$). This systematic review has also proven the safety of mesh use as the rate of the wound complications was found similar between the study and the control groups. The authors concluded that mesh reinforcement of primary colostomy formation is a promising method for the prevention of parastomal herniation.

A 2017 meta-analysis evaluated 10 randomized trials with a total of 649 patients of which 324 patients underwent mesh prophylaxis at the time of their index surgery. Parastomal herniation was found in 53 of 324 (16.4%) in the mesh group and 119 of 325 (36.6%) in the non-mesh group ($p < 0.001$). The type of mesh used and/or its anatomical location did not have any significant bearing on those favorable results. Furthermore, no differences in the wound and/or ostomy complication were reported between groups. A contemporaneous 2017 meta-analysis of 7 randomized PSH mesh prophylaxis trials (encompassing 432 patients) excluded studies with less than 12-month follow-up [65]. This study evaluated mesh type (synthetic and biologic) and technique of placement (onlay, inlay, and sublay) as well as the surgical approach (open and laparoscopic). Similar to other studies, mesh use was concluded to be safe and effective with 10.8% of PSH formation in the mesh group and 32.4% in the non-mesh group ($p = 0.001$). The rate of hernia formation was greater in both arms when radiological evaluations for hernia diagnosis were utilized, but the difference in outcomes remained significant (34.6% in mesh vs. 55.3% in the non-mesh group).

In the largest meta-analysis of this topic, Pianka et al. [61] evaluated manuscripts written in any language including 11 randomized and 3 nonrandomized controlled trials comprising a total of 755 patients. Like others, the RCTs demonstrated a significant decrease of PSH incidence in the mesh group (OR 0.24; 95% CI 0.10–0.58, $p = 0.034$). However, non-RCTs showed no benefit of mesh usage.

Although individual studies are limited in patient numbers, the collective body of evidence is supportive of the use of prophylactic mesh during stoma creation. Mesh complications are infrequent, and hernia rates are dramatically reduced. Although long-term follow-up is lacking in many studies, the benefits to the use of mesh are compelling. Identification of the ideal prosthetic, anatomic location, and technique for placement remain areas requiring further investigation.

PSH Prophylaxis with Biologic Mesh

Biologic mesh may be considered an alternative to a synthetic mesh in the prevention of PSH and may be favored by some in an attempt to avoid long-term complications associated with synthetic mesh. Although mesh erosion and infection are possible, the incidence of these events is low. Nevertheless, interest in biologic materials has resulted in several small series of parastomal prophylaxis. While these studies would not be considered landmark publications, they provide some insight into the anticipated outcomes associated with their use in PSH prophylaxis.

To date, there are limited publications evaluating the role of biologic mesh in the prevention of PSH. These studies include the previously mentioned randomized trial by Hammond et al. [66] evaluating PSH prophylaxis of loop ileostomy as well as a double-blinded multicenter RCT by Fleshman et al. [67] evaluating a non-cross-linked porcine acellular dermal matrix in patients undergoing elective permanent end stoma creations (71 colostomies, 42 ileostomies). In the latter study, the surgical technique was not standardized as the measured ostomy circumference in the mesh prophylaxis group was significantly larger (6.4 ± 3.9 vs. 4.8 ± 2.9 cm; $p = 0.002$) than the control group. Stoma size has been demonstrated to be directly related to the incidence of parastomal herniation with higher rates of hernia seen when the aperture is greater than 35 mm [68]. The larger stoma apertures in the mesh group may have impacted outcomes in this study. Nevertheless, the surgical technique was standardized to a mesh (average size 4.8 × 4.8 cm) with a 2 cm cruciate opening in the center of the mesh positioned in the retrorectus space without fixation. Following 24 months of follow-up, there was no difference in the incidence of parastomal herniation between groups (12.2% mesh vs. 13.2% control) with similar quality of life indicators. Accordingly, no benefit could be ascribed to the use of biologic mesh in the prevention of PSH in this study.

In light of the paucity of compelling data evaluating the role of biologic mesh for PSH prophylaxis, it is difficult to recommend this practice. Further well-designed studies comparing biologic mesh PSH prophylaxis to both synthetic mesh prophylaxis and controls are needed to fully understand both the advantages and drawbacks.

Conclusion

IHs are the most common complication of a laparotomy. Efforts to reduce the incidence of IH are needed due to the cost and morbidity of IH repair. Identification of patients at greatest risk for the development of IH may provide opportunities for demonstrating the greatest patient benefit when utilizing techniques to prevent IH. Numerous studies have demonstrated a benefit to the placement of mesh at the time of laparotomy closure in high-risk groups with morbidity comparable to sutured laparotomy closure. In light of the current evidence, consideration for placement of prophylactic mesh at the time of laparotomy closure in studied patient populations should be considered. It is not clear whether routine prophylaxis of all abdominal incisions will translate into improved outcomes and at this time cannot be recommended as a routine practice.

Complications following the placement of prophylactic mesh during laparotomy closure are infrequently reported and similar to the incidence of wound complications following laparotomy closure with sutures. Considering the incidence of IH today, further evaluation and assessment of current laparotomy closure techniques is warranted.

PSH rates are exceedingly common following the creation of stomas. Careful surgical technique with small stomal apertures and the use of prophylactic mesh may minimize hernia rates. Synthetic polypropylene mesh has demonstrated efficacy and safety when utilized adjacent to a stoma in the prevention of PSH. Despite the potential for inoculation of mesh with bacteria during stoma creation, synthetic mesh placed at the site of colostomy infrequently results in complications. Future studies will be required to understand the best techniques, mesh choice, and fixation methods when performing PSH prophylaxis.

Abdominal operations are performed commonly with significant rates of postoperative hernia formation. Efforts to reduce the incidence of this common complication should translate into improved patient outcomes and reduced healthcare costs. The use of mesh as a prophylactic measure is a burgeoning approach to enhancing patient care outcomes following abdominal surgery.

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5 The Application of Complex Systems Science to Healthcare and Hernia Disease

Kyle L. Kleppe and Bruce Ramshaw

Introduction

In 1998, two groups of scientists made a surprising discovery – our universe is expanding at a faster and faster pace. We see this accelerating pace of change in the waves of innovation over the past few centuries. From the agricultural age to the industrial revolution and more recently the information age, the time to go through each stage of innovation is less and less. In our organizations, we see an increased pace of disruption. The life span of a Fortune 500 company in the 1950s was over 60 years. At the beginning of the twenty-first century, the average life span was less than 15 years. This increasing pace of change in our world is revealing the fact that a reductionist scientific understanding is incomplete. Because we have applied reductionist thinking and reductionist system structures to our healthcare system, the result is an unsustainable increase in per capita spending and uncontrollable harm and waste as a result of this model for patient care. What is happening in our world? How does this apply to hernias and healthcare? And how does this knowledge help us to measure and improve the value of care we provide for our patients with hernia disease and related complications? The understanding required to address these questions cannot be obtained with the same kind of reductionist thinking we have used up until now in healthcare. The natural result of a reductionist model for healthcare in the face of increasing pace of change is increasing fragmentation. We have seen a significant growth in hospital department silos that results in a massive increase in administrators to manage these silos, and therefore we have more inefficiency, waste, costs, and harm. To compound the problems, information technology systems have been poorly designed to serve these fragments within our systems, rather than being designed to meet the needs of the most important process in healthcare, the patient's whole cycle of care. Applying a more complete scientific paradigm, complex systems science, will allow us to begin to understand and apply new thinking to improve the value of care for hernia disease and all other diseases that we attempt to manage and cure in our global healthcare system.

The US healthcare system has been criticized widely for its cumbersome nature, inefficiencies, and inability to deliver best scientific knowledge to the patient. The delivery of care is complex, and its application can vary widely resulting in vast differences in outcomes. With these limitations in mind, we seek to improve upon the care we deliver and provide the best quality and value to the patient.

> [Healthcare quality is] the degree to which healthcare services for individuals and populations increase the likelihood of desired health outcomes and are consistent with current professional knowledge – Institute of Medicine, Crossing the Quality Chasm 2001

Goals set forth by the Committee on Quality of Health Care in America suggested that care should have the following aims: safe, effective, patient centered, timely, efficient, and equitable. Traditional approaches utilizing the reductionist scientific method hardly can improve care in many of these arenas listed above [1]. It is certainly not timely; it has been reported that scientific knowledge derived from randomized controlled trials takes 17 years to be implemented widely in clinical practice [2].

This is where the tools from complex systems science such as clinical quality improvement (CQI) can potentially improve the value of care we provide in healthcare. CQI is an approach to improving patient care processes and value-based outcomes based on complex systems science. It consists of the attainment and application of clinical knowledge through the collection of data from continuous process improvement in the clinical environment. Clinical data is able to be collected in real time and affect change more rapidly than traditional research methods.

CQI applied to the whole patient care process is also quite different from traditional quality improvement projects that have been implemented in healthcare the past few decades.

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Notable projects have included application of central-line bundles to decrease the rate of catheter-related bloodstream infections and increasing safety in the OR through the use of checklists. The scope of these projects has historically been limited to a single element, or subprocess, of the entire patient care process. We have learned that in order to make greater change and improve outcomes, investigations of and improvements on the entire patient care process, from the moment of first symptoms to complete return to a full quality of life, must be made. Applying the principles of CQI to a subprocess without measuring the impact on the whole patient care process is termed suboptimization, where the improvement of the subprocess does not improve the outcome of the whole process, and there are often unintentional consequences as a result. CQI should not be thought of as a single improvement project. The process is continuous as patient data is gathered in real time. New attempts at process improvement can be implemented and the effects measured and the cycle repeated.

Implementing CQI as a part of the actual patient care process allows for the coordination of care and quality improvement within any program, such as a bariatric or hernia program. When these efforts are applied to actual patient care by a clinical team, they are exempt from HIPAA (defined under "healthcare operations"), and it is inappropriate for improvement efforts to be submitted for an IRB review. It is even appropriate to present and/or publish the results of any attempts to improve the patient care process without IRB submission according to a FAQ section about CQI on the HHS website (https://www.hhs.gov/ohrp/regulations-and-policy/guidance/faq/quality-improvement-activities/).

Healthcare and the Application of Complex Systems Science

A natural system differs significantly from a mechanical one where a specific input reliably results in an expected output. Natural (biologic) adaptive systems have the ability to react to inputs in many different and potentially unpredictable ways. Healthcare represents a very complex and adaptive system. Many clinicians and/or hospital policies attempt to apply the principles of a mechanical system to patient care. This thinking often leads to incomplete understanding and frustration when desired outcomes are not achieved.

The dominant scientific platform in healthcare has been reductionism, a belief that in-depth study of parts of systems would yield greater understanding and allow predictability of the system as a whole. Much knowledge has been garnered from this line of thinking, but its benefits are approaching the law of diminishing returns as our world continues to change faster and faster. Attainment of new clinical knowledge and application to the patient care process has continued to be cumbersome and time-consuming. Traditionally, clinical improvement has been dependent on established clinical research tools such as prospective, randomized controlled trials (PCRTs). We are beginning to understand that the use of these tools for a complex dynamic process, such as care for a hernia patient, may be not only inadequate but inappropriate for advancing clinical improvement. In fact, a peer-reviewed, published international guideline suggests that the use of complex systems science tools, such as CQI, is more appropriate and more likely to improve value for ventral/incisional hernia patients than the use of reductionist science tools, such as PRCTs [3].

PRCTs attempt to prove or disprove a hypothesis in an isolated system by attempting to control all variables. In an attempt to further control the test conditions, many inclusion and exclusion criteria are often implemented. The more complex the problem we are trying to study, the more unlikely PCRTs are to help gain insight into how to improve the value of care for that problem. CQI instead analyzes many patient and clinical factors that help to measure and improve the value of patient outcomes. These relationships have complex interactions and are dynamic – changing over time. Nonlinear statistical methods, such as factor analysis and predictive analytics, are used to gain insight into the care process.

Developing a Program

When developing a clinical program that will apply the principles of CQI, a specific patient population needs to be identified, patients with abdominal wall hernia problems, for example. Within each clinical program, there will be several different definable patient care processes. Defining one patient care process for all hernia patients is too broad. The factors that determine the outcomes of inguinal hernia patients can be significantly different for those that are important to the outcomes for ventral/incisional hernia patients. Some specific hernia program patient care processes are listed below Fig. 5.1. The principles of data science suggest that data should be analyzed in the context of

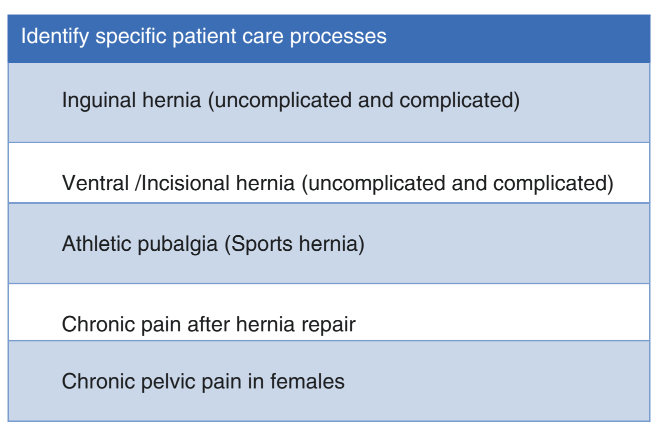

Fig. 5.1 A list of several definable patient care processes for an abdominal wall hernia program

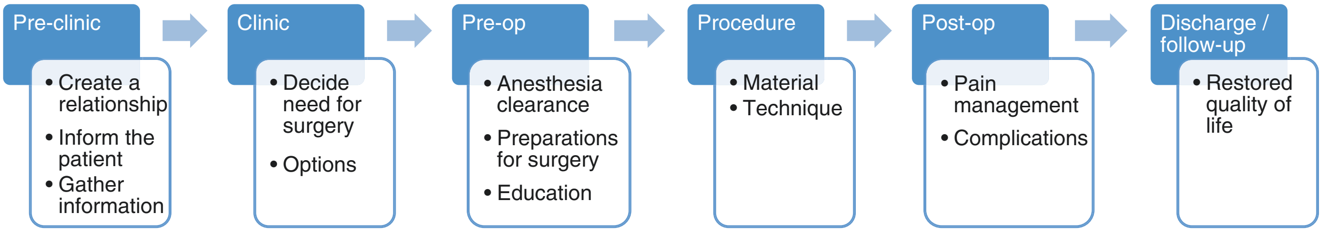

Fig. 5.2 An example of a whole patient care process for a problem treated with a surgical procedure

each definable process in each local environment. If data is pooled from many different definable processes, then there is too much noise for the analyses to result in adequate insights to improve outcomes.

In order to begin the development of a program, the stakeholders should be identified. These individuals can have diverse backgrounds and influence. Team members can include physicians, nurses, care coordinators, engineers, patients, patient family members, industry, and others. The multidisciplinary approach can bring different perspectives to the team. Multidisciplinary does not necessarily mean large (over 15–20 people may be too large) or one narrow perspective (having only different physician specialties on the team does not give you all perspectives that matter); small teams are ideal for interpreting data and making changes.

The next step is defining the dynamic cycle of care for a definable patient care process. The cycle of care can actually begin before the first encounter with the clinician. The process can terminate once the patient has returned to normal activities, which may be months or years. It is important to see how specific interventions or factors may influence outcomes that measure value. Below is a simplified diagram of a patient care process Fig. 5.2.

Defining Value

The team needs to have the ability to identify specific outcome measures and report them. Methods for automated data collection and interpretation need to be created. A benefit of CQI is that these data points can be changed at any time as more is learned about the patient care process. This would be difficult, if not impossible, with traditional research methods.

Obtaining accurate cost data has been the greatest challenge in our attempt to measure value. By looking at actual costs, correlations can be made to determine the impact that various factors such as smoking or obesity have on outcomes such as cost of care and hospital margin.

Satisfaction of the consumer of healthcare is often under-reported and under-rated in its importance in the patient care process. Perceptions of success can also be

$$V = \frac{\underset{\text{(Quality)}}{Q} + \underset{\text{(Outcomes)}}{O} + \underset{\text{(Safety)}}{S}}{\underset{\text{(Cost)}}{\$}}$$

Fig. 5.3 Value (V) is a measurement that addresses traditional quality measures (Q), patient perspective measures such as patient perspective outcomes (O), and safety and satisfaction (S) divided by the actual costs for the entire cycle of care ($) in the context of each definable patient care process

variable. A successful intervention could be an improvement in value despite not having a perfect outcome. A small non-limiting recurrence after a complex abdominal wall reconstruction or improvement in chronic groin pain, which may still be present but not lifestyle limiting, may both be viewed as a success.

The ultimate aim for CQI is to measure and improve value to the patient and the healthcare system as a whole. In general, value is influenced by quality, patient perspective outcomes, safety, satisfaction, and cost. With changing reimbursement models, it will be increasingly important to justify the diagnostic and treatment interventions we offer to patients. An intervention has three potential outcomes for the patient and the healthcare system: it can provide benefit, it can result in harm, or it can be wasteful (expense but no benefit or harm). Our goal should be to provide great benefit, while minimizing harm and waste based on the measurement of value in the context of each definable patient care process Fig. 5.3.

Identifying Ideas for Improvement

Determining areas for improvement can come from several sources. The first is the team: as mentioned previously, the CQI team should be composed of various individuals that bring multiple perspectives for each definable patient care process. These team members have observed or participated in the care process and have unique perspectives on how the value of care could potentially be improved. They are the people who determine what data points and outcome measures are programmed into the computing software for analysis and visualization, and they are the people who interpret the analyses and visualizations to generate ideas for improvement. From time to time, the team will obtain feedback from other perspectives such as patient and family members or an industry partner to gain insight and ideas for improvement from their perspective and their interpretation of the data analysis and data visualizations.

Another resource for identifying areas for improvement is the use of data analytics. We collect data including patient factors, treatment factors, and outcomes that measure value and use nonlinear statistical methods, such as factor analysis, that will produce weighted correlations (positive and negative) that reveal insight into the relationships between the patient and treatment factors with outcome measures that measure value. Traditional research methodologies attempt to find differences in means and medians of populations and to prove or disprove a hypothesis that is measured using linear statistics usually generating a *p*-value. Outlying data points are often discredited and excluded from analysis. One of the benefits of CQI is that it encourages us to more closely examine outliers and truly understand the contributing factors. These anomalies can either be positive (unexpected or rare benefit) or negative (unexpected or rare harm). Performing a more in-depth examination of outliers may lead to significant clinical insights and ideas for improvement.

Once an opportunity for improvement has been identified and a process improvement idea generated, several questions can be posed:

- Which patient subset benefits the most from the potential intervention?
- Is there a subset of patients that should not have the potential intervention?
- Are there other potential ways that the intervention can add value or might have a negative impact on the patient, the surgeon, and/or the hospital?
- What impact does the intervention have on the costs for the entire cycle of care?
- What are the barriers for implementation of the intervention?

After these questions have been answered favorably, the potential improvement idea can be implemented. Quality, outcomes, safety, satisfaction, and cost are all tracked to determine if value has been added to the patient care process.

Implementing Change, Examples of CQI

Below we have provided a few examples of how ideas have been generated and change has been implemented to improve value within our hernia program. Several of these examples and others generated using the principles of value-based CQI have been published previously [4–8].

A Negative Anomaly: Minimizing Harm

During a laparoscopic ventral hernia repair procedure, a CO_2 embolism occurred. The procedure was aborted, and fortunately the patient recovered without permanent harm. The hernia team did a literature search and brought ideas to one of the CQI meetings to discuss ideas for process improvement to address this negative anomaly. There were observations discussed such as the fact that the surgeon usually enters the abdomen in a left subcostal location, and in this patient a right subcostal location was used so this may have been a contributing factor. Also, the insufflation rate was on high early during the initial insufflation, and a slower insufflation rate could have been used. The research on insufflation pressure and pressure variation was reviewed, and it was found that a significant amount of literature is published in support of a lower insufflation pressure. Also, with new insufflation technology, it is now possible to control intra-abdominal pressure constantly in real time, rather than intermittently as is the case in standard insufflation technologies. This relatively new technology was thought to be a potential idea for process improvement for our patients who undergo laparoscopic ventral hernia repair. Potential improved value could come from a lower likelihood of rare complications from CO_2 embolus, from less visceral pain with a lower pressure and more stable pneumoperitoneum. There was also a potential benefit of better smoke evacuation from the operative field. Since the implementation of the low-pressure pneumoperitoneum system, there has not been another incidence of CO_2 embolus.

Postoperative Pain Control

Patients undergoing laparoscopic ventral hernia repair can have significant postoperative pain. This pain has been identified to be multifactorial and even derived from different neural pathways. Somatic pain is due to mesh fixation techniques, and visceral pain is related to CO_2 insufflation pressure during the operation. Initiatives that were identified for this specific clinical issue included administration of a transversus abdominis plane (TAP) block preoperatively and/or the administration of an intraoperative block using laparoscopic visualization with a long-acting local anesthetic, as well as a low-pressure pneumoperitoneum system. After implementation of a low-pressure insufflation system in combination with the long-acting local anesthetic blocks as a part or a multimodal pain strategy, patient outcomes have improved. Length of stay has decreased to just over 1 day, postoperative opioid use has decreased by almost 80%, and over 60% of patients require no opioid pain medication during the PACU stay.

The concepts of multimodal pain management and enhanced recovery were also applied to complex ventral and incisional hernias that are often repaired by technique of abdominal wall reconstruction. These operations have a high cost of care, often result in prolonged hospital stays, and have high complication rates. Specific processes that have been investigated in our program have included the use of a long-term resorbable synthetic mesh and the use of TAP block with long-acting local anesthetic. Over 100 patient's outcomes were reviewed, and these specific changes led to decreased costs and improved outcomes, including a shorter length of stay and less opioid use postoperatively.

Eliminating Use of Drains in Abdominal Wall Reconstruction

As mentioned previously, creating a multidisciplinary team can allow diverse ideas to be brought to the table. One issue brought up by patients and family members was a negative experience with abdominal wall drains placed during abdominal wall reconstruction. Patients did not like the irritation, discomfort, and hassle of drains, especially when they had to manage them outside of the hospital stay. Some patients had infections at the site where the drain tubing exited the skin. In an attempt to apply a process improvement, our hernia team did a literature search and found techniques that had been developed by plastic surgeons in abdominoplasty operations that led to the elimination of abdominal wall drains with improved rates of wound complications after the use of drains was discontinued.

We were already moving toward techniques to minimize the elevation of skin flaps – first using endoscopic approaches for external oblique component separation and then the transversus abdominis release (TAR) approach. We added the techniques of wide skin and soft tissue excision including excision of the umbilicus and the use of layered quilting (also known as tension reduction) sutures to eliminate the dead space and tension on the skin closure. In some cases, this included an inverted T (fleur-de-lis) incision. Although this did increase the operative time (a new improvement opportunity), the rate of wound complications has decreased significantly without using a single drain over the past several years. In a factor analysis performed to determine what factors contributed to poor outcomes, the use of drains had a highly weighted correlation (+0.875) to poor outcomes (increased LOS and opioid use and increased incidence of postoperative wound complications).

Summary

The application of complex systems science to healthcare has the potential to greatly improve the value of care for patients and the system as a whole. The principles of applying complex systems science to healthcare include measuring the value of care provided in the context of whole, definable patient care processes. To improve value, a multidisciplinary team determines what patient and treatment factors are most likely to impact outcomes that measure value for each definable patient care process. These data points and outcome measures can be analyzed with nonlinear analytical tools that produce weighted correlations to give the team insight into what can be changed in the care process to attempt to improve outcomes. This feedback loop is repeated regularly to allow for continued improvement in light of an ever-changing world.

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6 Anesthesia

Pär Nordin

Anesthesia for Groin Hernia Surgery

Not all surgical procedures are granted to have three choices of anesthesia as the open groin hernia operation. The optimal anesthetic technique has to meet several demands. It has to be simple and as safe as possible with low postoperative morbidity. It must provide good perioperative and postoperative analgesia, produce optimal operating conditions by immobility, be associated with few complications, and facilitate early patient discharge and has to be cost-effective. Finally, it is essential to remember that for an operation to be successful, the patient should be pleased with it.

Background

Groin hernia surgery is one of the most frequent operations performed in general surgery. Outcome evaluation has usually focused on recurrence rates and technical issues, but more recently there has also been a focus on chronic postherniorrhaphy pain [1]. However, the increasing demand by health-care providers for more efficient and cost-effective surgery has resulted in modifications of care to encourage more widespread adoption of day case, outpatient surgery [2]. In this context, the choice of anesthetic method for groin hernia repair plays a significant role regarding costs, morbidity, early pain relief, early discharge, and recovery. For the important question as to method of anesthesia, there is still no consensus about the best choice.

The choice of anesthesia is still controversial, and available data reflect a large variation in anesthetic practice. Only rarely nowadays is the patient totally unfit to undergo a suitably judged general or regional anesthetic. Local anesthesia for hernia repair does have particular advantages—organizational and economic as well as clinical.

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Local anesthesia is used almost exclusively in several either private hernia centers or public hospitals with a special interest in hernia surgery [3–8]. The EHS guidelines on IH treatment recommend that local anesthesia be considered for all adult patients with primary reducible unilateral His [9]. Large amounts of epidemiologic data, reflecting general surgical practice from Scotland [10], Denmark [11, 12], and Sweden [13], have shown that general anesthesia is the preferred method, for hernia repair in 60–70% of cases, regional anesthesia in 10–20%, and local infiltration anesthesia in about 10–20%. The type of anesthesia employed may depend on the preferences and skills of the surgical team rather than the feasibility of a technique in a given patient, intra- and postoperative pain control, facilitation of early recovery and monitoring requirements, postoperative morbidity, and costs.

Anesthetic Techniques

Ideally inguinal hernia repair should be performed using a simple and safe anesthetic technique that is acceptable for the patient and easily mastered in general surgical practice. The technique should carry a low morbidity risk and also be cost-effective. Postoperative side effects and prolonged hospital stay after groin hernia surgery are often related to the effects of anesthesia.

Preemptive Analgesia

Inguinal hernia repair results in pain postoperatively, and the optimal methods to treat this pain remain controversial. The concept of preemptive analgesia envisages that effective postoperative pain relief benefits the patient by providing comfort in the period after surgery [14]. It includes the use of preoperative and intraoperative local anesthetic infiltration and/or preoperative or intraoperative field block and paravertebral block and conventional NSAIDs or selective COX-2 inhibitors. The theory is that effective treatment of acute pain

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facilitates early rehabilitation and recovery, and those preemptive analgesic nerve blocks may prevent central sensitization and secondary hyperalgesia after tissue damage. It is clear that local anesthetic field blocks and subfascial and/or subcutaneous local infiltration reduce early postoperative pain scores and the need for supplemental analgesics [15–17]. Therefore, when general or regional anesthesia is used, local anesthetic field blocks and infiltration are recommended in all open groin hernia surgeries.

Paravertebral nerve blocks (PVBs) are established methods of providing analgesia to thoracic- and abdominal-surgery patients including those undergoing groin hernia repair. One systematic review [18] found a tendency to less postoperative pain in PVB patients when compared with general anesthesia and spinal anesthesia patients.

The transversus abdominis plane (TAP) block is a relatively new regional anesthetic technique developed in an attempt to reduce postoperative pain. It has evolved from a landmark technique to an ultrasound-guided one. A 2010 Cochrane Database Systematic Review found only limited evidence to suggest that the use of perioperative TAP blocks is opioid sparing or reduces pain scores after abdominal surgery [19].

A further concept in optimal management of postoperative pain relief is that of balanced analgesia [20]. This concept takes the advantage of multimodal additive and synergistic effects of a combination of analgesic drugs including nonsteroidal anti-inflammatory agents given preoperatively, incisional local anesthesia, and postoperative oral analgesics. Acting at different points on pain pathways, this approach allows low doses of individual drugs to be used thus decreasing the risk of side effects and maximizing the analgesic effect [21].

General Anesthesia

General anesthesia (GA) can provide the surgeon with optimal operating conditions in terms of patient immobility and muscular relaxation. It allows the surgeon to perform the procedure considered necessary and may have particular advantages in incarceration or suspected intestine strangulation.

Techniques

Modern GA with short-acting agents and combined with local infiltration anesthesia is safe and fully compatible with day-case surgery [22]. Inhalation anesthesia, intravenous drugs, or a combination of both may be used. In most patients optimal GA for groin hernia repair will include propofol induction supplemented with sevoflurane or desflurane inhalation for maintenance. An alternative is the total intravenous variant utilizing propofol and short-acting opioids such as remifentanil, which in most cases leads to a fast recovery.

There are disadvantages in introducing opioids such as fentanyl or alfentanil into the anesthetic sequence because of the incidence of nausea and vomiting, apnea, occasional awareness, and muscle rigidity. Benzodiazepines have proved useful for sedation; however, recovery from intravenous midazolam is not as rapid as recovery from intravenous propofol, which may be used during general anesthesia.

The disadvantages of GA are risk for airway complications, respiratory function, cardiovascular instability, nausea, vomiting, and urinary complications. Furthermore, recovery from central hypnotic effects may be prolonged, and as a consequence the method is not always suitable for day-case surgery. GA also incurs added costs since it requires specialized anesthesia staff and equipment as well as postanesthetic care facility.

Finally, the administration of a general anesthetic should not be underestimated; irrespective of technique there is incidence of side effects that may persist for up to 24 h, such as drowsiness, headache, cognitive effects, muscle pain, nausea, and vomiting.

The advantages of early ambulation to prevent thromboembolism are negated by the speed of recovery, and hence early ambulation can be achieved with modern general anesthesia.

Regional Anesthesia

Regional anesthetic (RA) techniques for groin hernia repair can be provided by either subarachnoid (spinal), epidural techniques or, more uncommon, paravertebral techniques [23].

It provides good analgesia intraoperatively and can allow the patient to be awake during the procedure if this is desired. It is quite easy to perform in the great majority of patients and avoids many of the airways and respiratory and gastrointestinal complications that may occur with GA. Its advantages include less postoperative nausea and vomiting, pain-free immediate postoperative period, and minimal drug and equipment costs.

The regional anesthetic techniques do have disadvantages, however, and are burdened with a higher (albeit low) risk of inadequate anesthesia. The bilateral motor and sympathetic block may induce a prolonged postoperative recovery due to postoperative urination difficulties. Spinal anesthesia regularly results in urine retention which results in prolonged postoperative recovery [15, 24–29]. It also carries a higher incidence of cardiovascular complications compared to general anesthesia [30]. Other disadvantages are postspinal headache and, very rarely, neurological damage due to direct neural trauma, infection, or vascular complications. The frequency of postspinal headache (due to dural puncture) is highly dependent on the age of the patients and type of needle use [31–33]. RA requires anesthesia staff during the operation as well as in the postanesthetic care.

Techniques

In recent years improvements of the regional anesthetic techniques have been made with the use of more short-acting local anesthetic agents and small-gauge pencil-point needles. Also the use of additional spinal opioids combined with a reduction in the amount of spinal doses may reduce the postoperative side effects [31, 34]. Paravertebral block (PVB) has been used for unilateral procedures such as breast and chest wall surgery but also inguinal hernia repair.

The most common regional technique for hernia surgery is spinal anesthesia with short-acting agents, although some hernia centers use short-acting epidural anesthesia but without providing specific intraoperative and postoperative data [35]. Because of the sparse data for epidural analgesia, this technique is not discussed or recommended until further data are available. More recently, the use of a paravertebral nerve block has been investigated [23, 36], but this technique only provides analgesia equivalent to a conventional intraoperative peripheral nerve block. Two randomized trial found advantages with PVB, compared to conventional spinal anesthesia [37, 38]. In these trials all patients received intravenous infusion with propofol during surgery.

Local Anesthesia

The open treatment of primary reducible inguinal hernias in adults is nearly always possible under local anesthesia (LA) [4, 6, 39] and can be provided by a local infiltration technique [40] or by a specific blockade of the ilioinguinal and iliohypogastric nerves or a combination of the two methods (see below) [41]. Evidence strongly supports that local anesthesia has several advantages over general or regional anesthesia in elective reducible IH repairs. The administration is technically quite easy, but it requires training. LA is only successful if the surgeon handles the tissues gently, has patience, and is fully conversant with the anesthetic technique [40, 42]. Among reported advantages are simplicity, safety, extended postoperative analgesia, early mobilization without postanesthetic side effects, and low cost. The method is ideally suited for day-case surgery as the anesthetic agents used have no significant central effect, and motor block is minimal.

The clinical advantages include the prolonged analgesia provided when long-acting local anesthetic solution is employed, enhanced definition of tissue planes afforded by the hydrodynamic dissection by the local anesthetic distending the tissues, and lastly the patient cooperation possible in testing and identifying anatomic defects. The technique is more demanding for the operator: he or she must be more precise and less traumatic to tissue than in the unconscious patient. Above all, when surgery is completed, the subject may be asked to cough or strain so that any deficiencies in technique are immediately observed. The patient is saved from the anxiety of GA and the hangover effect of recovery. The time taken to infiltrate the local anesthesia sufficiently to gain satisfactory analgesia has been similar to general in comparative studies [22, 26].

The infrequent use of LA may partly be the patient's wish to sleep because of fear of pain during surgery but also explained by traditions in anesthesia practice, preferences, and skills of the surgical team. Perioperative pain sensation is reported and can sometimes be a reason for conversion to general anesthesia [43]. Many surgeons have probably also been reluctant to learn the technique as they may find the operation easier to perform with RA or GA.

Some patients may prove unsuitable for LA, notably very young patients, anxious patients, morbid obesity, and patients with suspected incarceration or strangulation. Whether scrotal hernias and obese patients are suitable depends entirely upon the surgeon's familiarity with the technique [42]. LA is rarely appropriate during laparoscopic repair of groin hernias [44].

As suggested by national hernia database analysis, hernia recurrence may be more common following operation employing local anesthesia. The Swedish Hernia Registry found that local anesthesia is associated with an increased risk of reoperation for recurrence after primary IH repair [45]. A Danish Hernia Database reported an increased reoperation rate after local anesthesia versus general or regional anesthesia after direct—but not indirect—hernia repair [46].

History

The use of local anesthesia for the repair of groin hernia has a rather exciting history. Cocaine was isolated as a pure alkaloid from the leaves of the coca plant, *Erythroxylum coca*, by Niemann in 1860. It was then exploited by the Austrian Karl Koller in 1884 when he instilled it into the eye of a rabbit. This latter discovery is attributed by some to Sigmund Freud, who had been experimenting with cocaine but who deserted his experiments, and the reporting of them, for his fiancée [47]. Freud later wrote:

> In the autumn of 1886 I began to practice medicine in Vienna and married a girl who had waited more than four years for me in a distant town. Now I realize it was my fiancée's fault I did not become famous at that time. In 1884 I was profoundly interested

> in the little known alkaloid of coca, which Merck obtained for me to study its physiological properties. During this work, the occasion presented itself of going to see my fiancée, whom I had not seen for two years. I hurriedly finished my work with cocaine, confining myself in my report to remarking it would soon be put to new use. At the same time I suggested to my friend Konigstein, the ophthalmologist that he should experiment with cocaine in some eye cases. When I came back from holiday, I found it was not to him but to another friend, Karl Koller that I had spoken about cocaine. Koller had completed the research on the eyes of animals and demonstrated the results to the ophthalmological congress in Heidelberg. Quite rightly, the discovery of local anesthesia by cocaine, of such importance in minor surgery, was thereafter attributed to Koller. But I bear my wife no grudge for what I lost!

William Stuart Halsted, in 1885, demonstrated that cocaine could block impulses through nerves and in the process became a lifelong cocaine addict himself. He underwent sanatorium treatment for his addiction before his translation to the chair of surgery at Johns Hopkins. He apparently was never truly cured of this addiction, for he continued to require daily cocaine until his death in 1922. Halsted's resident, Harvey Cushing [48], pursued the development of local anesthesia for groin hernia repair and in 1900 published the original authoritative paper on the nervous anatomy of the inguinal region and his experiences of local anesthesia in the repair of these hernias.

More recently, Glassow and Bendavid have recorded the experience from the Shouldice Clinic in Toronto with a history of over 50 years and more than 250,000 repairs, almost exclusively done in LA [5, 49]. Kark, Callesen, Barwell, Amid, and others have described similar results using local anesthesia [4, 6, 50, 51], and Kingsnorth et al. [52] described an increase in the use of local anesthesia from 78 to 91% of cases in a specialized hernia service.

The choice of anesthesia is still controversial, and available data reflect a large variation in anesthetic practice. LA is preferred at most centers with a special interest in hernia repair, whereas in general surgical practice, however, LA is only used in 5–20% of the patients [10, 11, 13].

Local Anesthetic Agents

Several safe and effective anesthetic agents currently are available. In the 1970s lignocaine (lidocaine) was the drug of choice, but since 1980 it has been superseded by more long-acting agents such as bupivacaine, levobupivacaine, and ropivacaine. However, some surgeons use a combination of agents in order to achieve the advantages of rapid onset of action and longer duration of anesthesia. Adrenaline can be used with both drugs to protract their duration of activity. Bupivacaine is available in concentrations of 0.25, 0.50, and 0.75%. Its onset of action is approximately 20 min and the half-life is 2–3 h.

The maximum safe dose of lignocaine is 3 mg/kg body weight and with adrenaline 7 mg/kg. For bupivacaine the maximum dose is 2 mg/kg body weight and 4 mg/kg with adrenaline.

Bupivacaine is more potent and longer acting than lignocaine and maintains the analgesic block for 8–10 h, which is a major advantage in day-case surgery [53]. The safety margin in the recommended maximum safe dose is wide, as illustrated by serial postoperative plasma concentrations following doses approaching the maximum recommended for lignocaine or bupivacaine. For instance, administering lignocaine with adrenaline to the maximum dose of 7 mg/kg, peak lignocaine concentration ranged from 0.23 to 0.9 mg/L, the toxicity threshold being 5 mg/L [54]. The administration of 20 mL of 0.5% plain bupivacaine resulted in peak venous plasma concentrations of 0.07–1.14 m/L, the cardiovascular toxicity occurring at plasma concentrations greater than 4 mg/L [55].

Barwell reports 2066 patients with inguinal hernias operated on under local anesthetic use 0.5% lignocaine without adrenaline. He has had no cases of anesthetic toxicity, and perhaps the worst complication is "the occasional hematoma at the site of injection for the field block" [56]. Glassow, reporting the experience of the Shouldice Clinic in Toronto, recommends 150 mL of 2% procaine without adrenaline [57], whereas Wantz recommends a mixture of lignocaine and bupivacaine with adrenaline [58].

Newer local anesthetic agents with improved safety and anesthetic equivalence have been tested in inguinal hernia surgery. In a study testing the efficacy of ropivacaine, 32 patients operated under general anesthesia were randomized to receive subcutaneous infiltration with 40 mL of ropivacaine or bupivacaine [59]. There was no difference in pain or analgesic requirements after surgery. Bay-Nielsen et al. found neither differences in intra- or postoperative pain when comparing levobupivacaine with bupivacaine [60]. In a double-blind study comparing the efficacy of levobupivacaine with bupivacaine in elective inguinal herniorrhaphy in 66 patients, Kingsnorth et al. concluded that levobupivacaine exerted similar analgesic effects in the early postoperative period compared with bupivacaine, the theoretical advantage of levobupivacaine being its increased safety margin regarding cardiotoxicity and neurotoxicity [61]. Maybe, due to the cardiotoxicity of bupivacaine, ropivacaine or levobupivacaine should be preferred in cases with extensive need of infiltration (more than 40 mL).

Prolongation of the duration of LA by the addition of agents designed to prolong absorption from the local tissues, mainly dextran, has been explored by several investigators. For the present, additional agents are of no proven advantage, and therefore it is recommended that local anesthetic agents are used plain or with adrenaline [62].

Wantz claims that the burning pain caused by the administration of LA can be eliminated by neutralizing the agent

[63]. The addition of 1 mL of 8.4% sodium bicarbonate solution to 9 mL of plain local anesthesia brings the pH to a comfortable 7.5, which also enhances the anesthesia and reduces the quantity required. The pH of local anesthetic with adrenaline is 4, and therefore 2.5 mL of the sodium bicarbonate solution is required for neutralization.

Local Anesthetic Techniques

LA can be achieved by a variety of techniques. The most common is local infiltration technique [40] or by a specific blockade of the ilioinguinal and iliohypogastric nerves (see below) or a combination of the two methods [41]. Both are preferably performed by the operating surgeon. The administration is technically quite easy, but it requires training.

The use of LA does not necessarily require an anesthesia staff during postanesthetic care [6], but in the operating theater, a nurse anesthetist should be available if supplementary sedation or analgesia is needed or anesthesia monitored care is used. An anesthetist should be available if the need arises, for instance, in case of conversion from LA to GA or when unexpected complications are met. The equipment needed for LA performance is insignificant.

The recommended local anesthetic agent is a 50:50 mixture of bupivacaine and lignocaine with the possibility to addition of adrenaline1:200,000. The benefits of this mixture are the rapid onset of action of the lignocaine solution and the prolonged duration of the bupivacaine.

Care must be taken to avoid direct intravascular injection during the infiltration, which is a very rare event since the only major vein in the region is the femoral vein, which should be far from the wandering tip of the infiltrator's needle.

Because oxygen desaturation is common in procedures carried out under sedation [64], oxygen supplementation and measurement of arterial oxygen saturation by a pulse oximeter should be mandatory. Oxygen saturation and clinical monitoring should be supplemented by devices that continuously display the heart rate, pulse volume, or arterial pressure and electrocardiogram [65]. The patient must be able to respond to commands throughout the procedure: if they are unable to do so, the seditionist has become an anesthetist. The same standards should be applied to sedative techniques (and RA), when there is depression of consciousness or cardiovascular or respiratory complications.

A small dose of intravenous midazolam (2–4 mg) reduces anxiety and makes the patient more relaxed and cooperative. However, recovery from intravenous midazolam is not as rapid as recovery from intravenous propofol. Anecdotal evidence suggests that administration of propofol reduces local anesthetic requirements [64]. In some centers propofol is used in nearly every case to make the procedure easier.

Local anesthesia should achieve the following main steps:

1. Ensure skin anesthesia in the line of incision.
2. Block the nerve supply to the aponeurotic layers, which must be dissected and manipulated.
3. Ensure anesthesia of the parietal peritoneum of the hernia and especially of the neck of the sac, which is very sensitive.

Anatomy of the Groin Area

Knowledge of the fundamental physiology and neuroanatomy of pain in the abdominal wall is essential if adequate local analgesia is to be obtained. Free nerve endings are distributed throughout the skin; stretch and pain receptors occur in each of the aponeurotic layers and in the parietal peritoneum. The skin and subcutaneous tissue are sensitive to all noxious stimuli. Pinprick, pressure, and chemical stimuli (e.g., hypertonic solutions) cause pain in these tissues. The parietal peritoneum is also sensitive to pinprick, stretching, and chemical stimuli. In contrast, the visceral peritoneum and hollow organs are insensitive to touch, to clamp, to knife, and to cautery, but the visceral arteries to these organs are sensitive. There is no pain when viscera are handled under local anesthesia, until a clamp is placed on the vascular pedicle.

The inguinal area is mainly supplied by three nerves which all come from the lumbar plexus. The iliohypogastric nerve (L1) runs between the transverses and internal oblique muscles and supplies the skin above the inguinal ligament. The ilioinguinal nerve (L1) runs parallel to but below the iliohypogastric nerve and on top of the cord through the external ring and gives supply to the adjacent skin and to the scrotum. The genitofemoral nerve (L1 and L2) via its genital branch supplies the cord structures and anterior scrotum and via its femoral branch the skin and subcutaneous tissue in the femoral triangle. All the nerves of the anterior abdominal wall communicate with each other, and thus their cutaneous distribution overlaps (Fig. 6.1). Autonomic nerve fibers accompany the cord to the testis.

Inguinal Block Technique

Inguinal and femoral hernias lie in the borderland between the regular anatomy of the abdominal wall and the complex anatomy of the lower limb. However, the same technical sequence ensures adequate regional anesthesia:

1. An injection is made between the internal oblique and transversus muscles about 1 cm superior to the anterior superior spine in an endeavor to block the ilioinguinal and

iliohypogastric nerves. To do this the needle is pushed in vertically; the "give" as the needle penetrates the aponeurosis of the external oblique allows easy estimate of the depth of the injection. Twenty milliliters of local anesthetic is injected at this site (Fig. 6.2).
2. A local weal is raised in the line of the incision. This weal starts 2 cm above and medial to the anterior superior iliac spine. Long spinal needles may be used to deliver this 20 mL infiltration (Fig. 6.3).

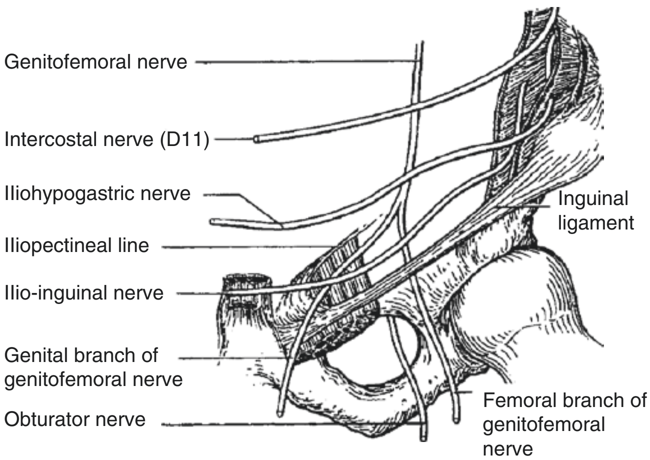

Fig. 6.1 Sensory nerve supply of the inguinal, femoral, and obturator regions

3. The medial end of the oblique subcutaneous weal is now "topped up" with 2 mL of local solution, taking care to carry the injection down to the pubic tubercle and the origin of the rectus muscle from the pubis.
4. The final 20 mL syringe of local anesthetic mixture is infiltrated along the direction of the spermatic cord and through the skin, subcutaneous fat, and external oblique adjacent peritoneal sac, beginning at the deep ring. To aponeurosis (the "give" is felt as the needle penetrates; to achieve this, the tip of the infiltration needle is inserted into the aponeurosis), the syringe is aspirated to ensure that the skin at the surface marking of the deep ring, traversed pampiniform plexus has not been penetrated, and the content of the syringe is then gently injected obliquely along the direction of the spermatic cord toward and including the pubic tubercle. This solution will anesthetize the deeper structures including the sac and the genital branch of the genitofemoral nerve (Fig. 6.4).
5. This anesthetic block can conveniently be applied by the surgeon or anesthetist under strict aseptic conditions but before scrubbing up and gowning. In the 5 or 10 min between application of the block, scrubbing, gowning, and preparing the skin and draping the patient, the infiltration will have become completely effective.
6. Patients should be informed that the slightest discomfort will be supplemented with additional local anesthetic solution. This event is the patient's greatest anxiety, and the nature of previous anesthetic experience is the prime determinant of any anxiety preoperatively [66].

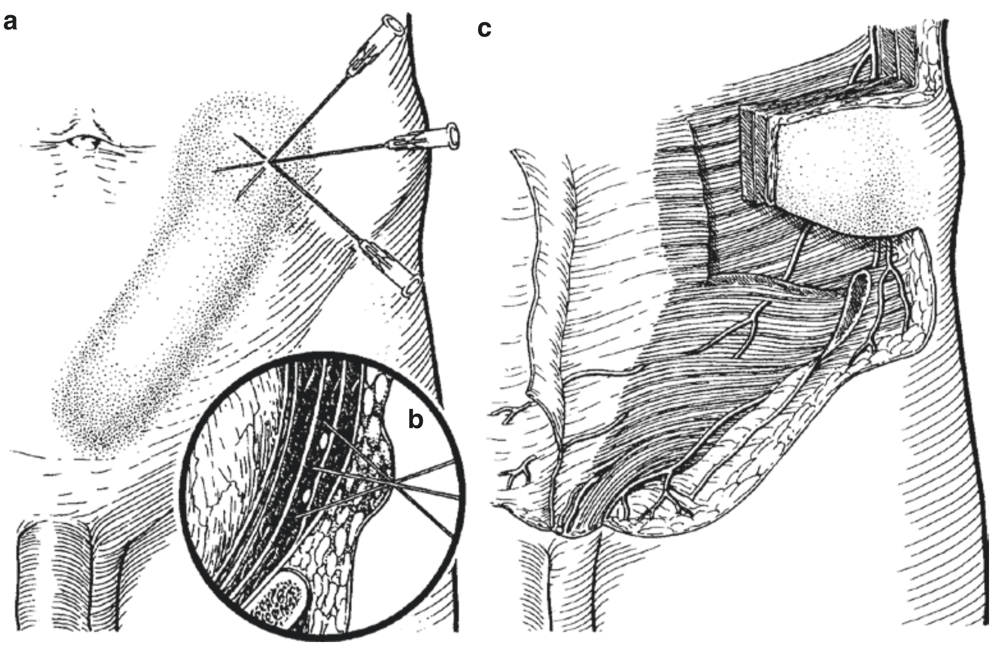

Fig. 6.2 (**a**, **b**) At the *upper* end of the previous weal, at a point approximately 1 cm above and medial to the anterior superior iliac spine, some 3 mL of the anesthetic solution is injected deep to the aponeurosis of the external oblique. The needle is pushed in until the external oblique aponeurosis is felt as a firm resistant structure. (**c**) The needle is pushed through the aponeurosis and the anesthetic solution distributed to block the ilioinguinal and iliohypogastric nerves which run between the external and internal oblique muscles at this point

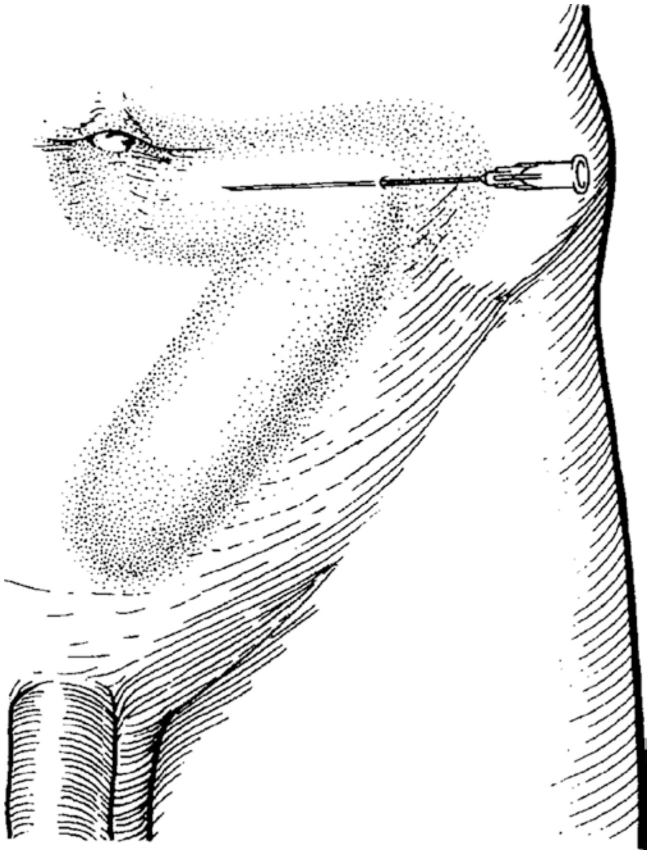

Fig. 6.3 Local anesthesia for an inguinal hernioplasty: using a long spinal needle, a weal of local anesthetic solution is made in the line of the groin incision

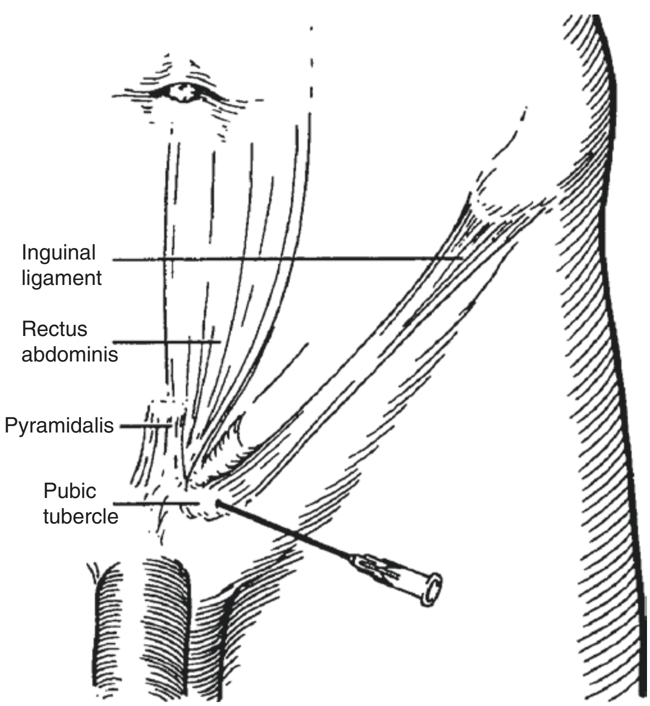

Fig. 6.4 The medial end of the oblique groin (incision) weal is topped up down to the pubic tubercle and origin of the rectus

Local Infiltration Technique

This method is based on preventing pain by infiltration before the incision and, as always when LA is applied, the use of a gentle and atraumatic surgical technique. Forty milliliters of the 50:50 mixture of a short- and a long-acting agent is usually sufficient for a unilateral hernia operation. It is a simple step-by-step infiltration procedure well described by Amid et al. [40] and contains no field blocks at all, only local infiltration. The method should contain the following steps:

1. *Subdermal infiltration*: 10 mL along the line of the incision.
2. *Deep subcutaneous infiltration*: 10 mL deep into the adipose tissue by vertical insertions 2 cm apart. It's often possible to feel the external aponeurosis with the top of the needle.
3. These first steps should be performed 5 or 10 min before the start of the operation (before scrubbing, gowning, and preparing the skin and draping the patient). Then the infiltration will have become completely effective.
4. *Subfascial infiltration*: 10 mL immediately underneath the aponeurosis through a window created in the adipose tissue at the lateral corner of the incision.
5. While the rest of the subcutaneous tissue is incised, the injection floods the enclosed inguinal canal and anesthetizes all three major nerves in the inguinal region. This injection also separates the external oblique aponeurosis from the underlying ilioinguinal nerve when the aponeurosis is incised.
6. *Pubic tubercle infiltration*: A few milliliters are infiltrated as early as possible in the soft tissue over the tubercle, which is a sensitive area.
7. Now the cord can be released and infiltrated around its proximal section.
8. *Hernia sac infiltration*: This is the final step of the infiltration. A few milliliters are placed around the neck of the hernia sac.

Laparoscopic Hernia Repair

Hernia surgery requiring intra-abdominal manipulation is rarely advisable under local anesthetic, and the technique is rarely appropriate during laparoscopic repair of inguinal hernias [44]. However, there are some who are attempting to pursue laparoscopic hernia repair under local anesthetic approaches combined with sedation. It is technically much more difficult to perform and requires extensive experience. In general surgical practice, GA should be the preferable choice when laparoscopic repair is to be adopted.

Complications of Local Anesthetics

The possible major complications are allergic reactions, CNS toxicity, cardiac arrhythmias, and cardiovascular collapse due to inadvertent intravascular injection of the local anesthetic. However, all is rare with the local infiltration technique and has never described in large hernia series (Callesen, Amid, Kark, Bendavid). A possible minor complication is a transient femoral nerve blockade, due to a deep injection or spread between fascia planes [67]. Apart from this, the technique is considered extremely safe. Patients undergoing local anesthesia should be questioned about previous side effects from local anesthetics.

Complications of local anesthetics are systemic and local. *Systemic*:

(a) Excitation of the nervous system, nervousness, nausea, and convulsions—these are very rare; increased patient excitability and garrulousness, a rising pulse rate, and an increasing blood pressure are the early signs of CNS intoxication.
(b) Depression of the cardiovascular system with hypotension and arrhythmias.
(c) Hypersensitivity reactions are very rare with lignocaine and bupivacaine.

Local:

(a) Ecchymoses and bruising.
(b) Local ischemia and tissue necrosis if too much adrenaline is injected at one site.
(c) These local complications can compromise wound healing.

Local Anesthesia for Other Small Abdominal Wall Hernias

The same concept of local anesthesia—a combination of regional block and field infiltration—can be employed for small incisional, umbilical, and epigastric hernias. Important points are to adequately infiltrate the subcutaneous layer, especially cranial to the proposed incision, and then to adequately anesthetize the intercostal nerves, which run deep to the internal, oblique/rectus sheath aponeurosis to within 2 cm of the midline.

The intercostal nerves run from their intercostal space forward between the internal oblique and transversus muscles to the lateral margin of the rectus sheath. They enter the sheath on its posterior aspect, supply the rectus muscle, pierce the anterior sheath, and then ramify in the subcutaneous tissue and supply the adjacent skin. Each of these nerves gives a lateral cutaneous branch, which pierces the flat muscles and becomes subcutaneous in the midaxillary line. Once subcutaneous, this lateral cutaneous branch gives anterior and posterior branches to supply the skin and subcutaneous tissue.

The anterior portions of the six lower intercostal nerves are continued forward from their respective spaces onto the anterior abdominal wall and are accompanied by the last thoracic (subcostal) nerve.

For local anesthesia nerve block to be successful, the intercostal nerve must be blocked before the lateral cutaneous branch is given off. The site of election for the local anesthetic injection is in the posterior axillary line. If the intercostal nerve is blocked too far anteriorly, the anterior division of the lateral cutaneous branch will remain sensitive (Fig. 6.5).

It should be remembered that the intercostal nerve is tucked under the lower border of the rib in its posterior third and in the center of the intercostal space more anteriorly (Fig. 6.6).

When the hernia is exposed, it is important to infiltrate the neck of the hernial sac (parietal peritoneum) to ensure adequate anesthesia, while the sac is dissected, incised, emptied, and closed (if this is the done rather than mere reduction into the preperitoneal space).

Hernia surgery requiring extensive dissection, major intra-abdominal manipulation, fluid shifts, or blood transfu-

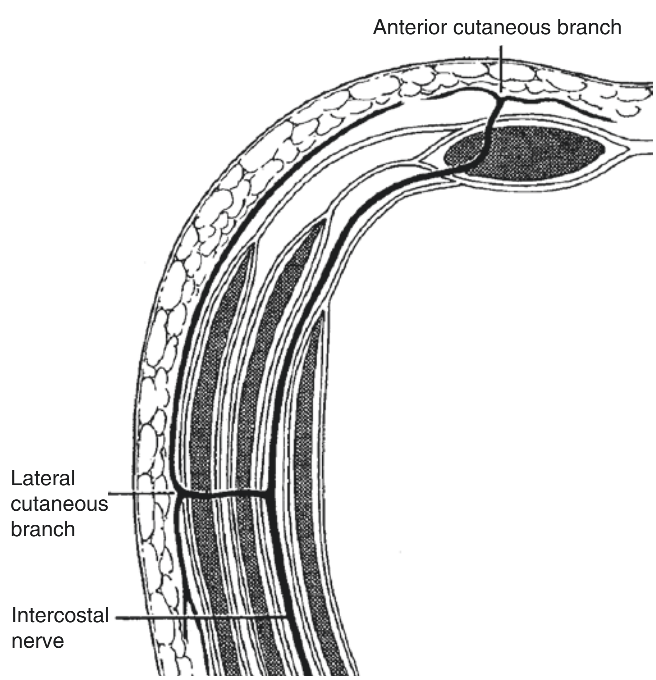

Fig. 6.5 Transverse section through the abdominal wall. The lateral cutaneous branch of an intercostal nerve gives an anterior and posterior division; the anterior division must be blocked for effective abdominal wall anesthesia

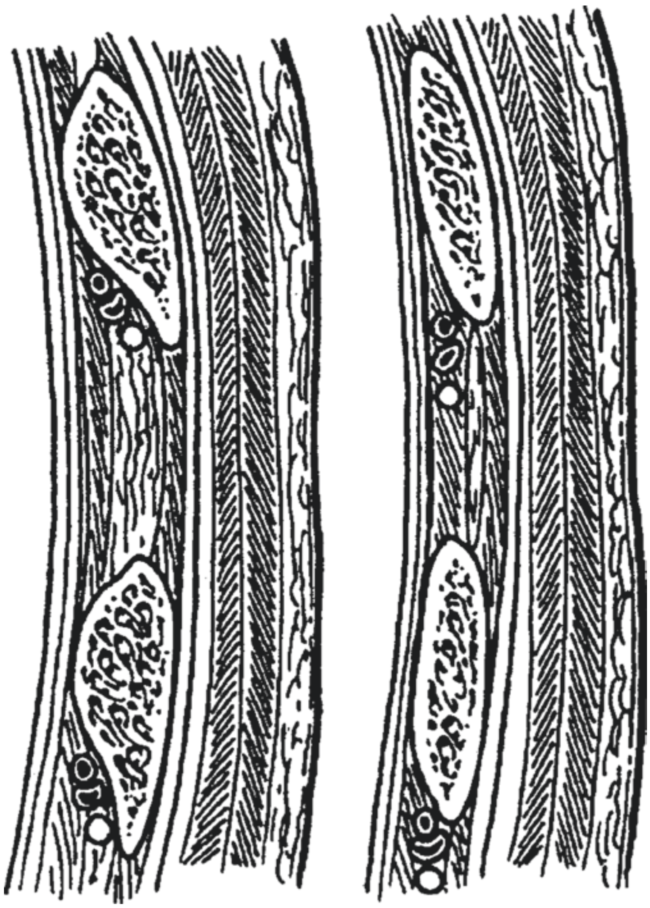

Fig. 6.6 The relative positions of the ribs and the intercostal nerves vary. Posterior to the midaxillary line, the intercostal nerves and vessels are tucked under the rib next above; anteriorly they lie midway between the ribs in the mid-intercostal space

sion is rarely advisable under local anesthetic, and the technique is rarely appropriate during laparoscopic repair of inguinal hernias [44].

Postoperative Outcome of the Anesthetic Techniques

Postoperative Pain

Effective postoperative pain relief benefits the patient by providing comfort in the period after surgery as well as modifying the autonomic and somatic reflexes to pain which delay recovery. Treatment of pain facilitates early rehabilitation and recovery [14]. Maximum pain is found on postoperative day 1, and often significant problems are present until the end of the first week [68].

Early postoperative pain is reduced when the operation is performed under LA with the use of a long-acting local anesthetic (bupivacaine, levobupivacaine, ropivacaine) that lasts 4–8 h. This is longer than that for RA or GA, as documented in large, randomized trials comparing the three anesthetic techniques [22, 26]. In earlier reports regarding postoperative pain, one study found no difference [69] between anesthetic methods, and five studies observed less pain with LA [6, 26, 70–73]. An exception is the randomized controlled trial of Teasdale et al. [43], where patients with LA required more postoperative analgesics than those in the GA group. Perhaps their use of a short-action agent may be held responsible.

When general anesthesia is used, the addition of local anesthetic field blocks of the ilioinguinal and iliohypogastric nerves and/or subfascial and subcutaneous infiltration reduces early postoperative pain scores and the need for other analgesics [15–17, 74]. Omission of this step should be considered suboptimal care [75, 76]. Patients given GA do not differ in pain scores or analgesic consumption whether given inguinal field block before the surgical incision or after wound closure [77, 78].

In addition to the preoperative and intraoperative pain prevention and treatment methods above, non-opioid and nonsteroidal anti-inflammatory medications, NSAIDs and selective COX-2 inhibitors, can be used for postoperative pain management [15, 79–81]. However, these drugs should be used with caution in patients with previous gastrointestinal ulceration, asthma, renal failure, heart failure, or bleeding diatheses.

Paracetamol has insufficient effect as single-agent therapy for moderate to severe pain. However, the combination of paracetamol and a nonsteroidal anti-inflammatory drug, given in a timely manner, seems to be optimal and provides sufficient analgesic during the early recovery phase provided that there is no contraindication [82].

Opioids are frequently necessary and used routinely in some areas of the world.

Early Complications

The reported risk of urinary retention is usually around 3% [25]. Spinal anesthesia regularly results in urine retention which results in prolonged postoperative recovery [15, 24–29].

In large epidemiologic and consecutive series and several randomized clinical studies, the lowest risk of urinary retention has been obtained with local infiltration anesthesia amounting to 0–1% [4, 6, 15, 25–28] and without an increase in local surgical complications.

The risk of hematoma, infection, and other complications in relation to the anesthetic technique has not been accurately elucidated but is probably inconsiderable owing to the otherwise low morbidity rate associated with elective groin hernia repair.

Recovery

Postoperative side effects after groin hernia surgery such as nausea and vomiting, time to first meal, and daily activities are often related to anesthesia. Of 13 randomized studies comparing LA with GA and/or RA [7, 22, 26, 28, 43, 71–73, 83–88], 12 bear witness of faster discharge and faster short-term recovery with local. This held true for the length of postoperative hospital stay as well as for the number of unplanned overnight admissions. The main reason was greater postoperative pain, requiring opioid analgesics after RA and GA, and the large number of patients, especially in the RA group, with pronounced micturition difficulties necessitating catheterization. One study did not reveal any difference [88], but interpretation was hindered because of the use of large doses of sedatives and intraoperative and early postoperative potent, long-acting opioids, which often leads to unnecessary nausea, sedation, and discomfort. The few data available from other reports concerning postoperative recovery also reported advantages for LA [6, 15, 69].

Recurrence

Although complication rates are low and hernia recurrence rates lower in many reported series using LA, it is difficult to suggest that the anesthetic has a direct effect on the recurrence rate, which is governed so much by surgical and technical factors. The long-term outcome of hernia repair is generally assumed not to be affected by method of anesthesia used. However, the evidence on which this assumption is based is far from convincing. The few studies on the topic have rendered conflicting results [39, 89–92]. Moreover, information from most randomized trials is limited since follow-up periods are relatively short.

In a register study from Sweden where 59,823 hernia repairs were recorded [45], LA was found to be associated with a somewhat higher reoperation rate in primary hernia repair. No similar association was found after operations for recurrence. In a study on the effect of smoking, Sorensen et al. [93] accidentally found LA to carry a higher risk of recurrence than GA and RA combined. The Danish Hernia Database reported an increased reoperation rate after local anesthesia versus general or regional anesthesia after direct—but not indirect—hernia repair [46]. Kingsnorth et al. [91] found that the surgeon's personal experience was the factor that most strongly influenced recurrence.

This leads us to stress the importance of proper training before adopting the local anesthetic technique, which is quite easy to learn, but only successful if the surgeon handles the tissues gently and has patience. Since skill and experience seem to be of such great importance in LA, substandard results are likely to occur if surgeons use the technique without appropriate training.

Patient Satisfaction

Most reviews and case series as well as randomized trials indicate that LA has the edge on its rivals GA and RA. But for an operation to be entirely successful, the patients should be satisfied with all aspects of management and are hardly likely to be so if they consider themselves to have been exposed to more pain than was absolutely necessary. Data from randomized studies comparing the three anesthetic techniques have shown similar patient satisfaction. The total satisfaction rate of patients operated under LA varies between 80 and 96% [4, 6, 22, 43, 69, 70, 94–96]. The main reason for dissatisfaction with local seemed to be intraoperative pain and discomfort [6, 96]. A great majority of patients from all three groups was satisfied or very satisfied with their anesthesia, and the proportion of patients who would prefer the same kind of anesthesia in the future was similar among the three groups [22, 28, 85, 95, 96].

However, in a dedicated ambulatory unit undertaking inguinal hernia repair under unmonitored local anesthesia, 1000 patients were sent a questionnaire after the surgical intervention [6]. The questionnaire was returned by 940 patients of whom 124 expressed dissatisfaction with the local anesthesia, the day-case setup, or both. The primary reason for complaint by the patients was intraoperative pain (7.8%). This is a relatively high rate of dissatisfaction and suggests that the local anesthetic care pathway still has room for improvement in the intraoperative phase.

Patient preference in the choice of anesthetic cannot be discounted, and LA is only successful if the surgeon handles the tissues gently, has patience, and is fully conversant with the technique [42]. When these conditions are fulfilled, surgeons should be able to offer the patient painless surgery, which no doubt is crucial for patient acceptance. Insufficient local infiltration technique may be accompanied by the risk of insufficient analgesia and unacceptable anxiety, emphasizing the need for optional supplementary sedation or analgesia [6]. Halsted and Cushing noted over a 100 years ago that pain during surgery under LA depends entirely upon the surgeon's familiarity with the technique, an experience that is presumably still valid today [48]. However, the learning curve required to provide effective local anesthesia is short.

Costs

Ideally inguinal hernia repair should be performed using a simple and safe technique that is acceptable for the patient and easily mastered by the surgeon. The technique should carry a low morbidity risk and also be cost-effective. The latter aspect, cost-effectiveness, has so far attracted only slight attention, but scrutiny to ensure that limited healthcare resources are used rationally is of the utmost importance.

Cost comparisons for the anesthetic alternatives have given similar results. LA provides cost advantage over both RA and GA, regarding both total intraoperative and postoperative costs [22, 97–100]. Of three randomized controlled trials [22, 88, 100], two found local to be cheaper than both GA and RA [22, 100], while one observed no major difference between LA and GA [88]. The probable explanation is that in the latter trial (O'Dwyer), all operations were performed on an in-patient basis with a mean hospital stay of 3 days. In day-case surgery, prolonged hospital stay after groin hernia surgery is often due to the effects of anesthesia. It follows that for cost-saving purposes, the avoidance of such side effects is of crucial importance. Shorter total theater time, earlier discharge, and to some extent, anesthetic equipment requirements were the main factors for the great difference in total costs.

Conclusions

Either general, regional, or local anesthesia is suitable for open groin hernia repair. The available scientific data support the use of local anesthesia. A great majority of randomized studies comparing the anesthetic techniques bear witness to advantage for local anesthetic such as less postoperative pain, less anesthesia-related complaints, less micturition difficulties, faster discharge, faster short-term recovery, and fewer costs. However, when surgeons inexperienced in its use administer local anesthesia, more hernia recurrences might result.

The knowledge of the benefits of LA has not been translated into general practice. There seems to be a discrepancy between existing scientific data and clinical practice. This may be due, in part, to patient preferences to undergo GA rather than either RA or LA.

The development of new short-acting intravenous general anesthetics (propofol, remifentanil) may be a valid alternative to local infiltration anesthesia alone, as the former can be combined with intraoperative local infiltration anesthesia for early postoperative pain relief.

Regional anesthesia especially when using high dose and/or long-acting agents seems to have no documented benefits in open inguinal hernia repair and increases the risk of urinary retention, prolonged recovery, and delayed discharge.

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7 Prostheses and Products for Hernioplasty

Karl A. LeBlanc

Introduction

The use of prosthetic biomaterials in the repair of hernias of the abdominal wall is now very commonplace throughout the world. In the USA over 95% of all inguinal and ventral hernias are repaired with a prosthetic material or device and some countries are also beginning to approach this figure. In other parts of the world, this is not the case. Limitations on the use of these products include a natural reluctance to place a biomaterial into a primary hernia or the cost of these products. Increasing usage of these products has increased due to the fact that recurrence rates are markedly decreased with their use (this is described in other chapters in this text).

Incisional hernias will develop in at least 13% and perhaps as many as 20% of laparotomy incisions. The risk of herniation is increased by fivefold if a postoperative wound infection occurs. Other factors that predispose to the development of a fascial defect include smoking, obesity, poor nutritional status, steroid usage, etc. While some of these may be avoided, those patients that are found to have such a hernia can present difficult management problems due to the high potential for recurrence. It has been known for many years that without the use of a prosthetic material, the recurrence rate for ventral hernia repair is as high as 51% [1]. The use of a synthetic material will reduce this rate to 10–24% [2]. While these publications are older, they are still relevant in today's management of hernia repair. Recent data still reveals a recurrence rate of 17.1% without the use of mesh, 12.3% with open mesh repair and 10.6% with laparoscopic mesh repair [3].

The laparoscopic repair of incisional and ventral hernias was first performed in 1991 using the Soft Tissue Patch made by W.L. Gore and Associates (Elkhart, DE, USA) [4]. The recurrence rate that has been reported in other recent literature varies from 0–11% but averages approximately 5.5%. The "ideal" prosthetic product has yet to be found. The hernia that is being repaired and the status of the patient into which this material will be placed should dictate the type of material that will be chosen. This chapter will identify these goals and the properties of the various biomaterials that are on the market today.

There are several hundred different products that can be used in the repair of inguinal, ventral, incisional and other hernias of the abdominal wall. In many of the products listed below there is a paucity of published literature that verifies the claims that are made by the manufacturers. It is very difficult to find Level 1 studies that evaluate the success or failure of the respective materials. While this is the situation at the time of the production of this textbook, the reader is advised to reference the available journals to identify the uses and results of these materials. Much of the information discussed was obtained from the respective manufacturer directly but not in all cases. Therefore, the reader should reference the particular manufacturer for in-depth information that cannot be provided in this text.

Indications for Use of Prosthetic Materials

Surgeons recognize that the main purpose in the use of these materials will be the repair of a fascial defect in the abdominal wall. The main indications of use of the materials are listed in Table 7.1.

Musculofascial tissue strength can be lost in a variety of ways. The most common, of course, would be due to the external etiology of the weakness that develops after a laparotomy or other abdominal incision that is larger than that of the 5 mm laparoscopic trocar (although even this small incision can rarely develop a hernia). Another example would be the loss of tissue with trauma such as gunshot wounds and/or treatment with an open abdomen. The increase of intra-abdominal pressure that results from sig-

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Table 7.1 Indications for prostheses

Replacement of lost musculofascial tissue caused by:
Trauma
External
Internal
Infection
Reinforcement of native tissue weakness
Aging (laxity of tissues)
Neurological deficit (denervation)

nificant weight gain will result in an internal source of weakening of the abdominal wall musculature. Poor nutrition and/or protein malnutrition are also sources of such problems. Other pre-disposing factors such as emphysema or the chronic bronchitis of individuals that smoke tobacco products result in a constant increase in intra-abdominal pressure because of a frequent cough. Life-threatening infections such as fasciitis and gangrene will produce large areas of necrosis and resultant tissue loss. More frequently, the development of a postoperative wound infection will increase the risk of herniation by as much as five times. In fact, almost 30% of patients that develop a postoperative incisional wound infection will eventually develop an incisional hernia [5]. Modern needs of patients have resulted in the development of products that are not permanent such as biologic meshes or synthetic products that resorb over varying lengths of time.

The effects of aging and the declining ability of the elderly patients to repair the native tissues will lead to the loss of fascial integrity. This is commonly seen with the direct inguinal hernia. It also occurs with the enlargement of the linea alba that is referred to as diastasis recti. These latter defects can enlarge and occasionally become symptomatic, requiring repair. The disruption of collagen that is seen by the effects of smoking will have a similar effect (i.e., metastatic emphysema).

The most common defect that results from a denervation phenomenon follows the flank incision that is utilized in a nephrectomy, lumbar sympathectomy, or an anterior approach to the lumbar interbody fusion for degenerative disc disease. In these entities, there is no defined fascial edge that is seen with the more common anterior abdominal wall defects. This is due to the broad surface of the denervated musculature that has intact fascia but lacks the reinforcement of healthy muscle tissue. These are very challenging to repair and such methods are described elsewhere in this textbook. Mesh materials are necessary for these problems to assure as durable a repair as feasible.

Prosthetic Materials: History

The use of materials for the repairs of hernias can be found in antiquity. It is believed that Heliodorus used cellulose from a cotton or flax plant to effect scarification in the inguinal area to treat herniation in A.D. 25. The use of silver as a synthetic prosthesis was reported in 1900 [6]. Metallic biomaterials have also included the use of tantalum gauze mesh and stainless steel mesh. None of these materials gained wide acceptance because of the complications that were associated with their usage. These included lack of pliability, seroma development, wound infection, fatigue fractures, herniation through the fracture sites, abnormal scarification, adhesions, loss of structural integrity, and allergic reactions. Re-operation in these patients was particularly challenging.

Table 7.2 Natural prosthetic products

Autogenous dermal grafts	Whole skin grafts
Dermal collagen homografts	Porcine dermal collagen
Autogenous fascial heterografts	Lyophilized aortic homografts
Preserved dural homografts	Bovine pericardium

Table 7.3 Nonmetallic synthetic products

Fortisan fabric (cellulose)	Polytetrafluoroethylene
Polyvinyl sponge	Polypropylene mesh/gelatin film
Polyvinyl cloth	Polyester-reinforced silicon sheeting
Nylon mesh	Silastic
Carbon fiber	Polyester (as a solid sheet)
Silicon-velvet composite	Carbon fiber

Natural prostheses were considered as myofascial replacement shortly after the use of silver filigree [7]. Other materials that have been used are listed in Table 7.2.

These materials were used with good results in some cases but scarcity and cost limited their widespread adoption. Additionally, there were concerns of viral transmission as one case of Creutzfeldt-Jacobs disease developed in a patient that had the use of a dural homograft. The development of other synthetic biomaterials that were closer to the ideal prosthesis hastened the demise of the use of these products in the past. As we now have seen over the last several years, some of these products have seen resurgence. Updated methods of processing these products have allowed for improved safety and efficacy resulting in an expansion of their use. The use of these biological products is still undergoing careful scrutiny for the most appropriate application of these expensive materials.

A series of nonmetallic synthetic prosthetic biomaterials were used as well (Table 7.3). As with the metal materials, there were significant disadvantages with these products also. These included infections, sinus tract formation, alteration of the product in vivo, and lack of incorporation into the native tissues. The use of the carbon fiber in humans has never been attempted because of concerns of potential carcinogenicity (although it functioned fairly well in the experi-

Table 7.4 Ideal characteristics of synthetic products

No physical modification by tissue fluids	Chemically inert
Does not incite inflammatory or foreign body reaction	Does not produce allergy or hypersensitivity
Noncarcinogenic	Resistant to mechanical strains
Can be fabricated to the form required	Sterilizable

Table 7.5 Ideal surgical clinical characteristics of synthetic products

Permanent repair of the abdominal wall (i.e., no recurrences)
In-growth characteristics that result in a normal pattern of tissue repair and healing
No alteration of the compliance of the abdominal wall musculature
Lack of adhesion predisposition
Cuts easily and without fraying
Inexpensive
Lack of long-term complications such as pain or fistualization

mental model). With some of these materials, newer hernia repair products have used these materials again because of more modern manufacturing capabilities.

All of these biomaterials were attempting to address the "ideal characteristics" that were promulgated by Cumberland and Scales [8, 9]. While it is widely felt that the ideal material has yet to be found, these criteria are the goals that are sought by the manufacturers (Table 7.4).

While the clinical uses of these prosthetic materials share these considerations, the operating surgeon does, in fact, desire slightly different priorities in the use of the prosthesis within his or her individual patient. Disregarding the obvious need to be non-carcinogenic, the clinical characteristics of the "ideal surgical" material are listed in Table 7.5.

Biologic prostheses are based upon the use of porcine, bovine, or cadaveric tissues to produce a collagen matrix. These materials are not truly absorbable as they are intended to provide a scaffold for the native fibroblasts to incorporate natural collagen to repair a fascial defect. It is the goal of these devices to repair the hernia defect with the tissues of the patient as these will be degraded and replaced over time.

The synthetic prosthetic materials can be divided into the absorbable and non-absorbable products. The synthetic non-absorbable materials are of many types, sizes, and shapes. The use of these products is commonplace in the repair of virtually all hernias. There has been an increase in the number of synthetic absorbable products over the last several years. More recently there are hybrid products that include both absorbable and non-absorbable layers. These attempt to capitalize on the attributes of both of these technologies.

The materials that are presented below are given in an arbitrary arrangement and with as accurate information that could be obtained. An effort was made, however, to stratify these products in a classification that grouped similar products together. I have attempted to identify all of the currently available products that are used in most parts of the world at the time of publication. Some of these materials have either no published clinical data or scant information as to the clinical performance characteristics. Therefore, it is certain that some products and/or details have been overlooked despite my efforts to present all that I could identify. Due to the very large variation in the sizes of the products, little comment regarding the sizes of these products will be given. The reader is referred to the respective manufacturer for these details. It should also be noted that not all of these products are available in all countries. Manufacturers have limited the release of many of them to only selected areas of the world or have not obtained the necessary governmental approvals for clinical distribution at the time of this writing. Finally, it is certain that all of the available products are not included in this compilation or that some of those listed are no longer available due to the lag in this research and actual publication. Many companies are quite small and/or have limited distribution. Therefore, if any of these that are not included it was not because of an intended omission but rather a lack of obtainable information.

Absorbable Prosthetic Biomaterials

The general purpose of these is the temporary replacement of absent tissue (Table 7.6). The strength of these materials and the lack of permanency make some of them unsuitable for the permanent repair of any hernia. The newer research has suggested that this materials might be preferred in some circumstances rather than a true biologic. This may be due to the fact that biologics require degradation then rebuilding of the collagen of the patient's fascia. These materials do not require the extent of cellular degradation that true biological

Table 7.6 Absorbable products

Bio-A, W. L. Gore & Associates, Elkhart, DE
Bio-A Hernia Plug, W. L. Gore & Associates, Elkhart, DE
Dexon, Medtronic, Minneapolis, MN, USA
Safil Mesh, B. Braun Surgical, Germany
TIGR mesh, Novus Scientific Pte Ltd, Singapore
Phasix mesh, CR Bard, Providence, RI, USA
Phasix mesh Plug and Patch, CR Bard, Warwick, RI, USA
Phasix ST mesh, CR Bard, Providence, RI, USA
Vicryl (knitted) mesh, Ethicon, Inc., Somerville, NJ, USA
Vicryl (woven) mesh, Ethicon, Inc., Somerville, NJ, USA

materials require and seem to progress to reconstructive metabolism more rapidly. This is an area of ongoing research. Clinical usage will be dependent upon the longevity of the material that is sought by the surgeon.

Bio-A, *Phasix*, and *TIGR* meshes represent a somewhat newer concept in synthetic materials. This field of materials perhaps represents part of the next phase of mesh development. As will be seen below, combination products have now been developed with a permanent backbone and the absorbable materials listed here. The *Bio-A* product is supplied in flat sheets (Fig. 7.1). It is made of trimethylene carbonate and polyglycolic acid. It will maintain approximately 70% of its tensile strength for 21 days. It serves as a scaffold to allow for fibroblastic infiltration and replacement by the patient's native collagen. Recent studies have shown efficacy for complex situations [10]. It can be used in inguinal, incisional, and hiatal hernia repair. The latter is specifically configured for that use. This material is also configured into the *Bio-A Hernia Plug* (Fig. 7.2). This configuration can be used in the groin, umbilical or ventral hernia repair.

Fig. 7.1 Bio-A

Fig. 7.2 Bio-A hernia Plug

Safil Mesh is a warp-knitted polyglycolic acid material that will retain 50% of its strength at 20 days and is totally resorbed in 60–90 days (Fig. 7.3). It is used to strengthen the closure of the abdominal and chest walls. The above photo also shows the bags into which this material is also shaped for use in splenic preservation.

Phasix is composed of poly-4-hydroxybutyrate (P4HB). This is produced from by-products of E. coli metabolism (Fig. 7.4). It is degraded by hydrolysis and hydrolytic enzymatic processes. The absorption of the material is minimal until about 26 weeks post-implantation and is essentially complete in about 52 weeks. The Phasix has been configured into a plug similar to the Perfix plug and patch (Fig. 7.5). Its use is similar to that device except that

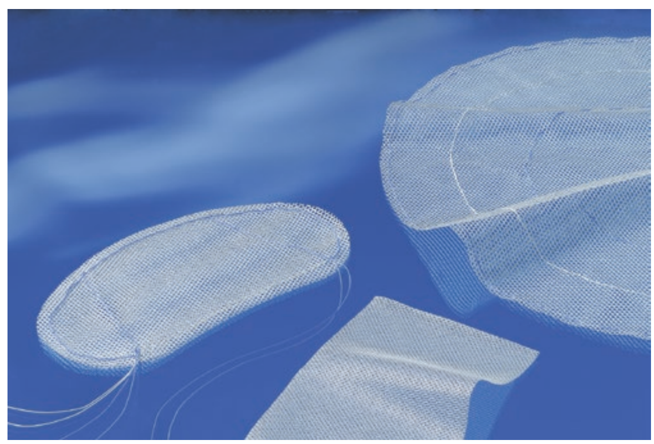

Fig. 7.3 Safil mesh

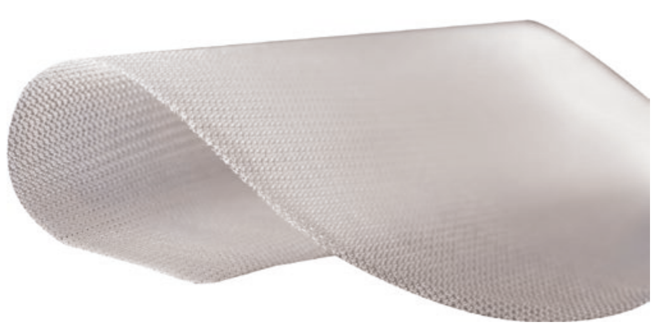

Fig. 7.4 Phasix

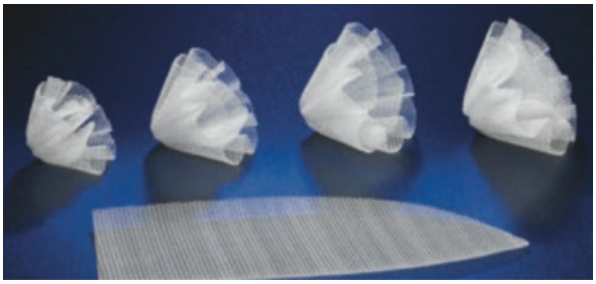

Fig. 7.5 Phasix plug and patch

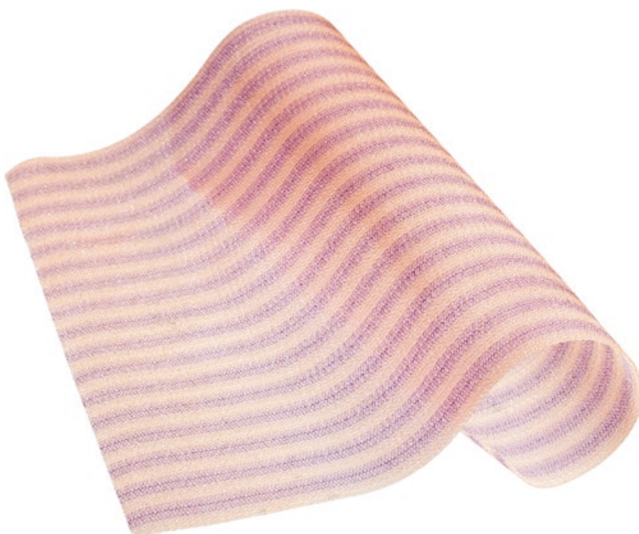

Fig. 7.6 Phasix ST

it is not permanent. The flat mesh is also available with a barrier coating of carboxymethylcellulose and hyaluronic acid as Phasix ST (Fig. 7.6). This product is placed in the intraperitoneal position against the intestine. There are many investigations that are ongoing to learn the unique properties of this product.

TIGR Matrix Surgical Mesh is knitted from two different synthetic resorbable fibers, polyglycolic acid and polylactic acid (Fig. 7.7). The Matrix is warp-knitted in a proprietary way, allowing it to gradually degrade over time. The strength of the Matrix is comparable to conventional mesh implants for the initial 6–9 months following implantation. The first fiber (polyglycolic acid) appears to lose its functional capabilities in 2 weeks while the second fiber (polylactic acid) maintains its strength for approximately 9 months.

The *Vicryl* and *Dexon* meshes are primarily polylactic acid (Figs. 7.8 and 7.9). The Vicryl is available in a knitted or woven configuration as noted in the figure. These products can be affixed onto the fascia directly with sutures but are not

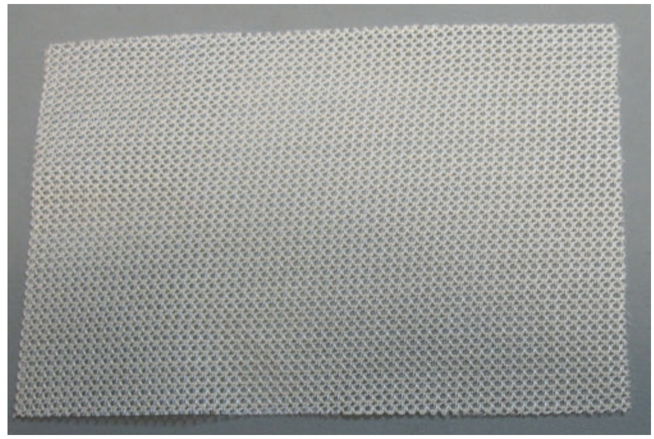

Fig. 7.7 TIGR matrix surgical mesh

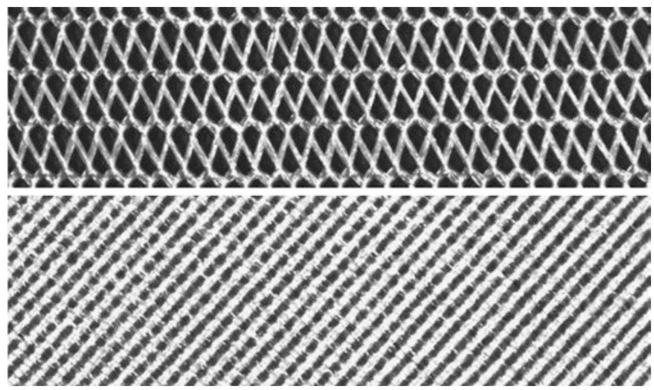

Fig. 7.8 Vicryl knitted (upper) & woven (lower) (Image courtesy of Ethicon, Inc.)

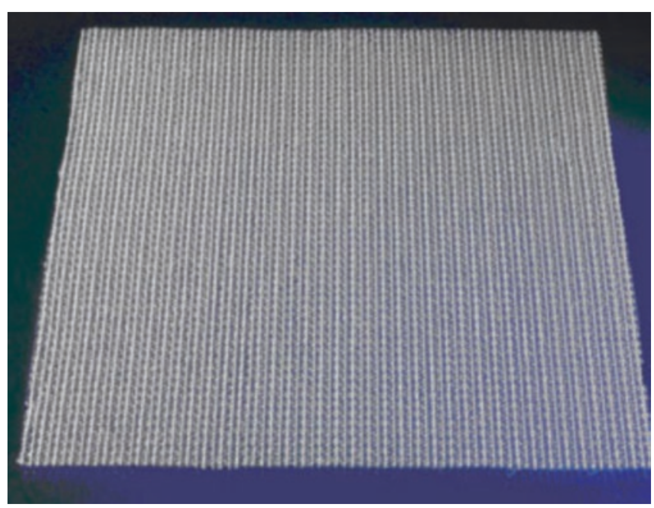

Fig. 7.9 Dexon mesh (All rights reserved. Used with Permission of Medtronic)

Biologic Products

As noted earlier, these products do not represent a new concept in hernia repair. They are marked improvement of the materials developed earlier in the last century. They are based upon a harvested collagen matrix that is manufactured into sheets of tissue-engineered materials that can be used to repair defects in the abdominal wall. The concept of these materials is that the biologic material will allow the migration of the patient's own fibroblasts onto them so that collagen will be deposited to form a "neo-fascia." For the most part, these are used in open techniques but there has been some usage in laparoscopic methods especially in the repair of hiatal hernias.

There are similarities of all of the biologic products. They are the most expensive of all prosthetic materials that repair or replace the abdominal wall fascia. They are all harvested from an organism that was once alive. The source will dictate the size of the material and in most cases, the thickness of the product. The thickness will be variable in nearly all of them. Some manufacturers have found creative techniques to increase the size of the materials available. All of the products are processed to eliminate all cellular and nuclear material as well as any prions. Following this, another process can be applied to crosslink the collagen at the molecular level. There is only one product that is currently cross-linked as discussed below. The final stage is the sterilization of the prosthesis. It is beyond the scope of this chapter to cover all of these in detail. However, it should be considered, when using any of these materials, that the processing plays a large part into the characteristics and the clinical behavior of them post-implantation.

In general, the biologic products were introduced for use in contaminated fields such as a synthetic mesh infection. While they can be used in this manner, it is recommended that the wound should not possess gross pus as the collagenases of some bacteria and inflammatory cells can degrade these products. These products are sometimes used in the repair of very complex non-infected hernias as well. One concern will be that if the patient possesses an undiagnosed collagen deficiency disorder, the remodeling of these products will not occur properly, leading to a predictable failure of the repair. It has also been learned over the last few years that these products perform best if they have direct contact with some type of vascularized tissue. Intuitively, if the expectation of these biologic scaffolds to become infiltrated by fibroblasts and subsequent collagen deposition, blood supply will deliver these cells more rapidly. Consequently, a higher failure rate will be noted if a biologic prosthesis is used as a "bridge" between fascial edges. It is recommended that if a bridge is unavoidable, then use of the peritoneum of the hernia sac can provide a source of vascular supply.

Bovine Products

The bovine products are from dermis or pericardium (Table 7.7). Only the *SurgiMend* is fetal (dermal) tissue (Fig. 7.10). As shown in the figure, it is available in four different sizes. The associated numbers are the thickness of the four different products in millimeters. *SurgiMend-e* is specifically designed for ventral hernia repair (Fig. 7.11). It is elliptical in shape, perforated and available in 3 mm or 4 mm thicknesses. *SurgiMend MP* is similar to the former product in that it is available in four different thicknesses but is also perforated over its entirety (Fig. 7.12).

Tutomesh and *Tutopatch* are of the same source (pericardium) and are processed in the same manner (Figs. 7.13 and 7.14). The only difference in these two is that the Tutomesh is perforated while Tutopatch is not. *Veritas* is also pericardium and does not require rehydration

Table 7.7 Bovine biologic prostheses

SurgiMend 1.0,2.0,3.0,4.0, Integra LifeSciences, USA
SurgiMend-e, Integra LifeSciences, USA
SurgiMend MP, Integra LifeSciences, USA
Tutomesh, RTI Biologics, Alachua, FL, USA
Tutopatch, RTI Biologics, Alachua, FL, USA
Veritas, Baxter Healthcare Corporation, Deerfield, IL USA

Fig. 7.10 SurgiMend 1.0–4.0

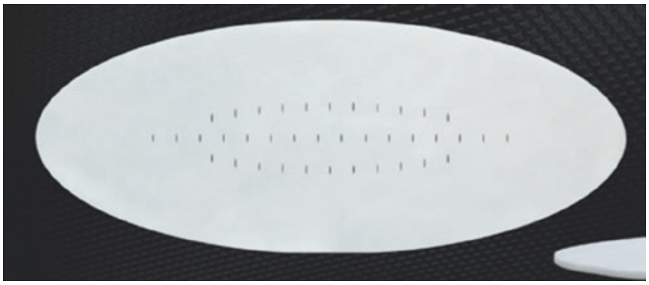

Fig. 7.11 SurgiMend-e

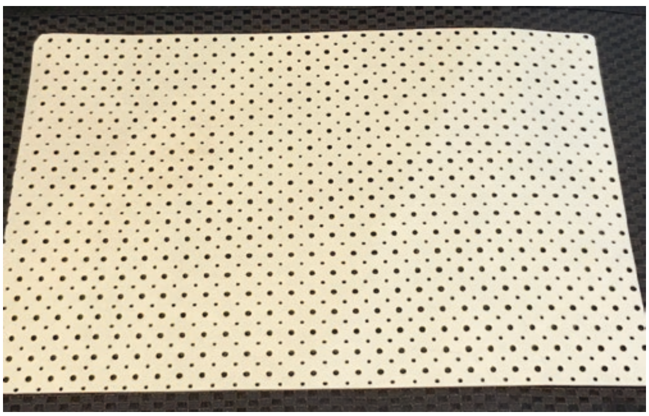

Fig. 7.12 SurgiMend MP

(Fig. 7.15). The use of all of these bovine products has generally been limited to the incisional hernia repair. However there has been increasing application in the repair of hiatal hernias.

Cadaveric Products

The human cadaveric products have a long history (Table 7.8). There is significant variability in the amount of stretch that each of these will undergo either at the time of implantation or subsequent to the procedure. This stretch varies from product to product and should be accounted for at the time of implantation. These products are not cross-linked and require rehydration. These are also used in the repair of hiatal hernias. *AlloMax* Surgical Graft is 0.8–1.8 mm thick (Fig. 7.16). *Cortiva* and *Cortiva 1 mm* are similar materials that are in two different thicknesses. *Cortiva* is thicker at 1.3 mm (0.8–1.8 mm) and

Fig. 7.13 Tutomesh

Fig. 7.14 Tutopatch

Fig. 7.15 Veritas

Cortiva 1 mm is 1 mm (0.8–1.2 mm) (Fig. 7.17). *DermaMatrix* is used for hernia repair but is additionally used for purposes other than hernia repair (Fig. 7.18). It is available in thicknesses of 0.2–0.4 mm, 0.4–0.8 mm, 0.8–1.7 mm, and ≥1.8 mm. It is notched so that if the notch is in the upper left the epidermal side (basement membrane) is facing up. It is recommended that the dermal side be placed against vascularized tissue. *Flex HD Structural* is available in a thick version (0.8–1.7 mm) or an Ultra Thick version (1.8–4 mm). The Musculoskeletal Transplant Foundation produces the latter two products (Fig. 7.19).

Porcine Products

There are a number of these materials that are available (Table 7.9). Depending on the manufacturer, they are in different sizes and shapes and construction. Some are laminated, some are cross-linked, some are perforated, some require rehydration and others do not. These are specific to the product and it is recommended that the user follow the instructions for use (IFU) that is provided with each product.

BioDesign Hernia Grafts are three products that are designed for the repair of specific hernias, ventral, inguinal, and hiatal (Figs. 7.20, 7.21, and 7.22). They are all developed from porcine small intestinal submucosa and are the only products with such a source. These are laminated, sewn together, and fenestrated. These must be rehydrated. *Cellis* is porcine dermal collagen and is available in many sizes and different thicknesses (Fig. 7.23). It also requires rehydration. *Fortiva* originates from dermis but does not require hydration (Fig. 7.24). *Gentrix Surgical Matrix* is also a laminated product. It is unique in this biologic category as it is the only one that is made from the urinary bladder of the pig. All of these

Table 7.8 Cadaveric biologic prostheses

AlloMax, Davol, Inc., Warwick, RI, USA
Cortiva, RTI Surgical, Alachua, FL, USA
Cortiva 1mm, RTI Surgical, Alachua, FL, USA
DermaMatrix, Synthes CMF, West Chester, PA, USA
FlexHD STRUCTURAL, Ethicon, Inc., Somerville, NJ, USA

Fig. 7.16 AlloMax

Fig. 7.17 Cortiva

Fig. 7.18 DermaMatrix

Fig. 7.19 Flex HD structural (Image courtesy of Ethicon, Inc.)

products have a notch to identify the correct positioning of the material. If the notch is placed in the upper top outside corner, then the basement membrane is facing up. The membrane should be placed away from the defect according to the product literature. *Gentrix* is available as *RS* (two ply), *PSM* (three ply), *PSMX* (six ply), or Plus (8 ply), (Figs. 7.25, 7.26, 7.27, and 7.28). *Permacol* is a dermal collagen based product that is the only material listed that is cross-linked and does not require rehydration (Fig. 7.29). It is known to be present for a prolonged period of time due to the cross-linkage of the collagen fibers. It is available in thicknesses of 0.5, 1.0, and 1.5 mm.

Table 7.9 Porcine biologic prostheses

Biodesign, Cook Surgical, Inc., Bloomington, IN, USA
Cellis, Meccellis Biotech, La Rochelle, France
Fortiva, RTI Biologics, Alachua, FL, USA
Gentrix Surgical Matrix, ACell, Columbia, MD, USA
Permacol, Medtronic, Minneapolis, MN, USA
Strattice RTM, Acelity, San Antonio, TX, USA
XenMatrix, Davol, Inc., Warwick, RI, USA
XenMatrix AB, Davol, Inc., Warwick, RI, USA
XCM Biologic Tissue Matrix, Ethicon, Somerville, NJ, USA

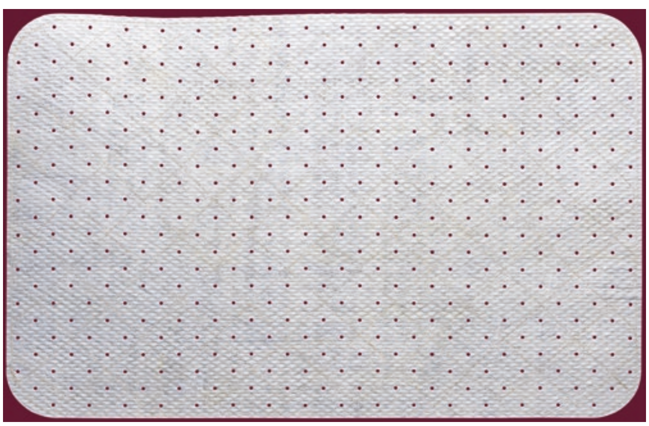

Fig. 7.20 Biodesign hernia graft

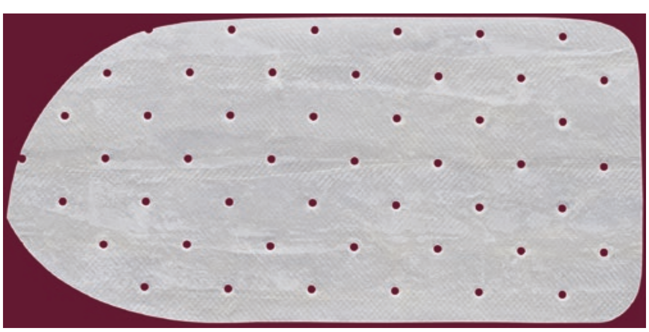

Fig. 7.21 Biodesign inguinal hernia graft

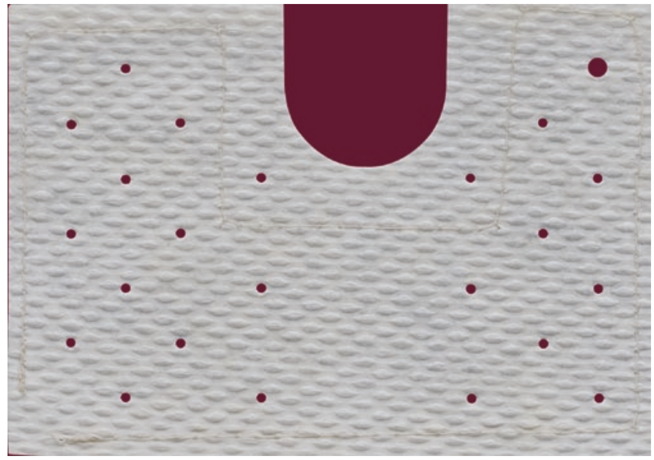

Fig. 7.22 Biodesign hiatal hernia graft

Fig. 7.23 Cellis

Fig. 7.24 Fortiva

Strattice Reconstructive Tissue Matrix (RTM) is available in two thicknesses, firm and pliable. It is made from dermis and does require rehydration. It is available many sizes, which depend upon which version is selected. These versions include a pliable and pre-shaped pliable, a firm (Fig. 7.30), a laparoscopic (Fig. 7.31), and a perforated version (Fig. 7.32). The Strattice Firm has a thickness 1.76 ± 0.012. The selection will depend on type of hernia to be repaired and the area to be covered. *XenMatrix* is also dermal based and is not cross-linked (Fig. 7.33). It does require rehydration but not refrigeration. It is one of the thickest porcine biologics due to its 1.95 ± 0.012 measure-

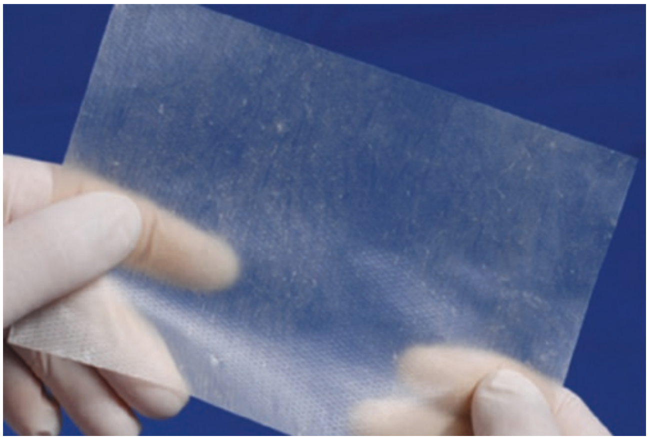

Fig. 7.25 Gentrix RS

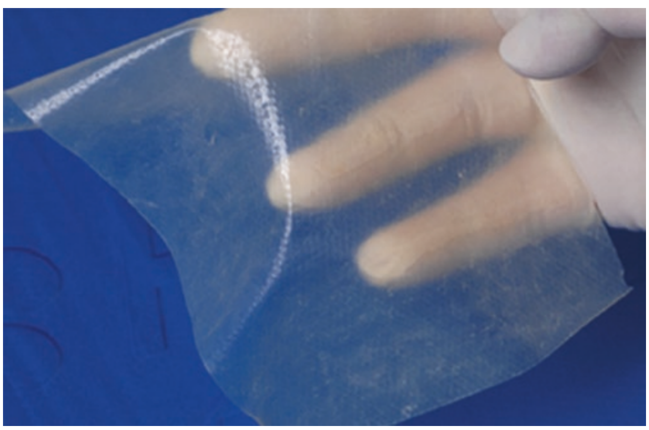

Fig. 7.26 Gentrix PSM

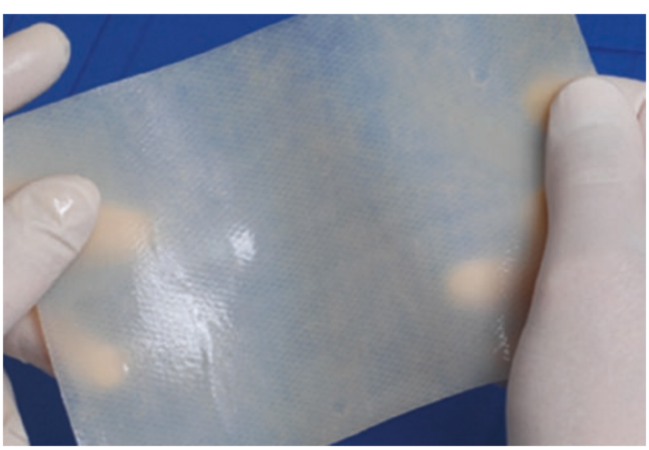

Fig. 7.27 Gentrix PSMX

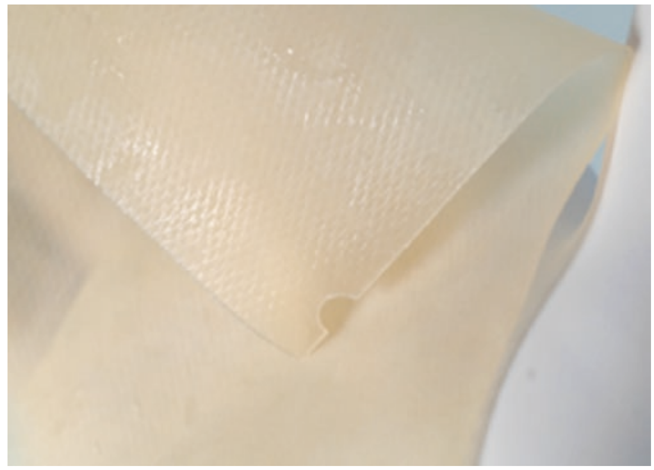

Fig. 7.28 Gentrix plus

Fig. 7.29 Permacol (All rights reserved. Used with Permission of Medtronic)

ment. It has recently been modified to contain the antimicrobials, rifampin and minocycline, which are present for over 7 days. *XenMatrix AB* has a distinct orange color due to the presence of the rifampin (Fig. 7.34). It is unique in all of the biologic materials in that it contains antimicrobial agents. *XCM Biologic Tissue Matrix* is also a non-cross-linked porcine dermal product and does not require rehydration (Fig. 7.35). It is approximately 1.5 mm thick (±0.3 mm).

Hybrid Products

This is a relatively new concept in mesh development. There are clear reasons to use a permanent material in the repair of fascial defects. There are real reasons to consider the use of products that are not permanent but seek to increases the levels of collagen deposition to enhance the healing process. These materials seek to capitalize on the benefits of both of these concepts (Table 7.10). There is relatively little data on

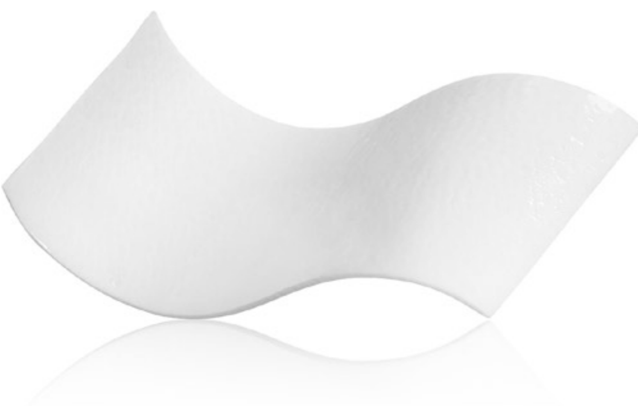

Fig. 7.30 Strattice firm

Fig. 7.31 Strattice laparoscopic

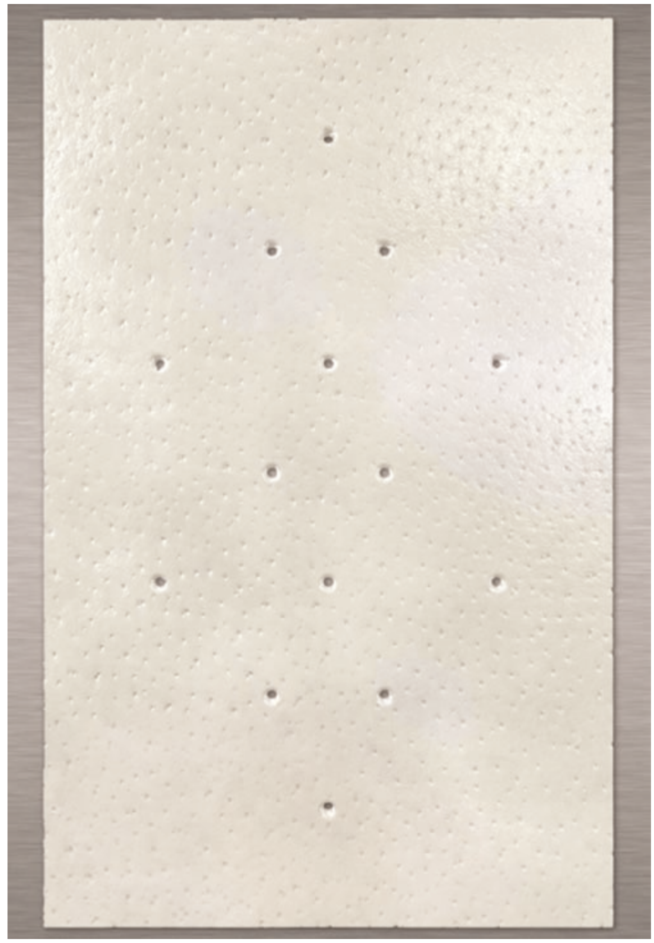

Fig. 7.32 Strattice perforated

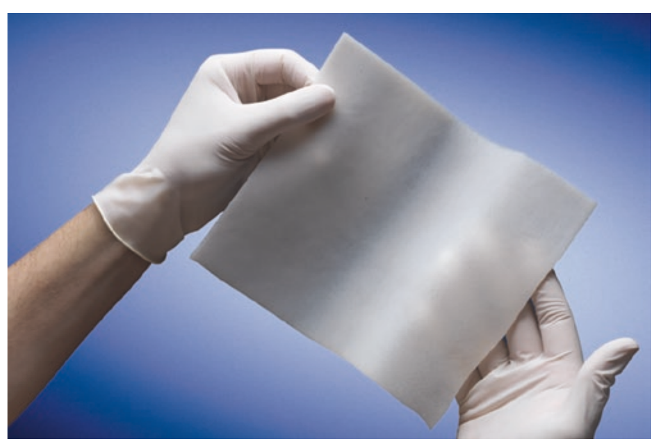

Fig. 7.33 XenMatrix

Fig. 7.34 XenMatrix AB

Fig. 7.35 XCM (Image courtesy of Ethicon, Inc.)

Table 7.10 Hybrid products

OviTex, OviTex 1S, Ovitex 2S, Permanent, TelaBio, Malvern, PA, USA
OviTex, OviTex 1S, Ovitex 2S, Resorbable, TelaBio, Malvern, PA, USA
Synecor, W. L. Gore & Associates, Elkhart, DE, USA
Zenapro, Cook Medical, Bloomington, IL, USA

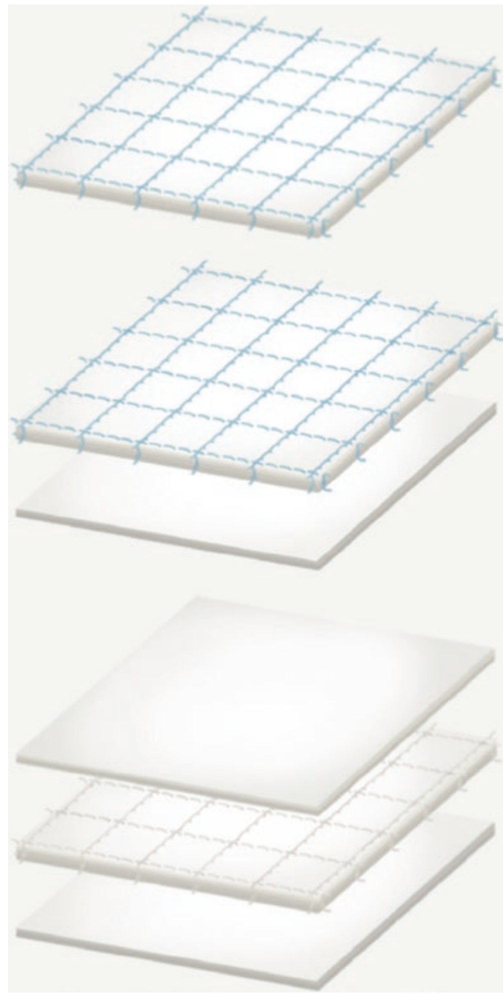

Fig. 7.36 OviTex, 1S, 2S (polypropylene)

the actual results of the use of these materials but these data will undoubtedly be researched in the future.

OviTex, OviTex 1S, and *2S* are the most recent additions to these class of meshes (Fig. 7.36, upper). They are a combination of ovine gastric submucosal extracellular matrix and embedded polypropylene or polyglycolic acid. There is a four-layer core of this matrix in the *OviTex* version. *OviTex 1S* has an additional two layers of matrix on one side *and* the *OviTex 2S* has the core plus two layers on both sides of the product (Fig. 7.36, middle & lower). Because of these differing designs, the thickness varies from 0.9 mm to 1.1 mm to 1.6 mm. The absorbable component option makes it the only biologic hybrid option with such a concept. The non-biologic portion is constructed with 6 mm pores. These figures are of the permanent component option. The resorbable polymer option is clear and will not be seen. Both *OviTex 1S* and *OviTex 2S* can be placed with visceral contact.

Synecor has combined some older materials together (Fig. 7.37). The internal permanent material is polytetrafluoroethylene. This is woven into a structure that is similar to other macroporous materials and is not the same as ePTFE. This is sandwiched between two types of polyglycolic acid/trimethylene carbonate (PGA/TMC). The parietal surface is similar to the Bio-A that is described above (Fig. 7.37, right). The visceral (tissue-separating) side is PGA/TMC and is a different structural weave which is quite tight to prevent ingrowth (Fig. 7.37, left). This material can be used either dry or wet.

Zenapro is the oldest of these three products (Fig. 7.38). It is a combination of the small intestinal submucosa that is found in the BioDesign materials described above. It has two layers of the submucosa on one side and four on the other and is perforated, unlike the other two hybrid products. Between these two layers is a large pore (5 mm) polypropylene mesh. It is not indicated in contaminated fields and requires rehydration. There is a rough and a smooth side with the rough side going against the abdominal wall in the repair of a hernia. The Instructions for Use state "The liberal use of transfascial sutures is recommended. Tacking devices alone may not provide adequate fixation to prevent recurrence."

Fig. 7.37 Synecor

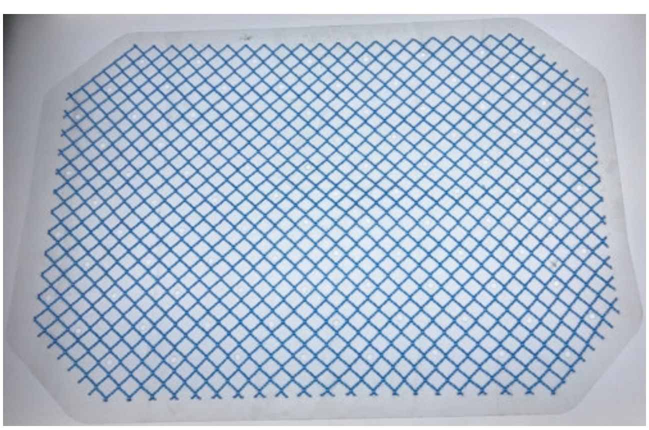

Fig. 7.38 Zenapro

Flat Prosthetic Products

The currently available products in use today are polypropylene (PP), polyester (POL), polytetrafluoroethylene (PTFE), expanded PTFE (ePTFE), or condensed PTFE (cPTFE). All are available in a variety of sizes and can be cut to conform to the dimensions that are necessary. There are currently so many products on the market today that it is quite difficult to become well versed in all of these materials. In fact, the similarities of these materials may result in many of them to be considered a "commodity" type of a product, whereupon only the pricing of the material will influence the use of it. The most prominent and commonly used are PP materials (Table 7.11). These, typically, can be used either in the open or laparoscopic applications (if not exposed to the viscera). Because of the complexities of pore sizes and the multitude of differing weights and shapes of the PPM within each of these materials, this chapter could not expound upon all of them. The reader is referred to the manufacturer for further information in the exact densities, weights, and pore sizes of these products.

The *2D* products are available in a variety of products and weights. The *2D PPT Std* and the *2D PPT LW* are both knitted and differ in the weight and pore size. The former is heavy weight while the latter is medium weight and more macroporous. The 2D PPNT is a non-woven PP material that is available in three different weights and thicknesses (Fig. 7.39). These meshes are configured in a variety of shapes and sizes as shown.

Basic mesh is a lightweight mesh (Fig. 7.40). Di.pro has developed an ultra lightweight version that is called *Basic Evolution* mesh (Fig. 7.41). *Bard Mesh* is probably the oldest flat sheet of heavy weight polypropylene in existence, having been brought to market in the early 1960s (Fig. 7.42). It is still in use today and like many of these prostheses, a lightweight and more macroporous version has been developed, the *Bard Soft Mesh* (Fig. 7.43). *Biomesh P1* (Fig. 7.44) is the standard weight material compared to the *Premium* (Fig. 7.45). It is available for extraperitoneal placement in various shapes and sizes to accommodate open or laparoscopic inguinal and ventral hernias. *Bulev B* and *Bulev UL* are somewhat similar to the Basic and Basic Evolution meshes discussed above (Figs. 7.46 and 7.47). The weights of the Bulev products are 48 gm/m^2 and 39 gm/m^2, respectively. They are different in that they possess blue lines to differentiate them from the other meshes and aid in positioning of the product.

DynaMesh comes in two weights; the standard is twice the weight of the lightweight product (Fig. 7.48). *Easy Prothes* is available as a heavy weight material (90 g/m^2), two medium products (70 and 60 g/m^2), and a lightweight version (40 g/m^2). Figures 7.49, 7.50, 7.51, and 7.52 detail the differences in the weaves of the products. Figures 7.53 and 7.54 compare the medium and lightweight versions. The *Hertra 0* mesh is designed only for use in the open repair of inguinal hernias,

Table 7.11 Flat polypropylene products

2D PPT Std, Microval, Saint-Just-Malmont, France
2D PPT LW, Microval, Saint-Just-Malmont, France
2D PPNT, Microval, Saint-Just-Malmont, France
Basic mesh, Di.pro Medical Devices, Torino, Italy
Basic Evolution mesh, Di.pro Medical Devices, Torino, Italy
Bard mesh, Davol, Inc., Warwick, RI, USA
Bard Soft mesh, Davol, Inc., Warwick, RI, USA
Biomesh P1, Cousin Biotech, Wervicq-Sud, France
Bulev B, Di.pro Medical Devices, Torino, Italy
Bulev UL, Di.pro Medical Devices, Torino, Italy
DynaMesh PP-Standard, FEG Textiltechnik mbH, Aachen, Germany
DynaMesh PP- Light, FEG Textiltechnik mbH, Aachen, Germany
EasyProthes, TransEasy Medical Tech. Co. Ltd, Beijing, China
Hertra 0, HerniaMesh, S.R.L., Torino, Italy
Hermesh 3,4,5,6,7,8, HerniaMesh, S.R.L., Torino, Italy
Lapartex, Di.pro Medical Devices, Torino, Italy
Optilene, B. Braun Melsungen AG, Melsungen, Germany
Optilene LP, B. Braun Melsungen AG, Melsungen, Germany
Optilene Mesh Elastic, B. Braun Melsungen AG, Melsungen, Germany
Parietene Flat Sheet, Medtronic, Minneapolis, MN, USA
Parietene Lightweight, Medtronic, Minneapolis, MN, USA
Premilene, B. Braun Melsungen AG, Melsungen, Germany
Premium, Cousin Biotech, Wervicq-Sud, France
Prolene, Ethicon Inc., Somerville, NJ, USA
Prolene Soft Mesh, Ethicon Inc., Somerville, NJ, USA
ProLite, Getinge Group, Wayne, NJ, USA
Repol Angimesh 0,1,8,9, Angiologica, S. Martino Sicc., Italy
SMX, THT Bio-Science, Montpelier, France
SMH2, THT Bio-Science, Montpelier, France
SMH, THT Bio-Science, Montpelier, France
Surgimesh WN, Aspide Medical, St. Etienne, France
Surgipro Monofilamented, Covidien plc, Dublin, Ireland
Surgipro Multifilamented, Covidien plc, Dublin, Ireland
Surgipro Open Weave, Covidien plc, Dublin, Ireland
TiMESH, GfE Medizintechnik, Nuremburg, Germany
TiLENE, GfE Medizintechnik, Nuremburg, Germany
TiLENE Blue, GfE Medizintechnik, Nuremburg, Germany
VitaMesh—Getinge Group, Wayne, NJ
VitaMesh Blue—Getinge Group, Wayne, NJ

especially for the Trabucco "sutureless" repair. The *Hermesh 3–8* have a huge variety of weights and sizes and can be used in either open or laparoscopic repairs (Fig. 7.55). The graduated weights of these vary from the heaviest (3) to the lightest (8). *Lapartex* is a heavier product than some of the other materials (Fig. 7.56). This product was discontinued during the producton of this textbook and is no longer available.

Optilene products are all lightweight materials that vary from the heaviest by that name (60 g/m^2) to the *Elastic* (48 g/m^2) and the lighter *LP* (36 g/m^2). The Elastic version has unequal pore sizes (3.6 × 2.8 mm) to allow for multidirec-

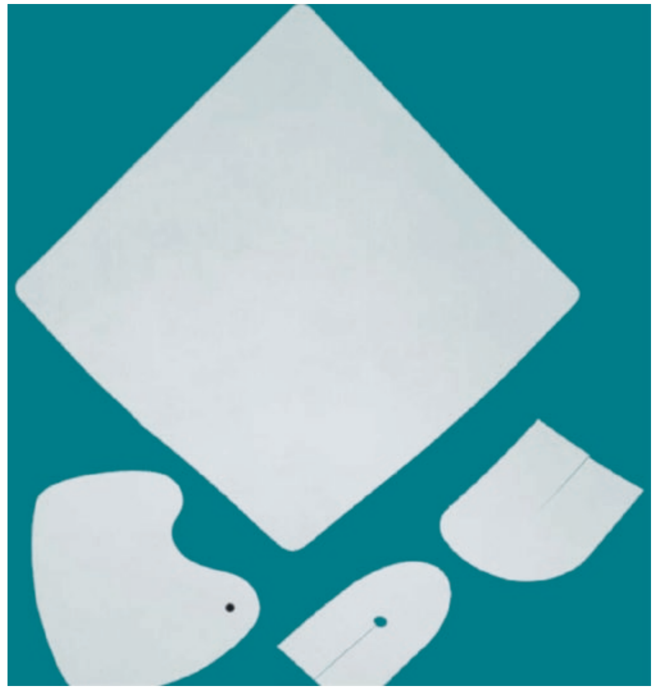

Fig. 7.39 2D PPNT

Fig. 7.40 Basic

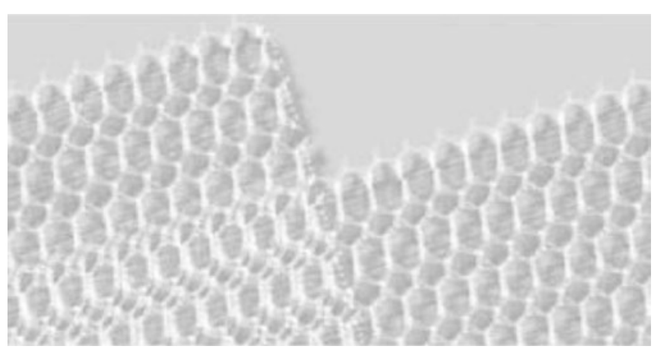

Fig. 7.41 Basic evolution

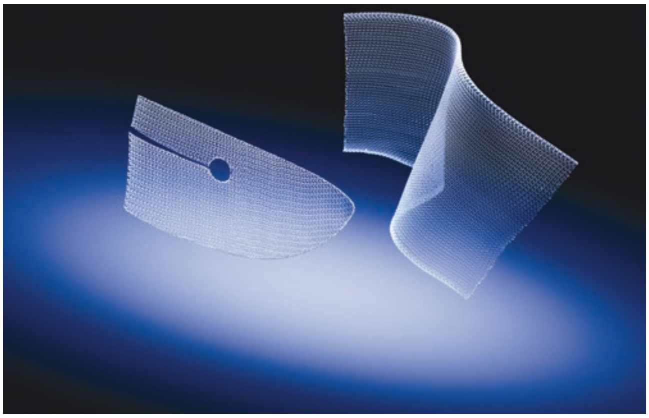

Fig. 7.42 Bard mesh (flat and preshaped)

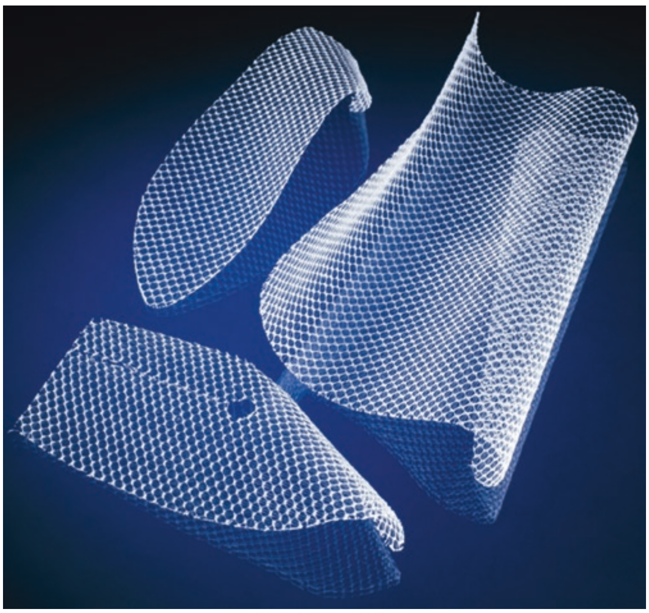

Fig. 7.43 Bard soft mesh (flat and preshaped)

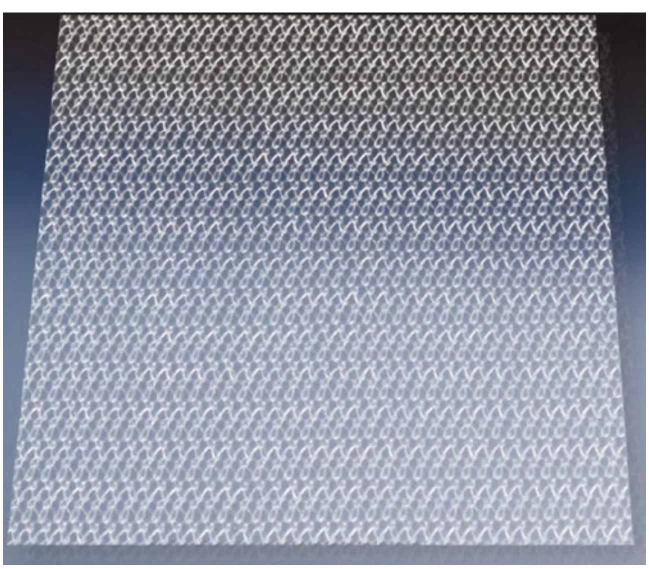

Fig. 7.44 Biomesh P1

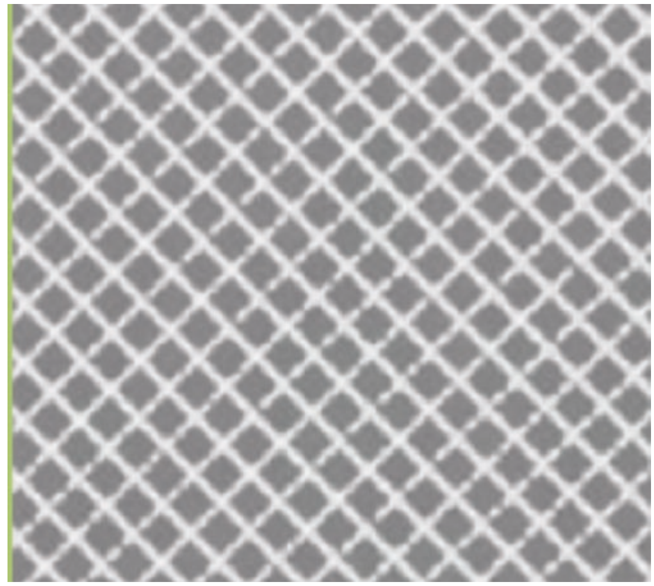

Fig. 7.45 Premium

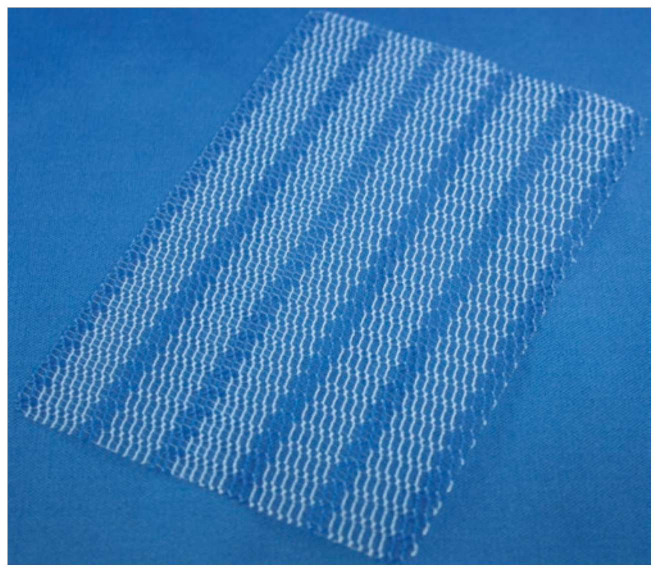

Fig. 7.46 Bulev

Fig. 7.47 Bulev UL

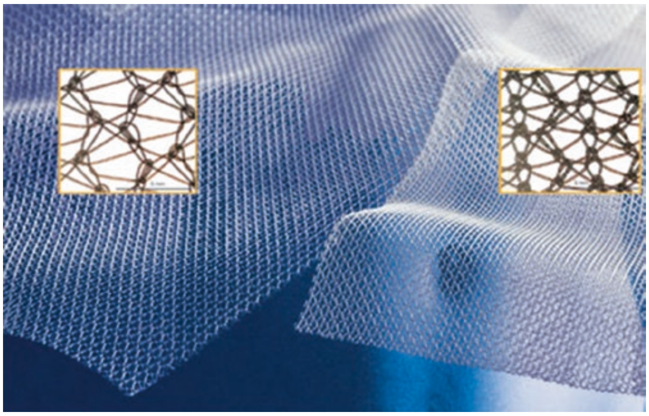

Fig. 7.48 Dynamesh (light and standard)

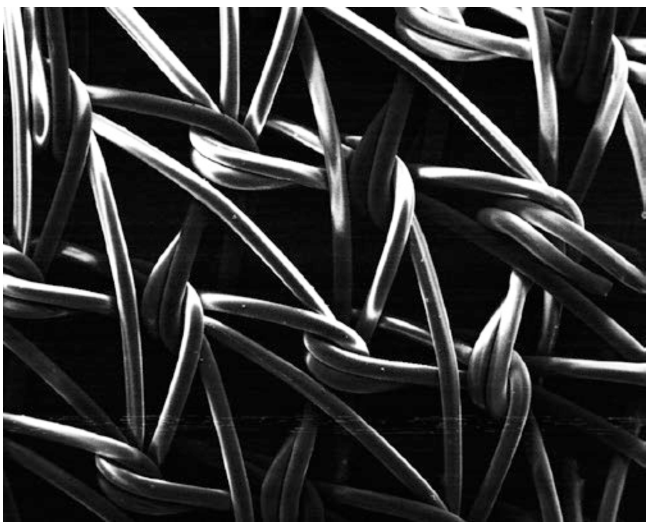

Fig. 7.49 Easy prothes (heavy weight)

Fig. 7.50 Easy prothes 70

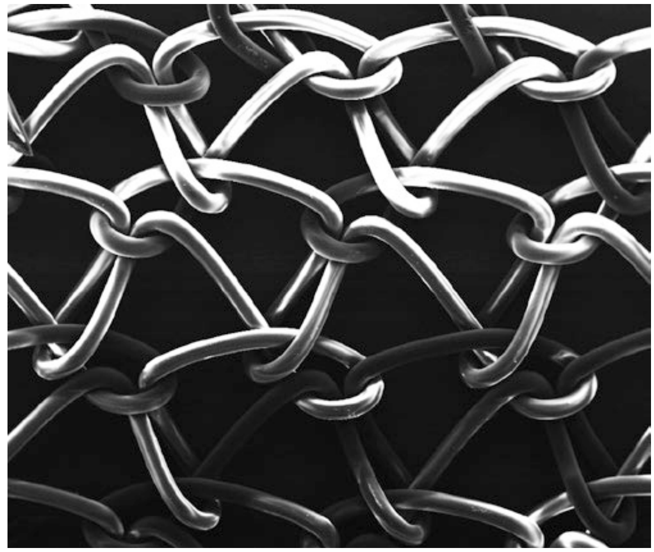

Fig. 7.51 Easy prothes 60

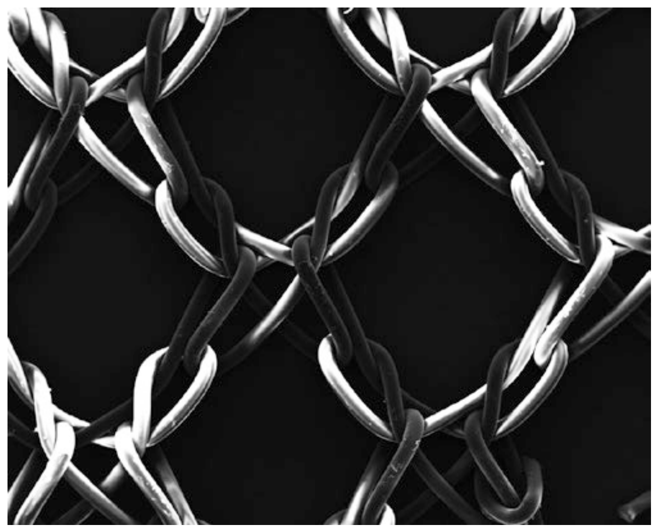

Fig. 7.52 Easy prothes (light weight)

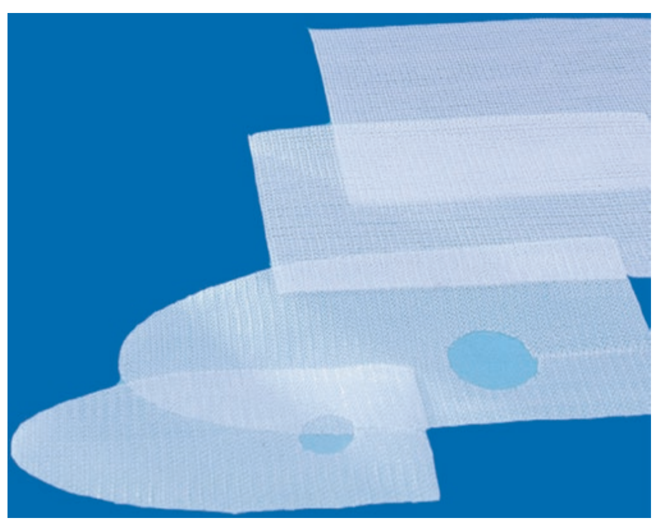

Fig. 7.53 Easy prothes 60

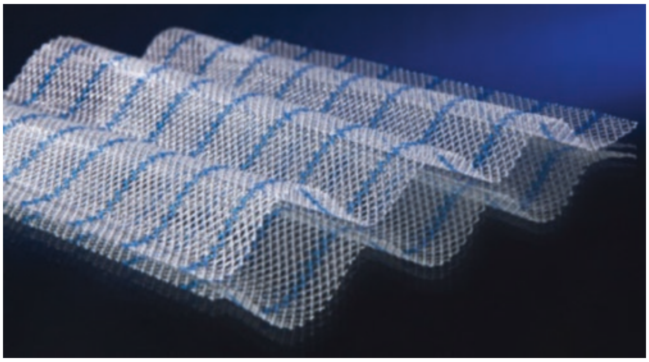

Fig. 7.54 Easy prothes (light weight)

Fig. 7.55 Hermesh

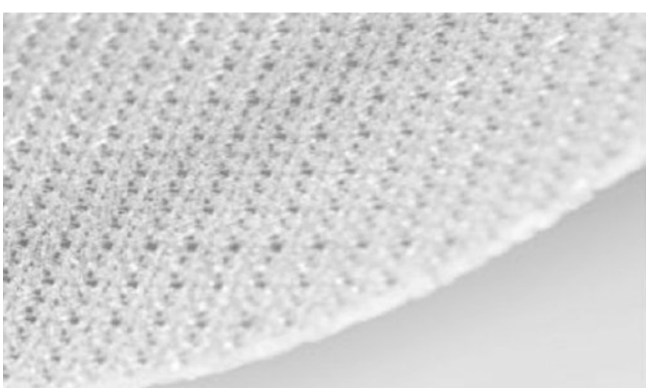

Fig. 7.56 Lapartex (this product is no longer produced)

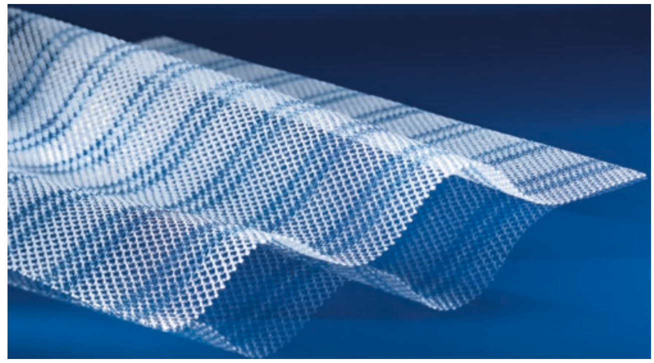

Fig. 7.57 Optilene

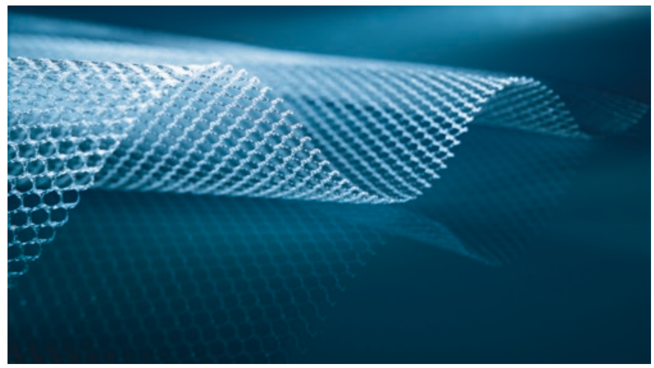

Fig. 7.58 Optilene elastic

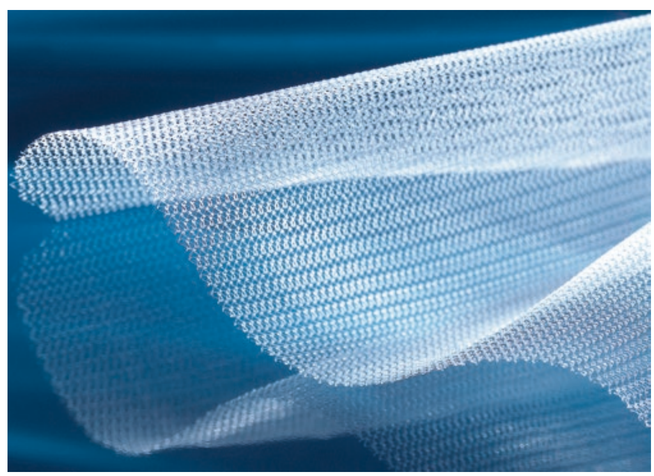

Fig. 7.59 Optilene LP

tional elasticity (Figs. 7.57, 7.58, and 7.59). Unlike some of the other prostheses, the blue lines in the Optilene do not signify an absorbable component. *Parietene Flat Sheet and Parietene Lightweight* products are monofilament flat sheet products (Fig. 7.60). *Premilene* is the heaviest weight (82 g/m^2) product in the Braun flat mesh product line (Fig. 7.61).

Premium mesh is a lightweight product similar to the Biomesh P1 described above (Fig. 7.44). This is configured into various sizes and shapes for use in open or laparoscopic inguinal and extraperitoneal ventral hernia repair (Fig. 7.62). *Prolene* is also a heavier weight mesh material and it is one of the older products available (Fig. 7.63). *Prolene Soft Mesh* is the lighter weight version that has larger pores than the original mesh and blue lines to help differentiate it (Fig. 7.64). *ProLite* was one of the earliest meshes that were introduced as a lighter weight material (Fig. 7.65). Today, it is considered a mid-weight mesh. *ProLite Ultra* possesses even less weight of mesh than ProLite (Fig. 7.66).

Repol Angimesh 0, 1, 8, 9 are all similar and differentiated in the weights and weaves from each other. The 0 is the lightest and 9 is the heaviest. *SurgiMesh WN* is a non-woven microfiber PP product that is extremely lightweight and has a differing microstructure than the other materials listed in this section (Fig. 7.67). It is available in several configurations for open or laparoscopic procedures but cannot be placed against the viscera. *Surgipro* was originally introduced as a multifilament mesh (Fig. 7.68). Because of the demand for a monofilament product, the second-generation product was released (Fig. 7.69). The multifilament material is noticeably softer than the monofilament one. There is now an open weave product called the *Surgipro Open Weave* (Fig. 7.70). *SMX* is a heavy product designed for all hernia repairs, either open or laparoscopic (Fig. 7.71). It is part of the "Swing-mesh" product line. It is available in a lightweight and ultra light material as *SMH2* and *SMH,* respectively (Fig. 7.72).

TiMESH is similar to the lightweight materials and has a bonded layer of titanium on the fibers of the PP using nanotechnology (Figs. 7.73 and 7.74). This is supposed to allow ingrowth in a flexible manner while inhibiting the develop-

Fig. 7.60 Parietene flat sheet (All rights reserved. Used with Permission of Medtronic)

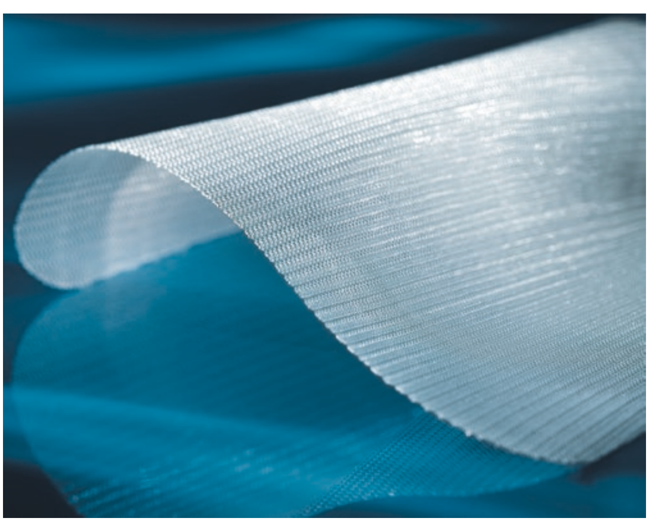

Fig. 7.61 Premilene

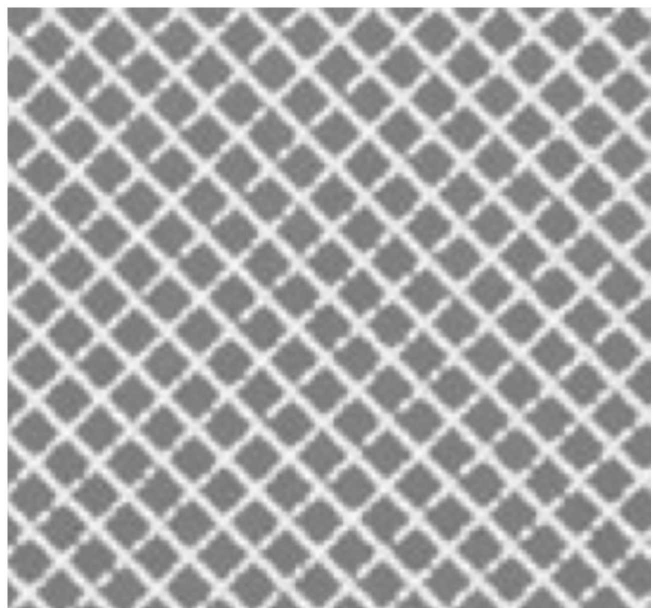

Fig. 7.62 Premium

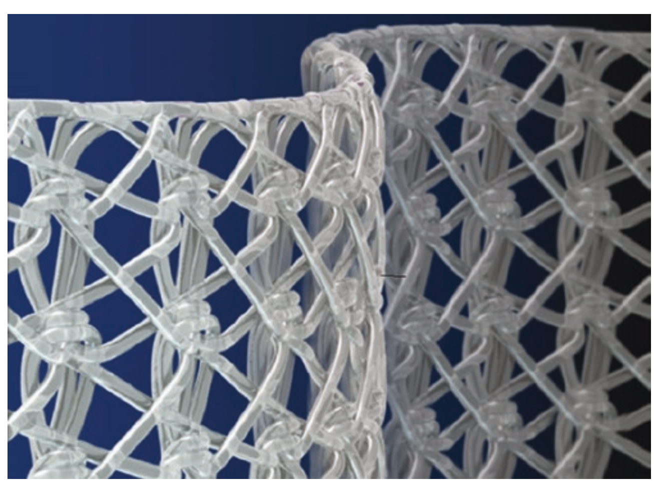

Fig. 7.63 Prolene (Image courtesy of Ethicon, Inc.)

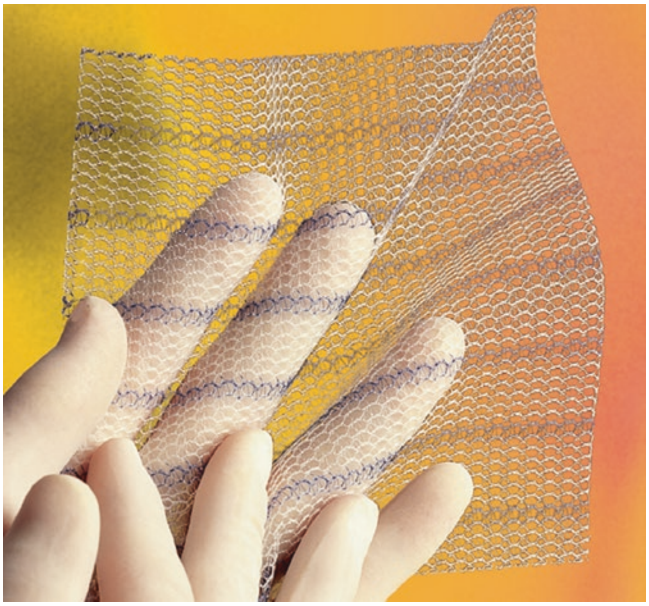

Fig. 7.64 Prolene soft mesh (Image courtesy of Ethicon, Inc.)

Fig. 7.66 ProLite ultra

Fig. 7.65 ProLite

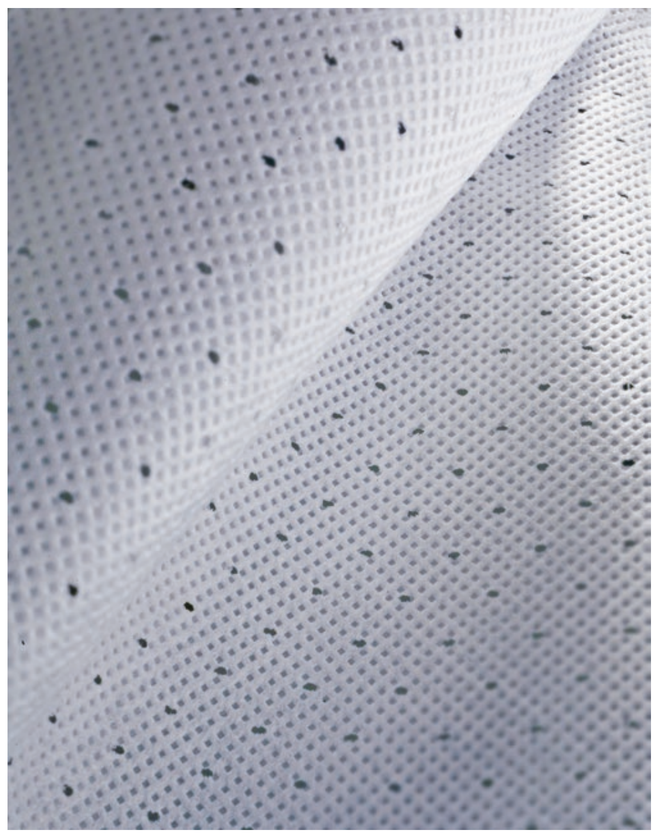

Fig. 7.67 SurgiMesh WN

ment of a scar plate. It can be used in either the intraperitoneal or extraperitoneal positions. *TiLENE Blue* has blue lines incorporated into the material to aid in positioning and can also be used in the intra- or extra-peritoneal planes (Fig. 7.75). It is also available without the blue lines as *TiLENE*. *VitaMesh* is of a single macroporous material (50 g/m^2) available for open and laparoscopic repair (Fig. 7.76). *VitaMesh Blue* is the lighter weight version (28 g/m^2) of this flat mesh and is differentiated by its blue color (Fig. 7.77). These products are singular in that they are made of condensed PP rather than the traditional PP. Regular PP mesh becomes condensed PP mesh

Fig. 7.68 Surgipro multifilament (All rights reserved. Used with Permission of Medtronic)

Fig. 7.69 Surgipro monofilament (All rights reserved. Used with Permission of Medtronic)

through compression during a post-knit heat treatment. This condensing process serves to reduce mesh thickness approximately 70%. This is said to improve deliverability through increased smoothness because fiber crossover points are flattened. Improved recovery of the shape of the mesh is asserted because the knots in the mesh are flattened. This provides greater shape memory than their non-flattened PP.

The differences in the appearance of the prosthetics are easily seen in these photos. The size of the pores of these materials as well as the thickness of the product will have a significant impact on the stiffness. These factors affect the degree of scarring within the tissues. Additionally, the pore sizes vary greatly from each of these products. Since the last edition of this textbook, the lighter weight products have significantly impacted the prosthetic repair of hernias. The current thought is that, for the most part, there is less pain and less scar plate with these lightweight, larger pore meshes. In some cases, these may have become "too thin" and there are reports of mesh fracture and hernia recurrence. Generally, these are well accepted in the inguinal area but one should be sure of the strength of these products in the ventral and incisional hernia repair.

Like the polypropylene materials, the polyester flat sheets can be used in inguinal and ventral hernia repair and can be placed either via an open approach or a laparoscopic technique (Table 7.12). The preponderance of the polyester products that are currently available is produced in various configurations and most have some type of coating. These are listed elsewhere in this chapter.

2D PET, Angimesh R2, R2–1, R2–9 and *Biomesh A2* are all fairly similar in appearance. The *2D PET* and *Biomesh A2*, however, have been configured into various shapes and sizes to allow use in open or laparoscopic inguinal and open ventral hernia repair (Figs. 7.78 and 7.79). *Angimesh R2* is multifilament polyester (Fig. 7.80). *Angimesh R2–1* and *R2–9* are monofilament materials very similar in appearance and differ only in thicknesses, *R2–1* being thinner than *R2–9* (Figs. 7.81 and 7.82). *CO3+* is a rather unique material and is actually combination products that are configured in a variety of shapes and sizes. As such, it will be mentioned later in the chapter again. It is a three-dimensional weave of polyester that has impregnated polyurethane. The differentiating factor are the knitted "grips" that are on both sides of the product (Fig. 7.83). These are designed to fixate the mesh. It can be used in open or laparoscopic surgery and for nearly all hernias.

Fig. 7.70 Surgipro open weave (All rights reserved. Used with Permission of Medtronic)

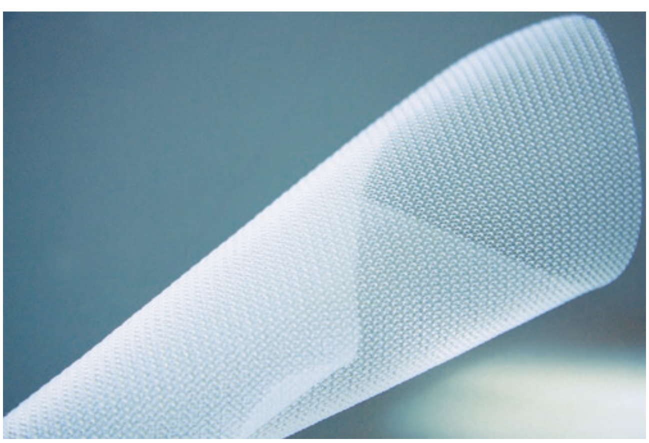

Fig. 7.71 SMX

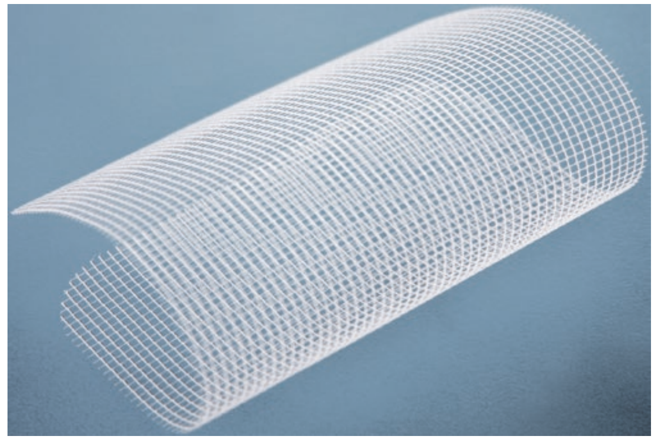

Fig. 7.72 SMH2

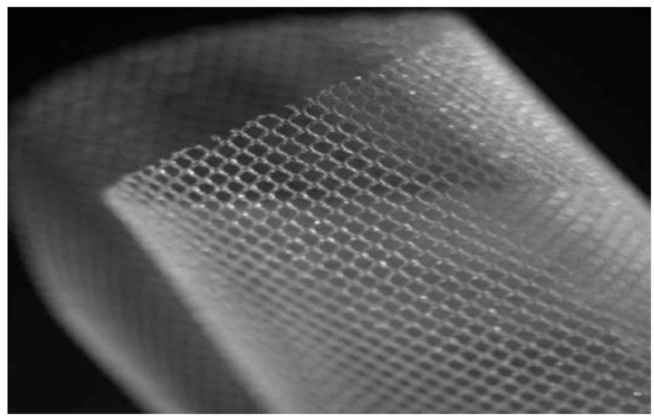

Fig. 7.73 TiMESH

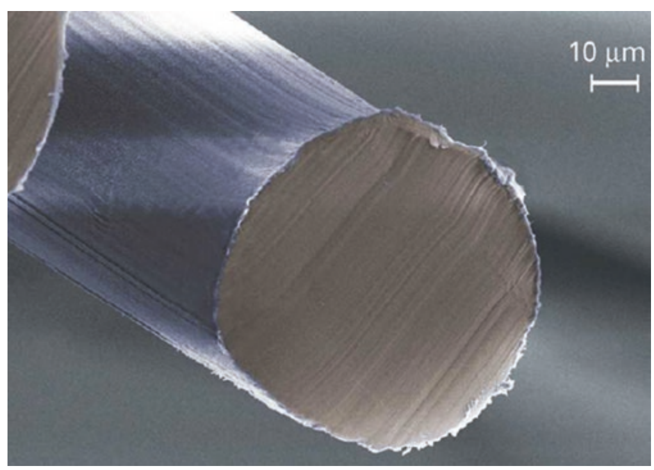

Fig. 7.74 TiMESH (SEM)

The *Parietex Flat Sheet Mesh* is available in two- or three-dimensional weaves (Fig. 7.84). The 2D material is more rigid and is touted for laparoscopic repairs due to this fact. The 3D product is more supple and soft. *Parietex Lightweight* product is a monofilament product (Fig. 7.85). *Parietex Monofilament Macroporous* is available in a flat sheet and is a two-dimensional construct (Fig. 7.86). *SM2* is a heavy-weight bi-dimensional weave material that is indicated for all hernia repairs (Fig. 7.87).

SM3 and *SM3+* are three-dimensional weaves of polyester (Figs. 7.88 and 7.89). Both are available in a variety of shapes and sizes and can be used in open or laparoscopic

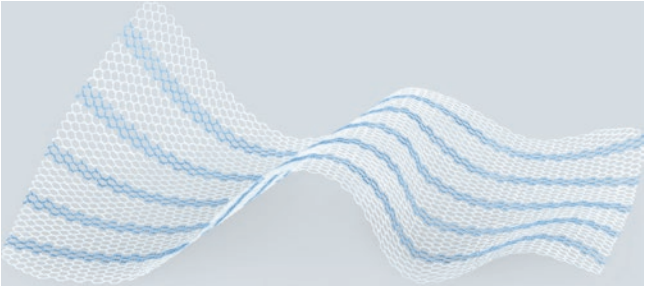

Fig. 7.75 TiLENE blue

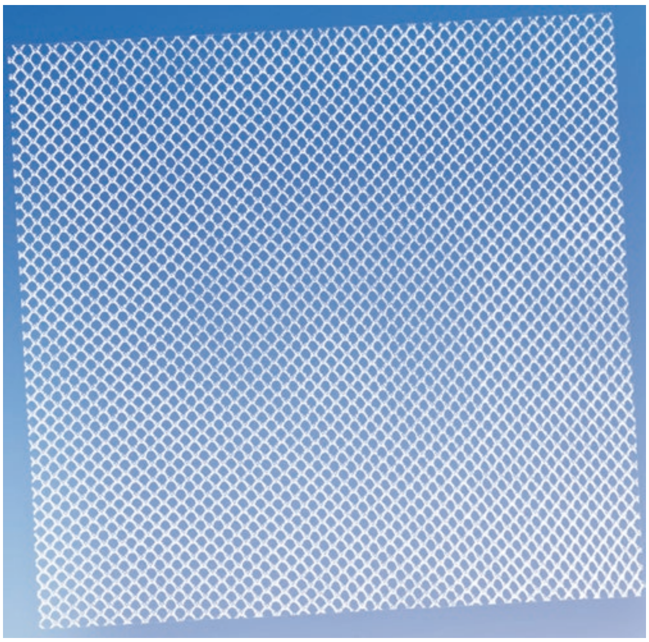

Fig. 7.76 Vitamesh

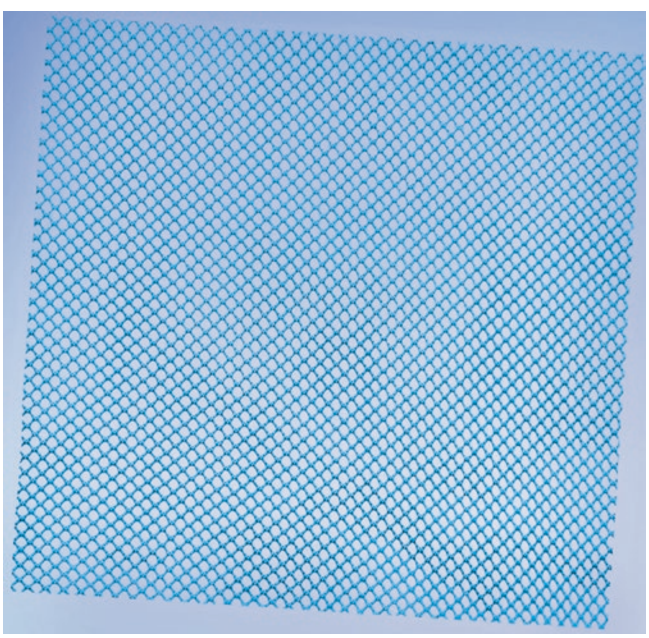

Fig. 7.77 Vitamesh blue

Table 7.12 Flat polyester products

2D PET, Microval, Saint-Just-Malmont, France
Angimesh R2, Angiologica, S. Martino Sicc., Italy
Angimesh R2-1, Angiologica, S. Martino Sicc., Italy
Angimesh R2-9, Angiologica, S. Martino Sicc., Italy
Biomesh A2, Cousin Biotech, Wervicq-Sud, France
CO3+, THT Bio-Science, Montpelier, France
Parietex Flat Sheet Mesh, Medtronic, Minneapolis, MN, USA
Parietex Lightweight Mesh, Medtronic, Minneapolis, MN, USA
Parietex Monofilament Macroporous Mesh, Medtronic, Minneapolis, MN, USA
SM2, THT Bio-Science, Montpelier, France
SM3, THT Bio-Science, Montpelier, France
SM3+, THT Bio-Science, Montpelier, France
Versatex, Medtronic, Minneapolis, MN, USA

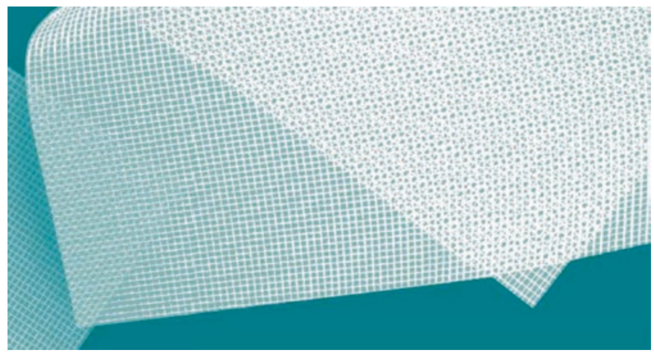

Fig. 7.78 2D PET

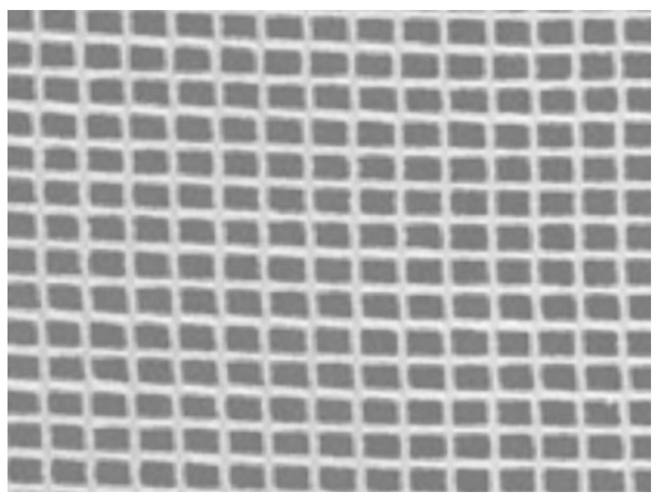

Fig. 7.79 Biomesh A2

applications. *SM3* is pure polyester while the *SM3+* is polyester with impregnated polyurethane and is configured in anatomical shapes. *Versatex* has a 3D construct and is macroporous (Fig. 7.90). It is a medium weight (64 g/m^2) monofilament product that is designed for placement in the

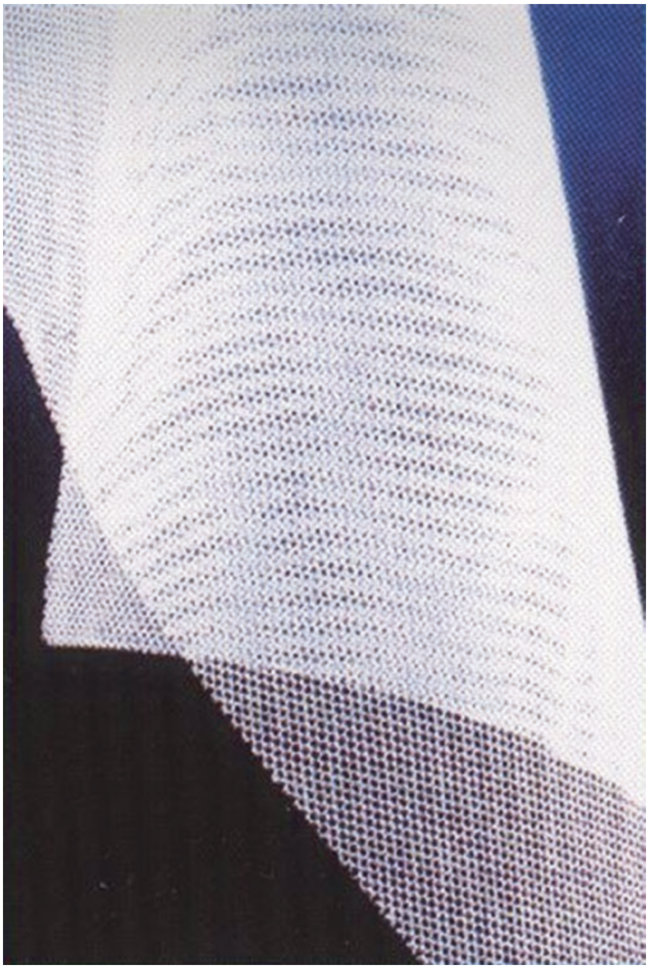

Fig. 7.80 Angimesh R2

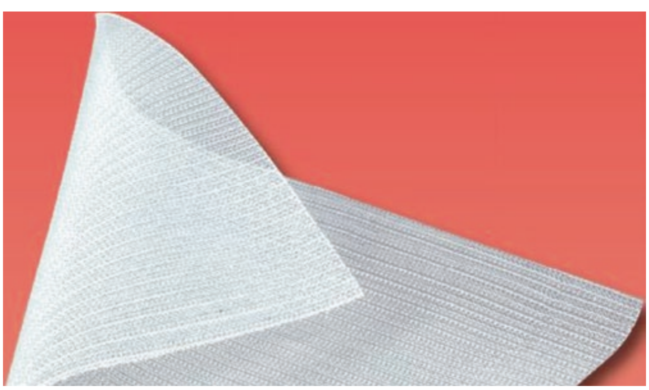

Fig. 7.81 Angimesh R2-1

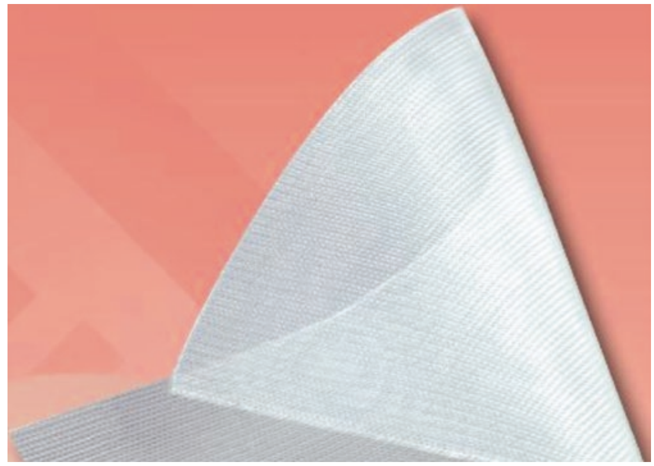

Fig. 7.82 Angimesh R2-9

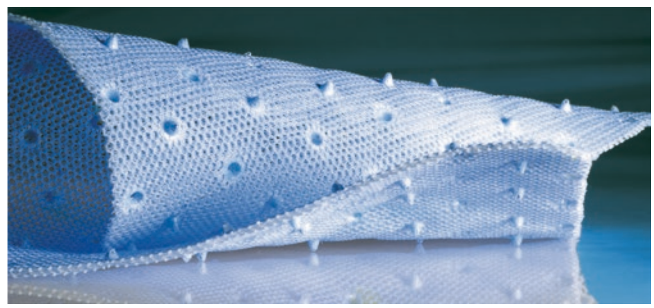

Fig. 7.83 CO3+

Fig. 7.84 Parietex flat sheet (All rights reserved. Used with Permission of Medtronic)

preperitoneal space. It also has a central teardrop that is two-dimensional polyester and is placed as an orientation aid.

Expanded polytetrafluoroethylene (ePTFE) prostheses (Table 7.13) have also been available in a flat sheet configuration for many years. In fact, the earliest products used in the intraperitoneal space for incisional hernia repair were of ePTFE. Because of their structure, they are solid and white unless an antimicrobial agent has been added.

The current DualMesh products are very similar in construction and are one of the oldest "tissue-separating" products (Fig. 7.91). These represent the second generation of this prosthetic material. These all have two distinctly different surfaces. One side is very smooth and has interstices of 3 μm while the other has the appearance of corduroy with an approximate "ridge to ridge" distance of 1500 μm. This prosthesis is designed for use in the intraperitoneal space. The smooth side must therefore be placed facing the viscera as this minimizes the potential for adhesion formation. The rough surface is applied to the abdominal wall so that maximum parietal tissue

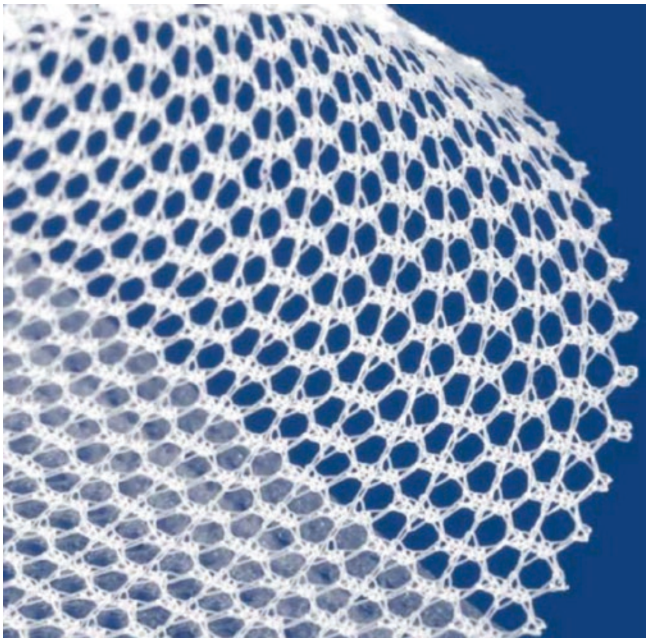

Fig. 7.85 Parietex lightweight (All rights reserved. Used with Permission of Medtronic)

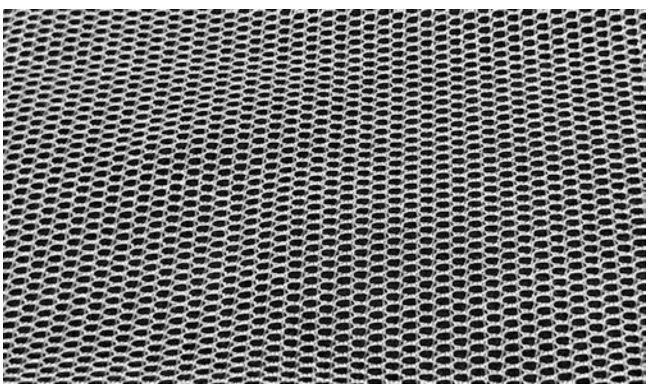

Fig. 7.86 Parietex monofilament macroporous (All rights reserved. Used with Permission of Medtronic)

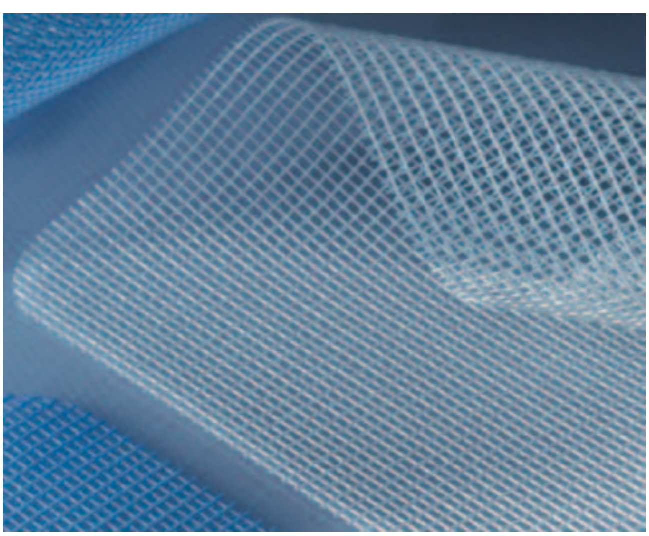

Fig. 7.87 SM2

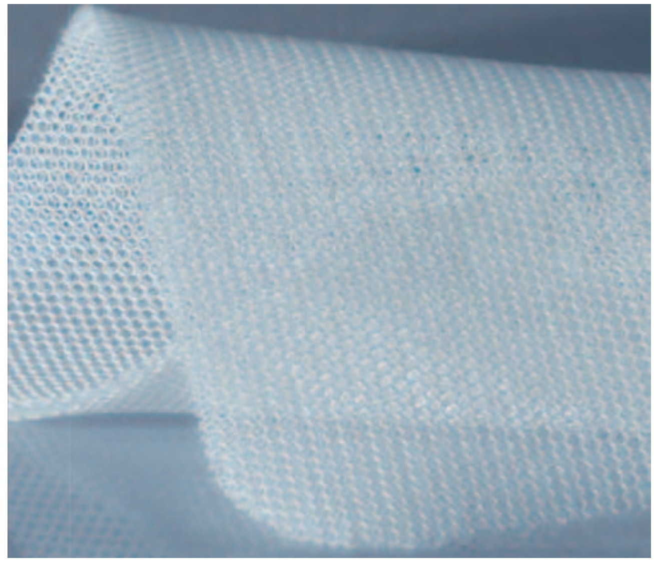

Fig. 7.88 SM3

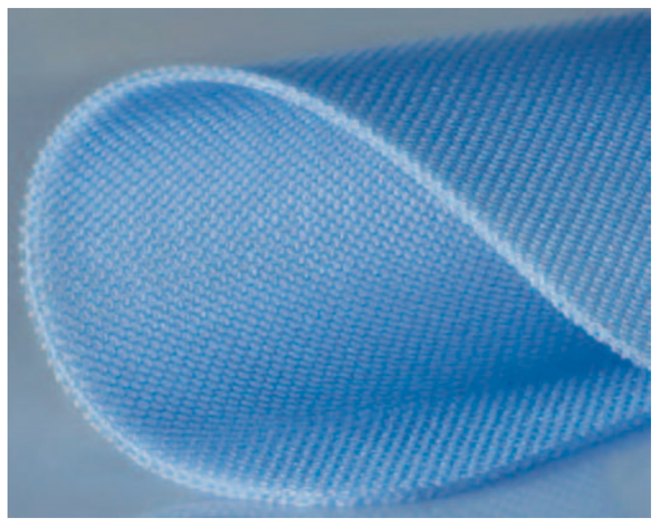

Fig. 7.89 SM3+

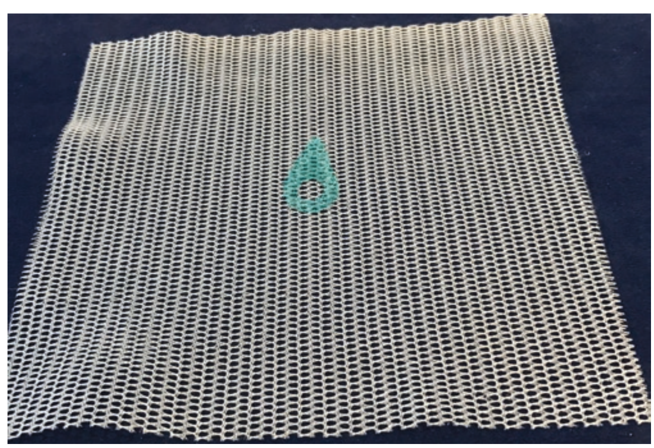

Fig. 7.90 Versatex (All rights reserved. Used with Permission of Medtronic)

penetration will occur. *DualMesh* is available in one thickness, 1 mm. It is available with the impregnation of silver and chlorhexidine as *DualMesh PLUS* (Fig. 7.92). The two-millimeter product is only available as DualMesh Plus with the antimicrobial agents within it. These two chemicals are antimicrobial agents that are added to decrease the risk of infection and, because of the silver, impart a brown color to the "PLUS" products. At this time, these products are the only synthetic materials impregnated with any type of any antimicrobial or bactericidal agents. *DualMesh PLUS with Holes* (Fig. 7.93) is of the same construction as that of the DualMesh. The penetration of the holes requires that this product be of 1.5 mm in thickness. The concept of the addition of these perforations is that there may be greater penetration of the fibroblasts and other cells across the material. Additionally, seroma formation might be diminished.

Dulex is manufactured of laminated ePTFE and is available in 1 or 2 mm thick (Fig. 7.94). One surface of the material is studded with numerous outcroppings as seen on the scanning electron microscopic view that are approximately 400 µm apart. This gives the product the gross appearance of sandpaper. The intent of this surface is to provide for greater fibroblastic attachment and subsequent greater collagen deposition on this parietal surface. When used in the intraperitoneal fashion, the smooth surface should contact the intestine.

MycroMesh is also a dual-sided perforated prosthetic with one surface of 3 µm and the other of 17–22 µm (Fig. 7.95). The latter surface is textured. This material is perforated for reasons that are similar to that of the DualMesh Plus with holes. It is only 1 mm thick, however. *Mycromesh PLUS* is impregnated with the antimicrobials silver and chlorhexidine (Fig. 7.96). It is not designed for intraperitoneal usage.

Table 7.13 ePTFE products

DualMesh, W. L. Gore & Associates, Elkhart, DE, USA
DualMesh Plus, W. L. Gore &Associates, Elkhart, DE, USA
DualMesh Plus with Holes, W. L. Gore &Associates, Elkhart, DE, USA
Dulex, Davol, Inc., Warwick, RI, USA
MycroMesh, W. L. Gore &Associates, Elkhart, DE, USA
MycroMesh Plus, W. L. Gore &Associates, Elkhart, DE, USA
Soft Tissue Patch, W. L. Gore &Associates, Elkhart, DE, USA

Fig. 7.91 DualMesh

Fig. 7.92 DualMesh PLUS

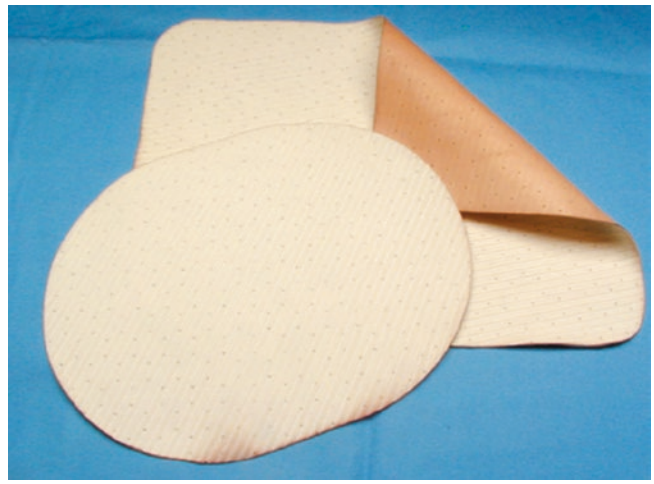

Fig. 7.93 DualMesh PLUS with holes

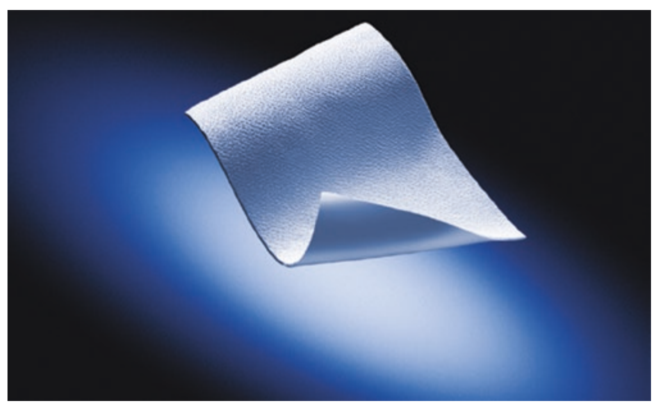

Fig. 7.94 Dulex

Fig. 7.95 MycroMesh

Soft Tissue Patch is the earliest implants of these ePTFE products and was the product utilized in the very first laparoscopic incisional hernia repair (Fig. 7.97). The variety of available configurations of this product has increased over the last several years. Its use, however, has waned because of the development of the other products that are listed in Table 7.12. Like the *MycroMesh*, it should not contact any viscera when applied.

Miscellaneous Flat Products

There are ranges of materials that do not fit into the exact categories above (Table 7.14). For instance, *Inomesh* is a product made of PVDF with laser cut holes (Fig. 7.98). *MotifMesh* and *Omyra* are identical in design and concept (Figs. 7.99 and 7.100). These are made of condensed PTFE (cPTFE) and designed for use in contact with the intestine. The PTFE is laminated and then condensed with a heated compression process. The nonporous material is then laser micromachined to

Fig. 7.96 MycroMesh PLUS

Fig. 7.97 Soft tissue patch

Table 7.14 Miscellaneous flat mesh products

Inomesh, Secqure/Medlinx Acacia, Singapore
Mosquito netting, numerous manufacturers
MotifMESH, Proxy Biomedical Ltd, Galway, Ireland
Omyra, B. Braun Melsungen AG, Melsungen, Germany
Rebound HRD V, ARB Medical, Minneapolis, MN, USA
TiO_2 Mesh, BioCer GmbH, Bayreuth, Germany

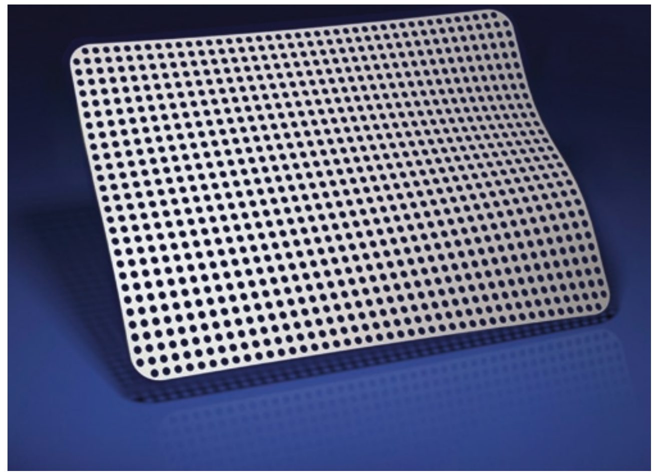

Fig. 7.98 Inomesh

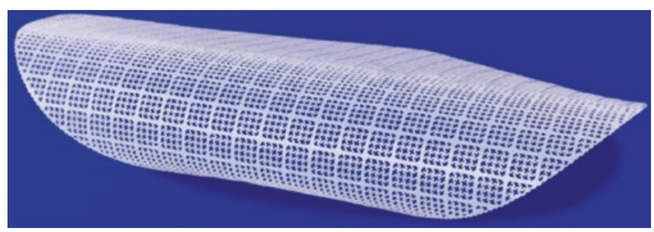

Fig. 7.99 MofifMesh

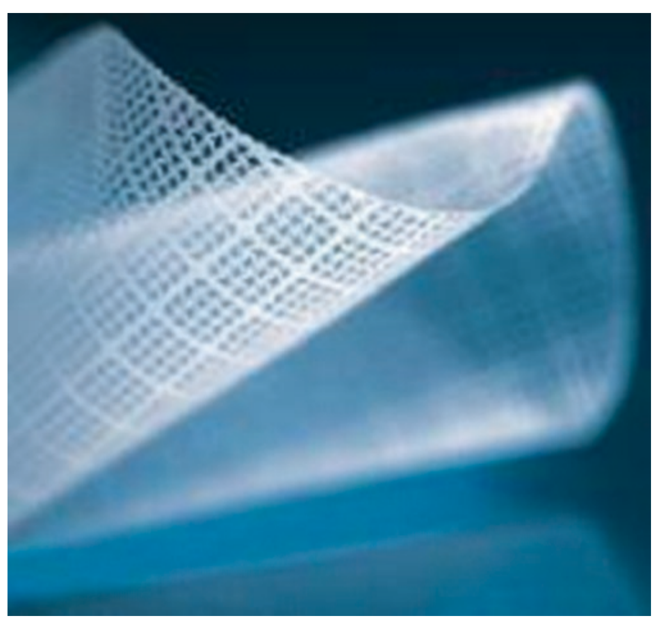

Fig. 7.100 Omyra

create the macroporous structure of the final product. They claim to be "a bacterial resistant anti-adhesive mesh."

Rebound HRD V is a unique material in that it is PP that has a ring of nitinol to stiffen the product and is available as an oval shape for umbilical hernia repair (Fig. 7.101). *TiO_2 Mesh* is a titanized PP is that is completely covered by a 100% pure titanium oxide layer (Fig. 7.102). It is lightweight (47 g/m²), large pore (2.8 mm) and has blue orientation strips. It is stated to be hydrophilic so that there is an apparent "stickiness" to the product, which eases intraoperative handling. It can be used in either open or laparoscopic inguinal and incisional hernia repairs.

This chapter would be remiss if it did not include the use of mosquito netting for the repair of inguinal hernias. This has been reported in the past in underserved countries. It appears that if this material is acceptable for use in areas of the world where the other products described in this chapter are either unavailable or are too expensive [11, 12].

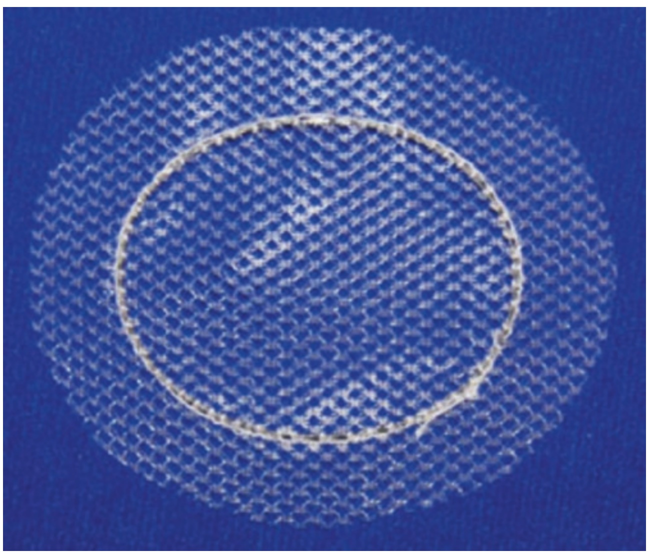

Fig. 7.101 Rebound HRD V

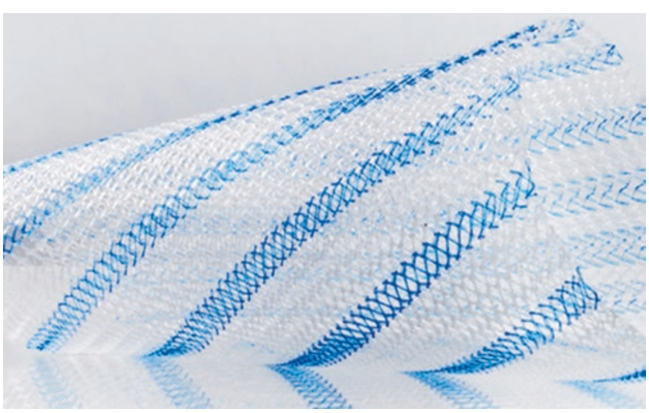

Fig. 7.102 TiO_2

Flat Mesh Devices for Inguinal Hernioplasty

There are several modifications of the shape of the synthetic meshes described above. For the most part, the ones listed in Table 7.15 are merely the same permanent material (Table 7.11) that is either pre-shaped with rounded edges and/or have a slit and/or keyhole to be used for open inguinal hernia repair. Some of these keyholes will be located on the long axis of the mesh to be placed while others will be placed on the short axis of the mesh. If there is a significant modification, it is noted below.

Angimesh XCO is a combination of two layers of PP (Fig. 7.103). One folds over the other to be used as a sutureless inguinal hernia repair, if desired it is available in the thick (*A5*)

Table 7.15 Flat mesh devices

2D PPT Std, Microval, Saint-Just-Malmont, France
2D PPT LW, Microval, Saint-Just-Malmont, France
2D PPNT, Microval, Saint-Just-Malmont, France
2D PET, Microval, Saint-Just-Malmont, France
Angimesh XCO A5, Angiologica, S. Martino Sicc., Italy
Angimesh XCO A9, Angiologica, S. Martino Sicc., Italy
Bard Mesh, Davol, Inc., Warwick, RI, USA
Bard Soft Mesh, Davol, Inc., Warwick, RI, USA
Biomesh A2, Cousin Biotech, Wervicq-Sud, France
CO3+, THT Bio-Science, Montpelier, France
C-Qur FX, Getinge Group, Wayne, NJ
Easy Prothes, TransEasy Medical Tech.Co.Ltd., Beijing, China
Hetra 1,2,2A, Herniamesh, Torino, Italy
Hertra 6, 6A, 7, Herniamesh, Torino, Italy
Hertra 9, 9A, Herniamesh, Torino, Italy
HydroCoat Mesh, Promethean Surgical Devices, East Hartford, CT, USA
MycroMesh, W. L. Gore & Associates, Elkhart, DE, USA
Optilene, Optilene LP mesh, B. Braun, Melsungen AG, Melsungen, Germany
Premiline mesh, B. Braun, Melsungen AG, Melsungen, Germany
Parietex ProGrip Polypropylene, Medtronic, Minneapolis, MN
Parietex ProGrip Polyester, Medtronic, Minneapolis, MN
P1, Cousin Biotech, Wervicq-Sud, France
P3, Di.pro Medical Devices, Torino, Italy
P3 Evolution, Di.pro Medical Devices, Torino, Italy
Premium, Cousin Biotech, Wervicq-Sud, France
ProLite, Getinge Group, Wayne, NJ
ProLite Ultra, Getinge Group, Wayne, NJ
SM2+, THT Bio-Science, Montpelier, France
SM3, THT Bio-Science, Montpelier, France
SM3+, THT Bio-Science, Montpelier, France
SurgiMesh WN, Aspide Medical, St. Etienne, France
T4 Pre-shaped Mesh, HerniaMesh, S.R.L., Torino, Italy
TiLENE, GfE Medizintechnik, Nuremburg, Germany
TiPATCH, GfE Medizintechnik GmbH, Nuremburg, Germany
Wings, Angiologica, S. Martino Sicc., Italy

or standard (*A9*). *CO3+* has a similar configuration and has included grips. It is described in the flat mesh section above (Fig. 7.83). *Parietex ProGrip Polyester* is composed of the three-dimensional POL of Parietex with polylactic acid micro-grips (see above) and is manufactured with a left and a right mesh (Fig. 7.104). It is elliptical in shape with a colored marker on the median edge of the prosthesis to indicate the location of the suture that is placed at the pubic tubercle for fixation. There is a self-gripping flap that is designed to overlap the slit that is precut into the biomaterial, which allows for the exit of the cord structures through the mesh. This flap is placed in the inferior position of the inguinal floor. The manufacturer recommends that the external oblique fascia be closed below the cord structures so that there is no direct contact with the polyester fabric. There is a *Parietex ProGrip Polypropylene* version that is identical but is made of PPM as its name implies.

Hertra 1 and *2* are indicated for male inguinal hernias but the *Hertra 2A* can be used for male or female hernias (Fig. 7.105). *Hertra 6 and 6A* are lightweight materials (Fig. 7.106). They are all indicated for male hernias but the 6A can also be used for hernias in the female patient. The *Hertra 7* is an ultra lightweight material (Fig. 7.106, lower). Hertra 9 and 9A are preshaped with the patented quadraxial weave (Fig. 7.107). Both are recommended for inguinal hernias in males and the latter is also recommended for female patients. The T4 plug is actually a rounded flat sheet of mesh that is to be placed in the preperitoneal space (Fig. 7.108).

The *P3* is manufactured in light, medium, and heavy weight PPM with products for the male and female patient (Fig. 7.109). The "male" product is supplied with a slit and keyhole for the cord structures to pass while the "female" product has no slit or hole. Only the "male" mesh is provided in the heavy weight mesh. The *P3 Evolution* version is similar but ultra lightweight (Fig. 7.110). *ProLite* and *ProLite Ultra* are available in the non-keyhole and the keyhole prod-

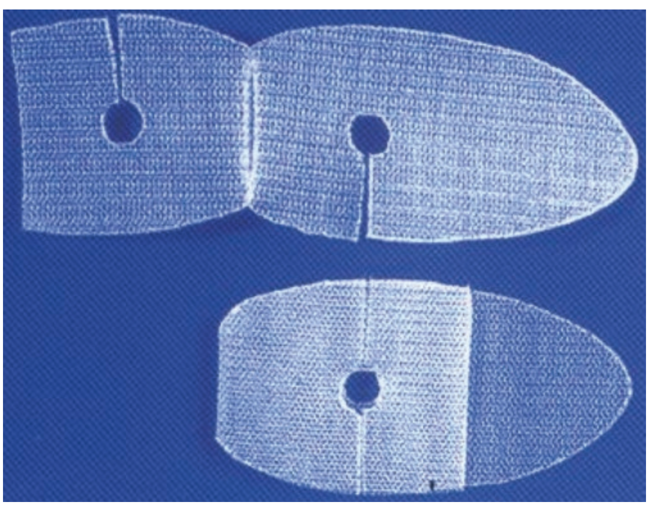

Fig. 7.103 Angimesh XCO

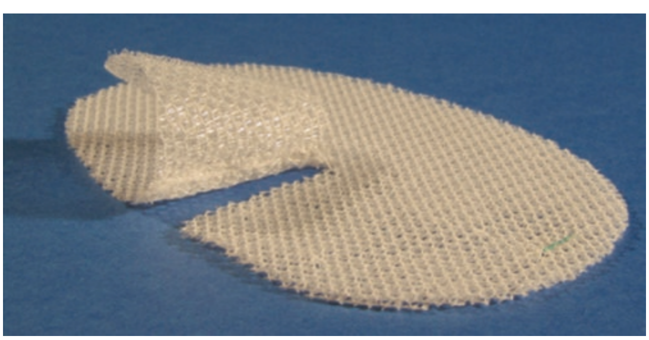

Fig. 7.104 Parietex ProGrip polyester (All rights reserved. Used with Permission of Medtronic)

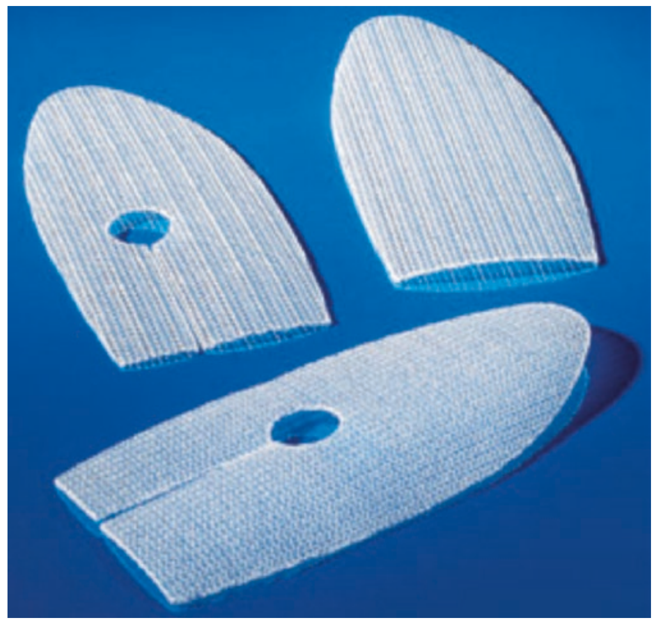

Fig. 7.105 Hertra 1 (upper left), 2 (lower), 2A (upper right)

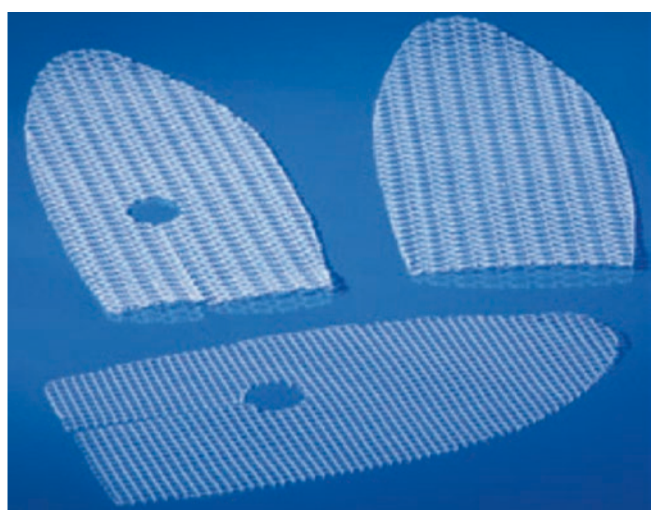

Fig. 7.106 Hertra 6 (upper left), 6A (upper right), 7 (lower)

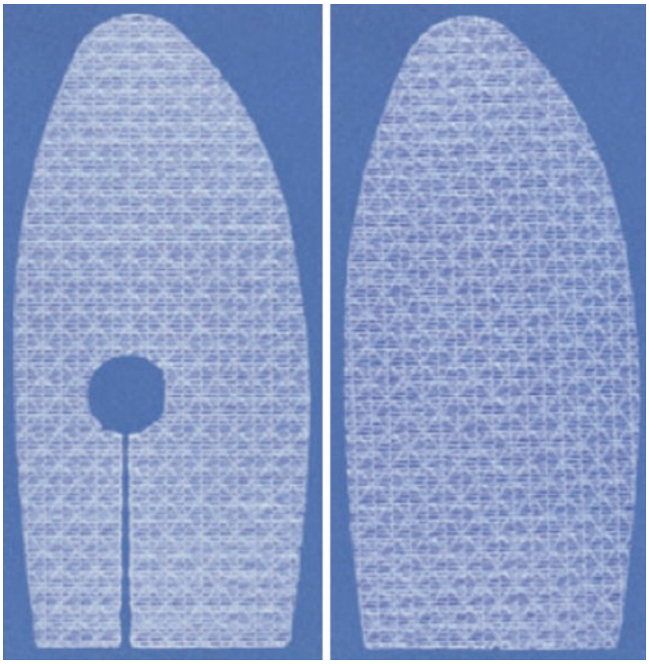

Fig. 7.107 Hertra 9 (left), 9A (right)

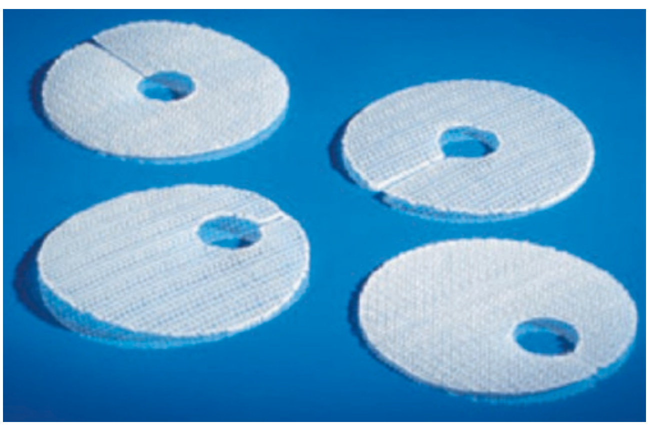

Fig. 7.108 T4 plugs

Fig. 7.109 P3

uct like most of these here but are also available in a unique shape with one side larger than the other.

SM2+ is a bidimensional polyester preshaped product (Fig. 7.87). It is a combination product of PP and PUR and is recommended for all hernias, although its shape lends itself to inguinal repair. *SM3* and *SM3+* have been described in the flat mesh section (Figs. 7.88 and 7.89). They are configured in several sizes for open inguinal hernia repair. *TiPATCH* is made of the same material as TiMESH but this has two overlapping pieces of the mesh to cover behind the cord structures of the inguinal hernia repair (Fig. 7.111). It is PPM that is titanized. *Wings* mesh also has overlapping portions of the product to allow exit of the cord and potentially be used as a sutureless technique (Fig. 7.112).

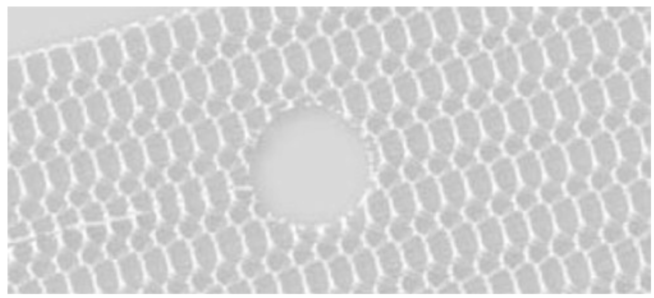

Fig. 7.110 P3 evolution

Fig. 7.111 TiPATCH

Combination Flat Synthetic Prosthetics

This grouping of these products is made because there is a permanent portion of these materials and an absorbable component to the product. These prostheses are generally not meant to contact any viscera and do not possess a specific shape. (Table 7.16)

Adhesix, Parietene ProGrip, and *Parietex ProGrip* all have self-attaching portions of the prosthesis so that once placed onto the tissue surface, they will fixate themselves (Figs. 7.104 and 7.113). These "gripping portions" are absorbable. The permanent portions of Adhesix and Parietene ProGrip are made of PP while the Parietex ProGrip is POL. *Adhesix* has a coating on one side that is made of polyvinylpyrrolidone and polyethylene glycol. This coating turns into an adhesive gel when it comes into contact with both heat and humidity. *Parietex ProGrip Laparoscopic* is a flat sheet of polyester that has micrograps of polylactic acid that lasts >18 months (Fig. 7.114). It differs from the other ProGrip products in that it has a green portion to delineate the medial aspect of the mesh and has a light coating of collagen to make manipulation during laparoscopic use easier.

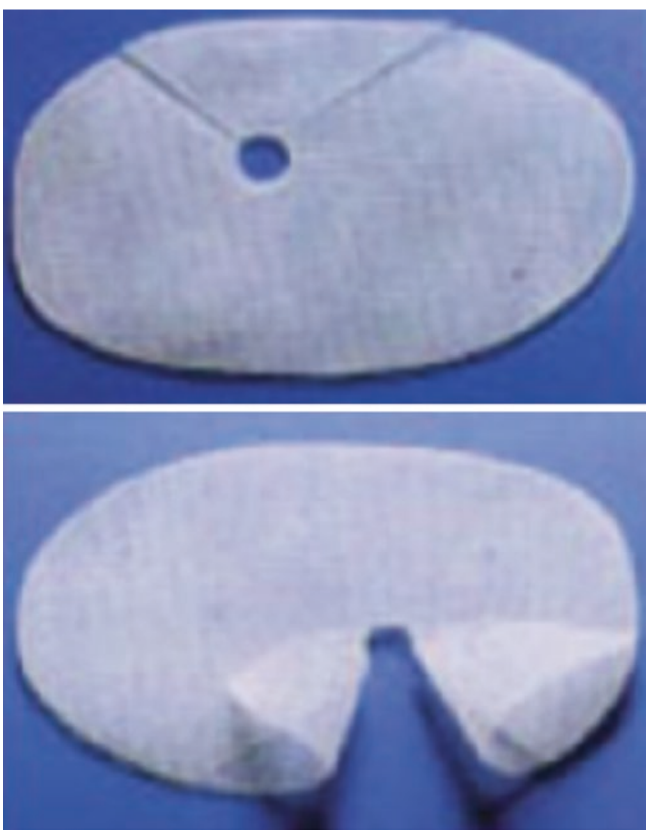

Fig. 7.112 Wings

Table 7.16 Combination products

Adhesix, Davol, Inc., Warwick, RI, USA
Easy Prosthesis Partially Absorbable PAF, TransEasy Medical Tech.Co.Ltd, Beijing, China
Easy Prosthesis Partially Absorbable PAS, TransEasy Medical Tech.Co.Ltd, Beijing, China
4D Mesh, Cousin Biotech, Wervicq-Sud, France
4D Mesh Ventral, Cousin Biotech, Wervicq-Sud, France
Hybridmesh, Herniamesh, Torino, Italy
Parietene ProGrip, Medtronic, Minneapolis, MN, USA
Parietex ProGrip, Medtronic, Minneapolis, MN, USA
Parietex ProGrip Laparoscopic, Medtronic, Minneapolis, MN, USA
TiMesh, GfE Medizintechnik, Nuremburg, Germany
Vypro, Ethicon, Inc., Somerville, NJ, USA
Vypro II, Ethicon, Inc., Somerville, NJ, USA
Ultrapro, Ethicon, Inc., Somerville, NJ, USA
Ultrapro Advanced, Ethicon, Inc., Somerville, NJ, USA

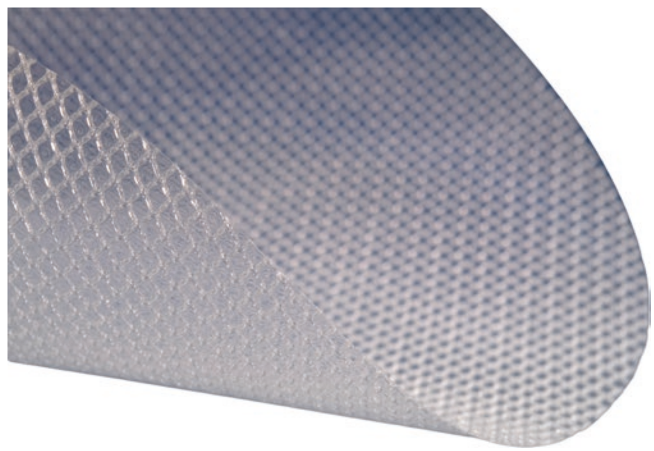

Fig. 7.113 Adhesix

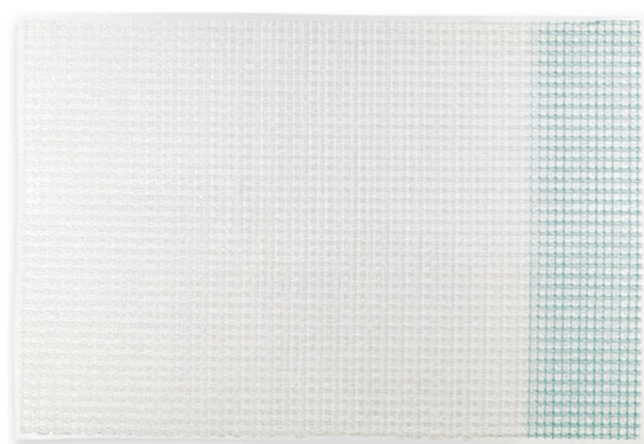

Fig. 7.114 Parietex ProGrip laparoscopic (All rights reserved. Used with Permission of Medtronic)

Easy Prothes Partially Absorbable is a partially absorbable product (Fig. 7.115). It is a combination of PP and poly(glycolide-cocaprolactone) [PGCL] monofilaments. The PGCL portion will be completely absorbed within 90–120 days. It is available in two versions, both of which have a PP weight of 30 g/m^2, which is the final weight of the material after degradation of the absorbable material. The difference lies in the weight of the PGCL, which are 30 g/m^2 in the *PAF* material and 60 g/m^2 in the *PAS* product. *4D Mesh* is made of a base of a 25% PP base with the remainder of resorbable PLLA (Fig. 7.116). It is approximately 30gm/m^2 postabsorption. The design shown is for open inguinal hernia repair but there is also a preshaped product for laparoscopic repair (Fig. 7.117). The *4D Ventral* is a flat sheet and differs from the 4D mesh in that it is 40% PP and 60% PLLA (Fig. 7.118). *Hybridmesh* is a quadraxial mesh co-knitted with 25% non-absorbable PP and 75% monofilament PLLA (Fig. 7.119). This results in an implantation weight of 80gm/m^2 and a final weight of 20 g/m^2 after 18–24 months.

Timesh is one of the few products in this section that can be placed against the viscera (Fig. 7.120). The materials, *Vypro* and *Vypro II* are actually a combination of PP and the absorbable polymer polydioxione (Fig. 7.121). The combination of these materials results in a very pliable and malleable material. Once the polydioxione has been absorbed, the PP that remains has very large interstices into which the fibroblasts and collagen are deposited. The aim of these type of products is the improvement in the abdominal wall compliance that is more normal in function because of the very lightweight PP that remains. *Ultrapro* mesh is a similar concept and is manufactured from approximately equal parts of the absorbable poliglecaprone-25 monofilament fiber and the non-absorbable lightweight PP (Fig. 7.122). A portion of the PP is dyed. The absorbable portion is essentially absorbed by 84 days. *Ultrapro Advanced* is similar to the former product but is designed to allow for more stretch of the abdominal wall, allowing a 2:1

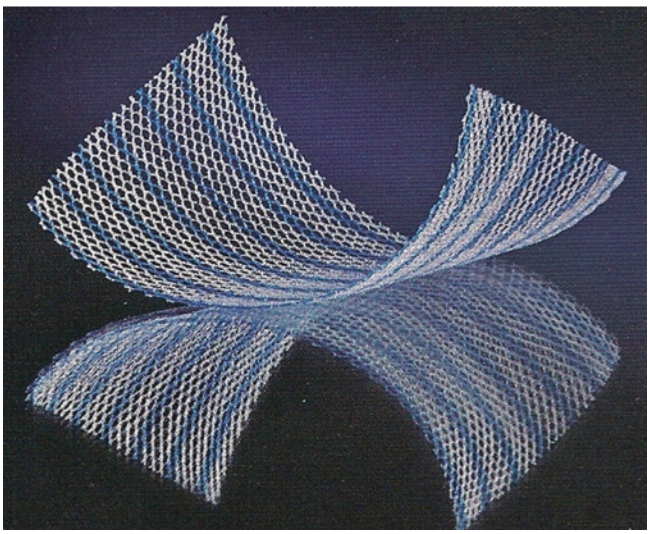

Fig. 7.115 Easy prothes partially absorbable

Fig. 7.116 4D inguinal

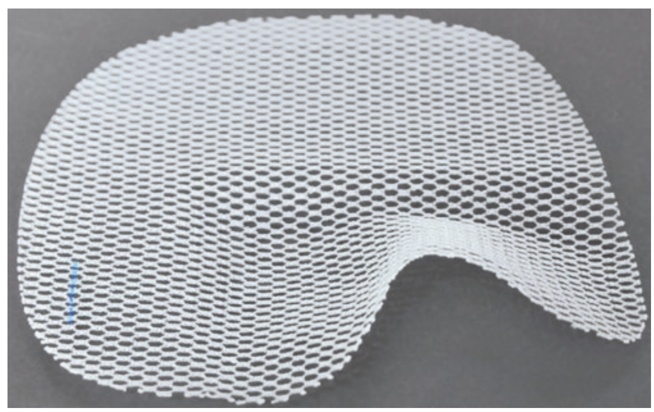

Fig. 7.117 4D laparoscopic

Fig. 7.118 4D ventral

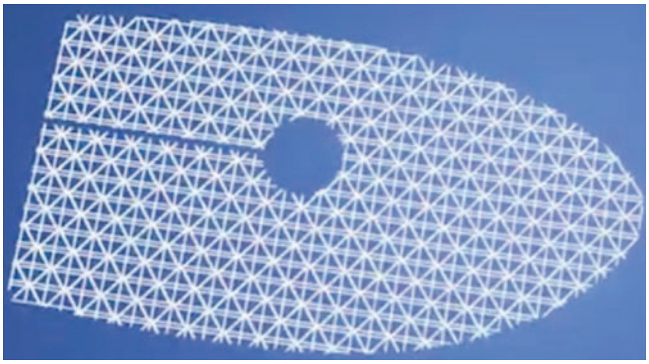

Fig. 7.119 Hybridmesh

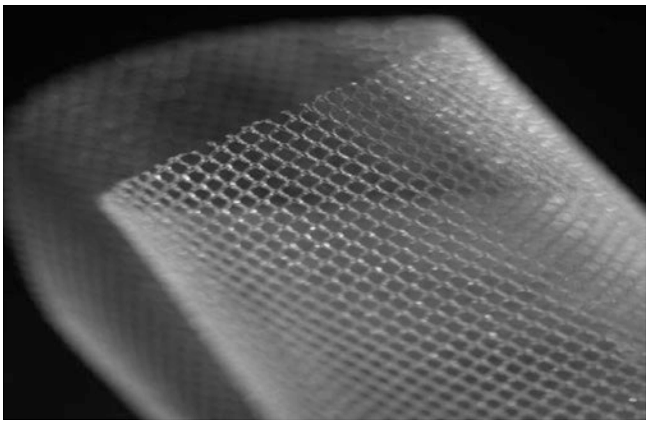

Fig. 7.120 TiMESH

stretch (Fig. 7.123). It stretches to the greatest degree perpendicular to the blue stripes.

Preformed Prosthetic Devices for Open Hernioplasty

These products are inserted into the defect of the fascia that the hernia represents. The repair of inguinal hernias with these products simply involves the insertion of the plug through the fascial defect into the extraperitoneal plane, which is then secured to the edges of the fascia. Additionally, they also employ the use of an overlay of an additional piece of mesh to complete the repair. There are structural differences with these products that alter the concept of each one. Some surgeons also modify these plugs prior to insertion to more completely protect the preperitoneal space. All are of a polypropylene biomaterial with the exception of the Parietex Plug (Table 7.17).

There are several "self-forming" plugs. These are flat, round, and without a hole rather than being preshaped, as one might expect in a true plug-like product. The *Repol Basic plug* is one of these (Fig. 7.124). The makers of such devices believe that this is a "one-size-fits-all" concept in that they can be utilized in any size of a fascial defect. Other products that correspond to this design are the *Self-Forming Plug,* the *SurgiMesh WN Easy Plug* and the *T1* plugs. (Figs. 7.125–7.127). The *Self-Forming Plug* differs from the other two single layer products in that it is made

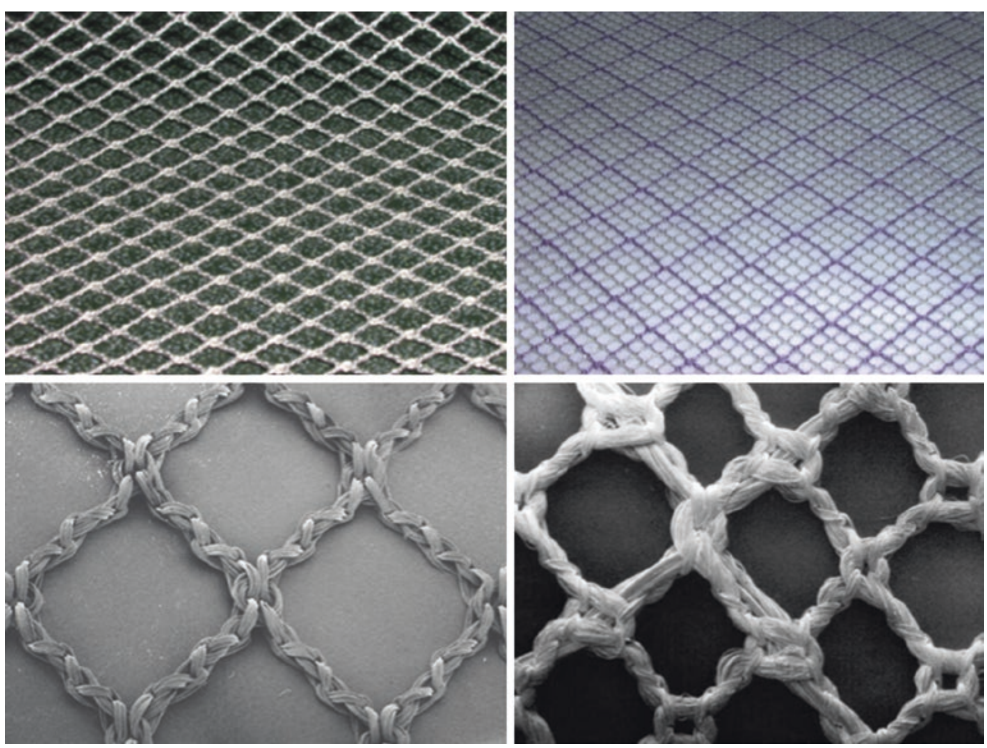

Fig. 7.121 Vypro and Vypro II (Image courtesy of Ethicon, Inc.)

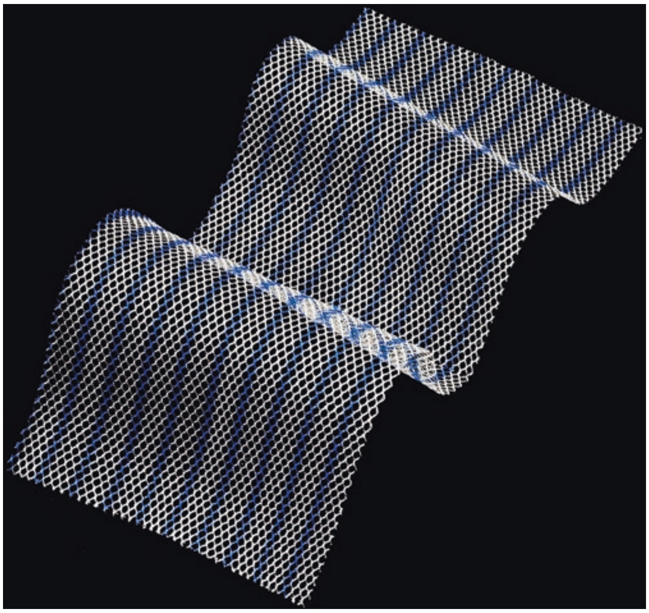

Fig. 7.122 Ultrapro flat mesh (Image courtesy of Ethicon, Inc.)

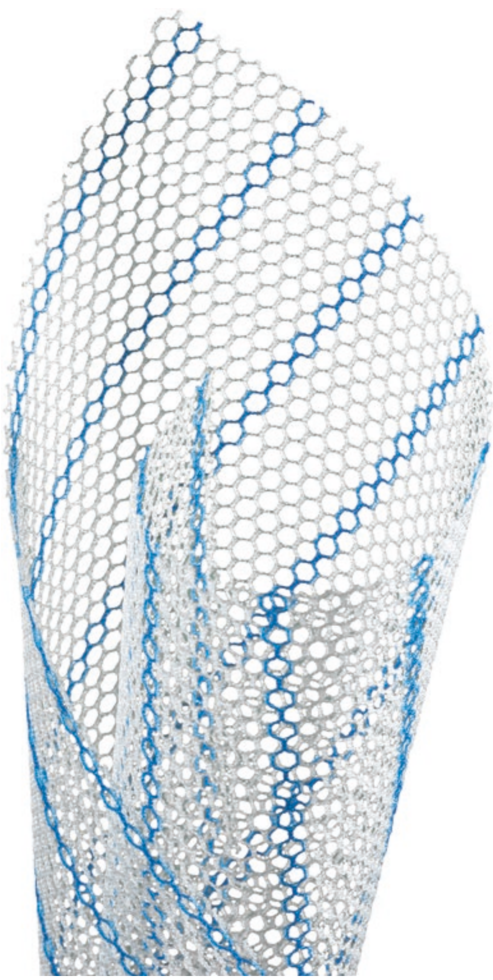

Fig. 7.123 Ultrapro advanced (Image courtesy of Ethicon, Inc.)

Table 7.17 Plug type products

Bard Mesh Dart, Davol, Inc., Warwick, RI, USA
Repol Basic plug, Angiologica, S. Martino Sicc, Italy
Easy Prothes Partially Absorbable, TransEasy Medical Tech.Co. Ltd, Beijing, China
Easy Prothes Plug, TransEasy Medical Tech.Co.Ltd, Beijing, China
Easy Prothes Light Plug, TransEasy Medical Tech.Co.Ltd, Beijing, China
4D Dome, Cousin Biotech, Wervicq-Sud, France
NeT Plug and Patch, Herniamesh, Torino, Italy
Parietex Plug and Patch System, Medtronic, Minneapolis, MN, USA
PerFix Plug, Davol Inc., Warwick, RI, USA
Perfix Light Plug, Davol Inc., Warwick, RI, USA
Plug P, Microval, Saint-Just-Malmont, France
Plug S, Microval, Saint-Just-Malmont, France
Premilene Mesh Plug, B. Braun Melsungen AG, Melsungen, Germany
Proloop Plug, Getinge Group, Wayne, NJ
Repol Plug Cap, Angiologica, S. Martino Sicc., Italy
Repol Plug Flower, Angiologica, S. Martino Sicc., Italy
Self-Forming Plug, Getinge Group, Wayne, NJ
SMPX, THT Bio-science, Montpelier, France
SMPH2, THT Bio-science, Montpelier, France
SurgiMesh WN Easy Plug, Aspide Medical, St. Etienne, France
SurgiPro Plug, Medtronic, Minneapolis, MN, USA
T1 Plug, HerniaMesh, S.R.L., Torino, Italy
T2 Plug, HerniaMesh, S.R.L., Torino, Italy
T3 Plug, HerniaMesh, S.R.L., Torino, Italy
TB plug—Di.pro Medical Devices, Torino, Italy
TEC-T plug—Di.pro Medical Devices, Torino, Italy
TiLENE plug, GfE Medizintechnik, Nuremburg, Germany WEB
TiPLUG—GfE Medizintechnik, Nuremburg, Germany WEB
TP plug, Di.pro Medical Devices, Torino, Italy
Ultrapro Comfort Plug, Ethicon Inc., Somerville, NJ, USA

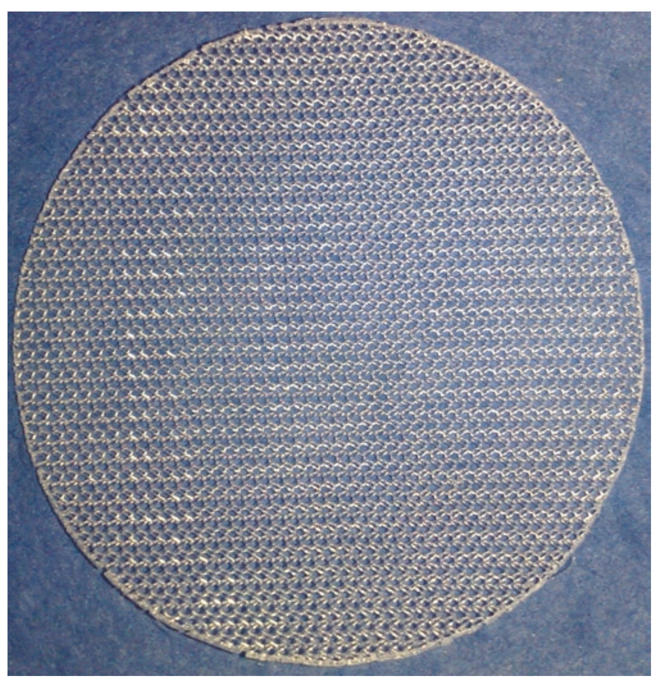

Fig. 7.124 Repol basic

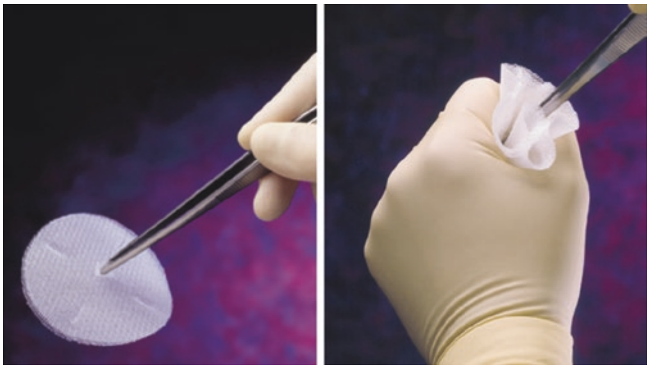

Fig. 7.125 Self-forming plug

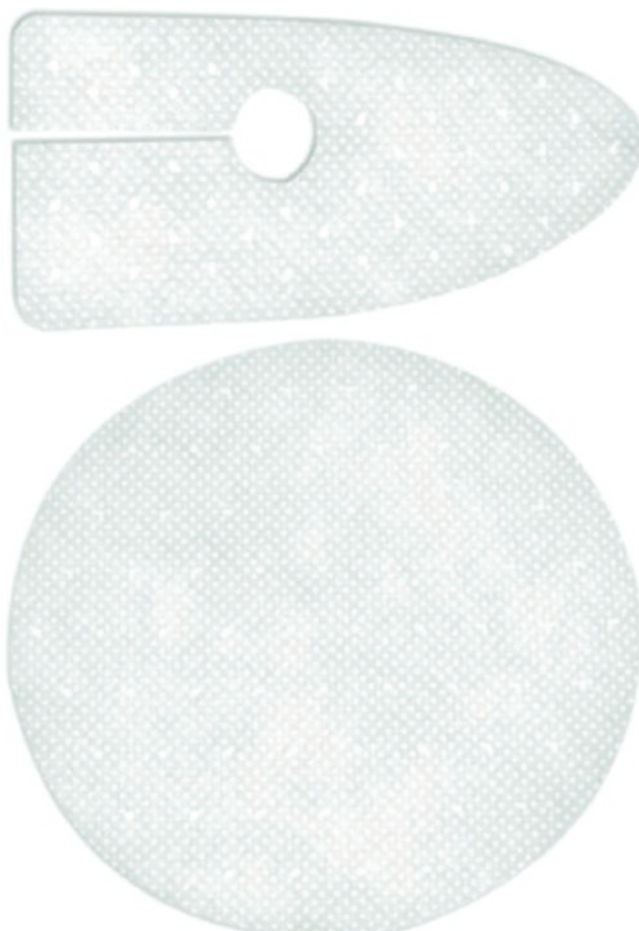

Fig. 7.126 SurgiMesh WN easy plug

of three circular flat meshes in either the ProLite and ProLite Ultra meshes. These are bonded together with a tab on one surface to allow for the grasping of the product by forceps during insertion. This is still soft and pliable so that it assumes the shape of the defect rather than forcing itself into defect. It is available in different sizes. The *Parietex Plug* is available in a 6 or 8 cm size.

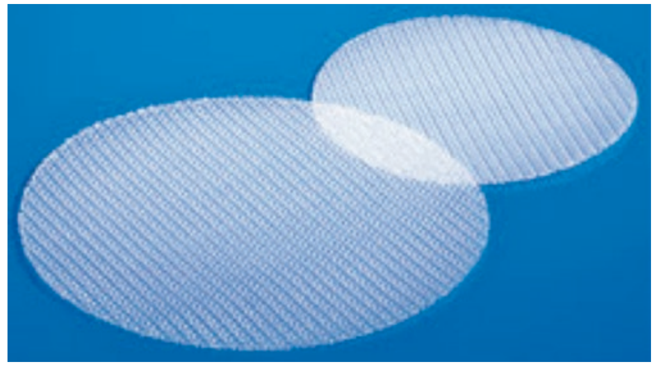

Fig. 7.127 T1

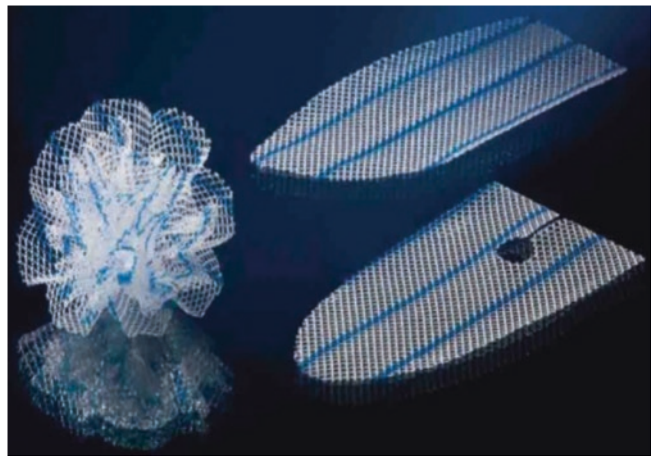

Fig. 7.128 Easy prothes light plug

Fig. 7.129 Easy prothes plug

The *Easy Prothes Plug* is a traditionally designed plug with petals within it. These can be modified, if needed, depending upon the choice of the surgeon. It is available in the 60 g/m^2 and the 40 g/m^2 versions (Figs. 7.128 and 7.129). The *4D Dome* is different from all of the other plug type devices. It is a single layer of PP but it is shaped into a rounded, rather than a pointed, shape (Fig. 7.130). It is constructed of two products, 87% poly-L-lactic acid (absorbable) and 13% polypropylene. The insertion and fixation is the same as the more traditional plugs. Another unique design is that of the *NeT Plug and Patch,* which has the plug portion of the device incorporated into the patch itself (Fig. 7.131). This is designed to eliminate the potential migration that has been rarely seen with plugs. *Parietex Plug and Patch System* is constructed of monofilament polyester and polylactic acid and is therefore partially absorbable (Fig. 7.132). There is another version of this product, the *Parietex Plug Collar with Grips* (Fig. 7.133). This plug has a section on the collar that is of the microgrips similar to that of the Parietex ProGrip products described earlier in the chapter.

The *PerFix Plug* is available in four different sizes (Fig. 7.134). This is the most mature of these commercial products. Because of the trend to lighter weight PP in the repair of hernias, it is also available in the *PerFix Light Plug* (Fig. 7.135). It, too, is available in 4 different sizes. These allow

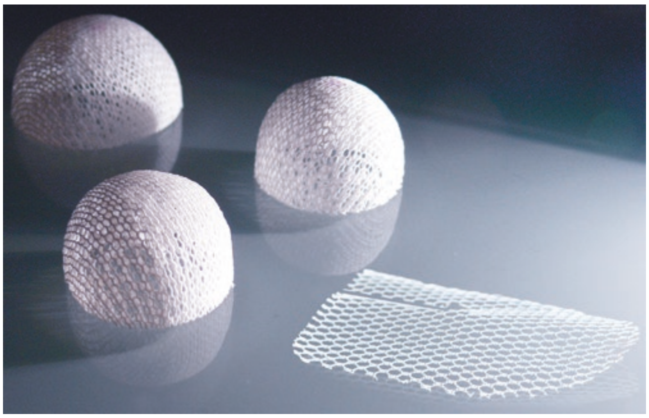

Fig. 7.130 4D dome

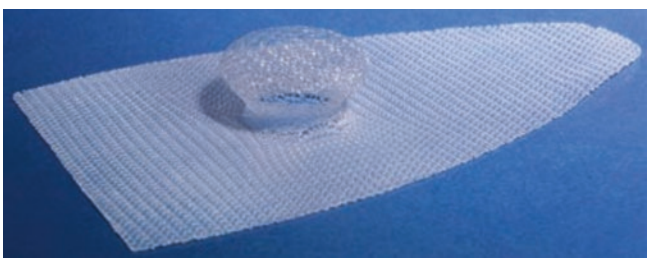

Fig. 7.131 NeT plug and patch

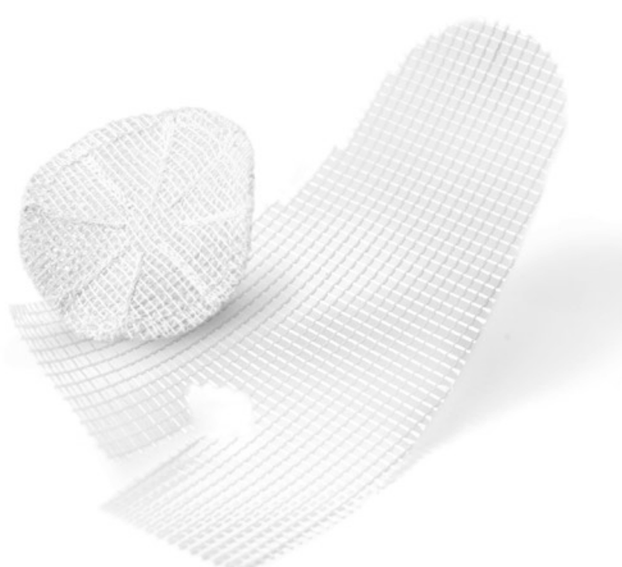

Fig. 7.132 Parietex plug and patch system (All rights reserved. Used with Permission of Medtronic)

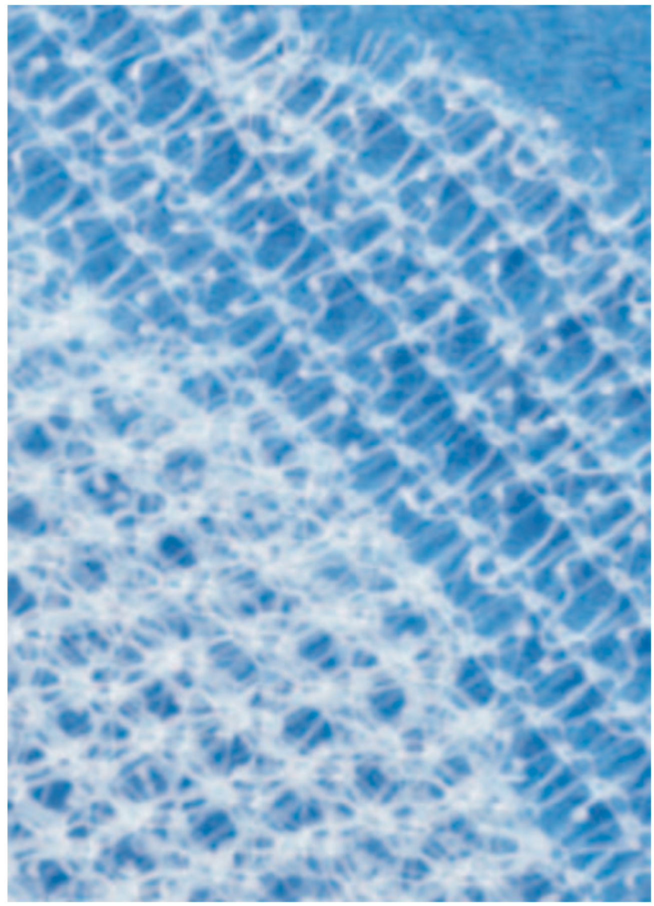

Fig. 7.133 Parietex plug collar with grips (All rights reserved. Used with Permission of Medtronic)

Fig. 7.134 Perfix

for modification of the plug in that the surgeon can remove the inner petals at the time of implantation. Some surgeons have reported good results with completely opening the petals in the preperitoneal space [13]. Other products that are also fluted but do not allow any modification are the *Premilene Mesh Plug* and the *Repol Flower* (Figs. 7.136 and 7.137). The *Proloop Plug* is a pointed type of plug but it lacks any internal structure so it, too, cannot be modified (Fig. 7.138). As shown in the photo, this product is quite different in appearance than the other plug devices. Although preformed into a cylindrical shape, it is very supple and conforms to the defect into which it is inserted. *Plug P* is a PP plug that can be adjusted with the pull of the string to confirm to the inguinal opening (Fig. 7.139). *Plug S* differs from the Plug P in that it is similar to the other unadjustable preformed and preshaped plugs listed in this section.

Surgipro mesh that was described above (Table 7.11) is also available as *Surgipro plug and patch* system (Fig. 7.140). *SMPX* and *SMPH2* are the standard weight or lightweight version of a plug. The *SMPX* is adjustable while the other is not (Fig. 7.141). There is another *SurgiMesh WN EasyPlug* but this device is a preformed plug with variable geometry and is adjustable to the size of the defect (Fig. 7.142). A purse-string suture is part of the device to help in sizing of the plug.

The *Bard Mesh* Dart, *Repol Plug Cap*, and the *T2 Plug* represent a concept that combines a small piece of a round, flat PPM atop a cone shaped plug (Figs. 7.143, 7.144, and 7.145). These devices are also significantly different from all of the other plugs. The *T3 Plug* has a rectangular piece of mesh affixed to it (Fig. 7.146). There are differing

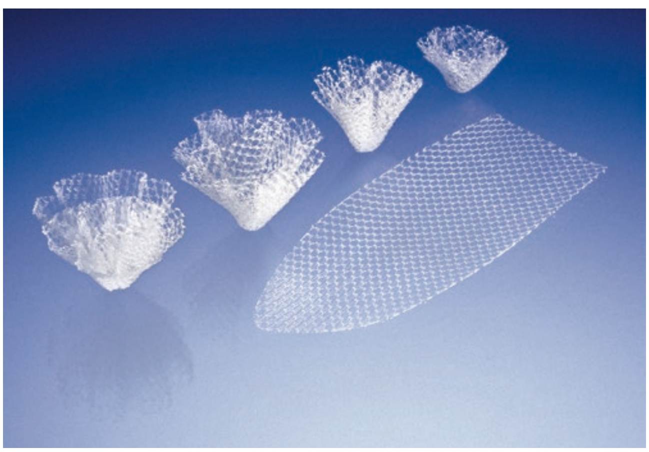

Fig. 7.135 Perfix light

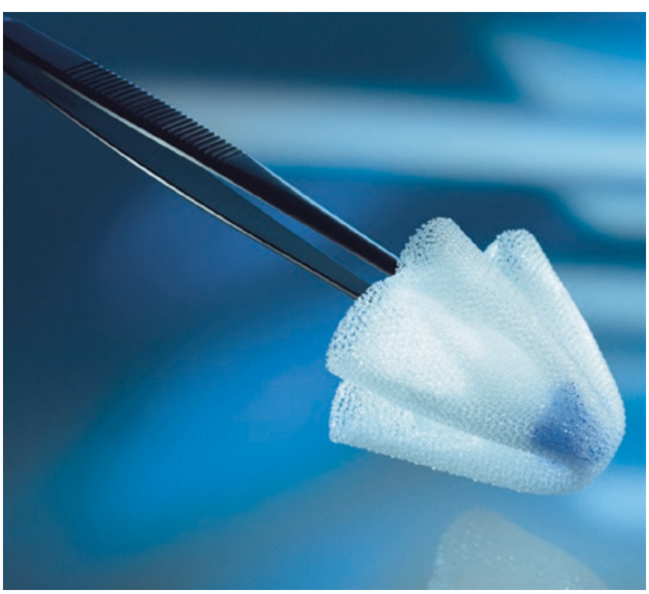

Fig. 7.136 Premilene mesh plug

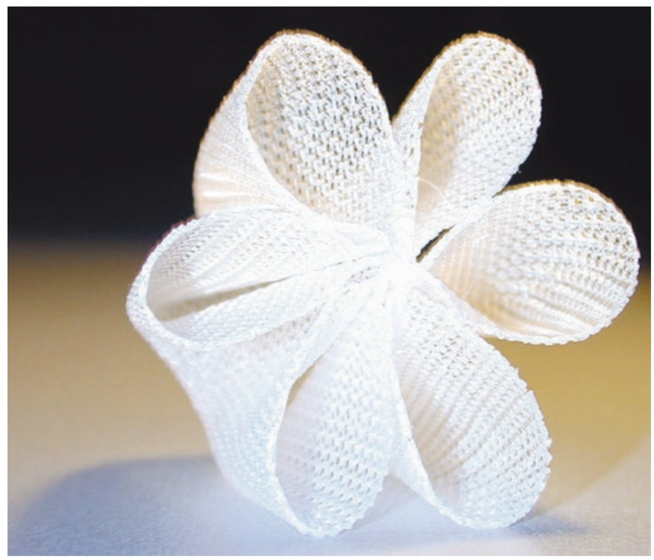

Fig. 7.137 Repol flower

Fig. 7.138 Proloop

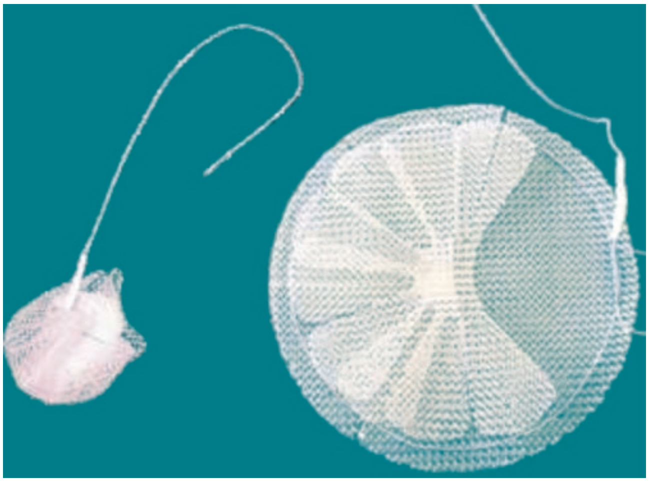

Fig. 7.139 Plug P

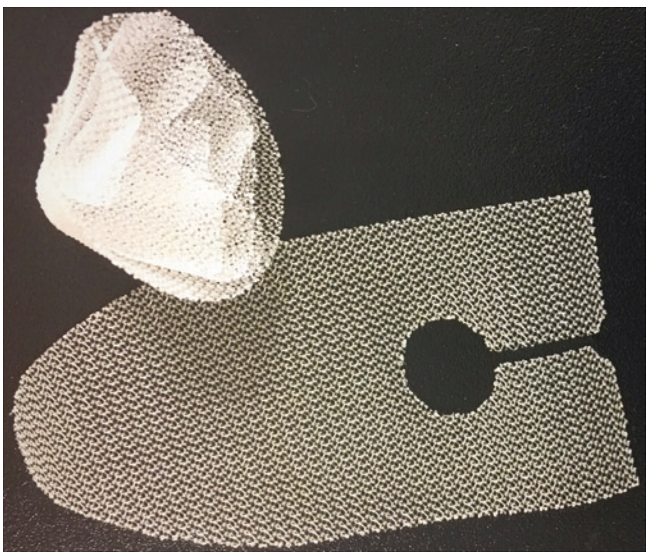

Fig. 7.140 Surgipro plug (All rights reserved. Used with Permission of Medtronic)

Fig. 7.141 SMPX

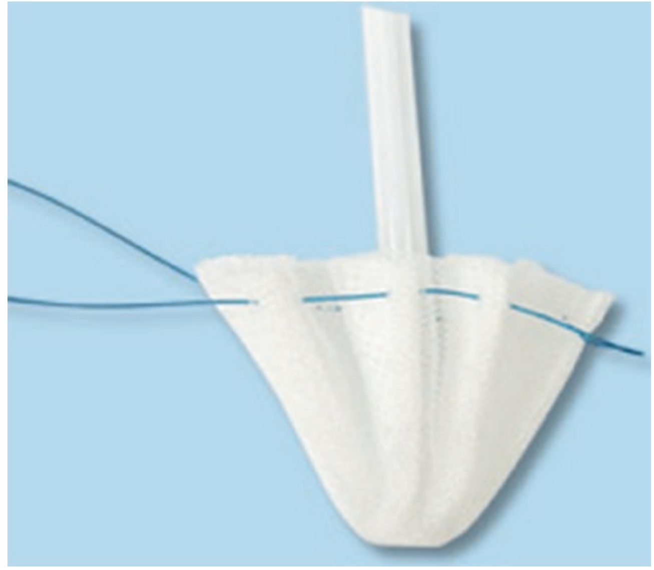

Fig. 7.142 SurgiMesh WN EasyPlug

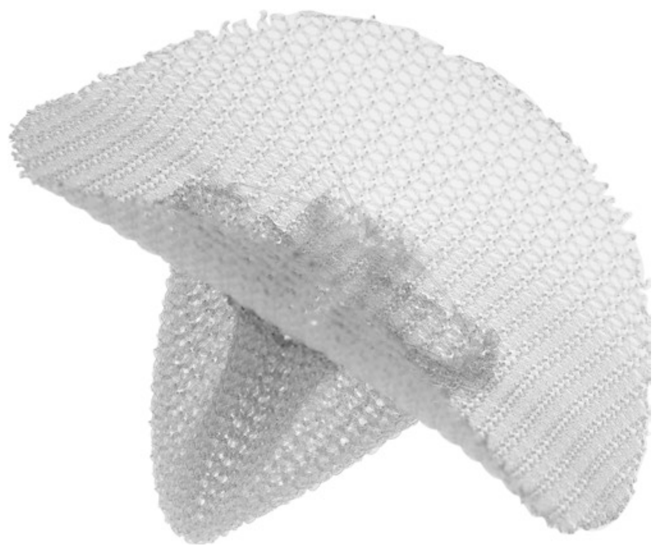

Fig. 7.143 Bard mesh dart

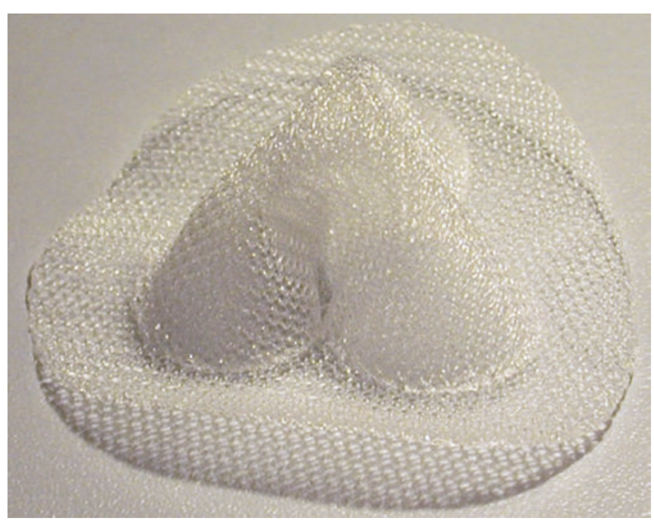

Fig. 7.144 Repol plug cap

sizes that are chosen based upon the size of the defect. With any of these three devices, one can insert the plug component into the preperitoneal space and use the flat portion to sew to the fascial edges as a small onlay or underlay.

The *TEC-T* plug is made in the conical shape and is fluted as are most plugs but of an ultra lightweight PP material (Fig. 7.147, left). There is a second design of the *TB* plug that has lightweight petals and a medium weight PPM atop the cone (Fig. 7.147, right). The *TP* plug is another of the "self-forming" plugs of PPM (Fig. 7.148). The *TiLENE Plug* is of the TiMesh product that has been previously described (Fig. 7.149). It is a flat product that will conform to the hernia defect as it is inserted but differs in appearance from all of the other "self-forming" plugs. The outer layers of the petals are medium weight PP and the inner petals are a lighter weight PP. *TiPLUG* is also made of TiMESH (Fig. 7.150). It has a flap through which the cord structures are to be placed. As such, it differs from all of the other plugs listed. The *TP* plug is a rounded mesh with or without an eccentric hole and with or without a slit to that hole. The *Ultrapro Comfort Plug* is made from the previously described Ultrapro mesh (Fig. 7.151). The absorbable and nonabsorbable portions are connected by the absorbable poliglecaprone-25 fibers. It is supplied with an onlay patch.

Fig. 7.145 T2

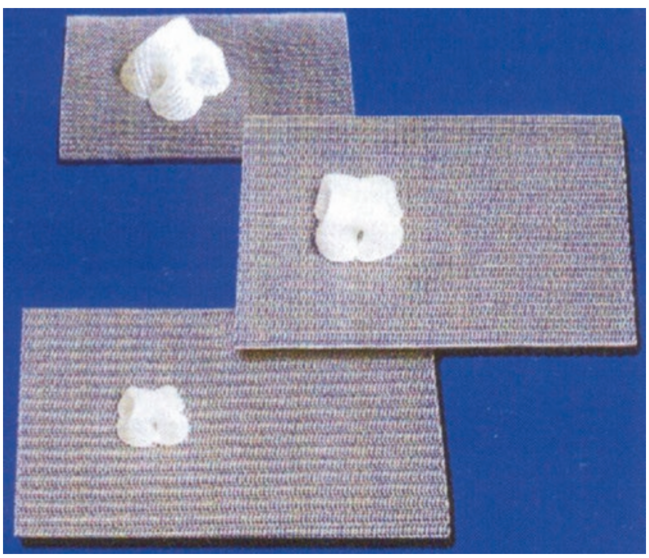

Fig. 7.146 T3

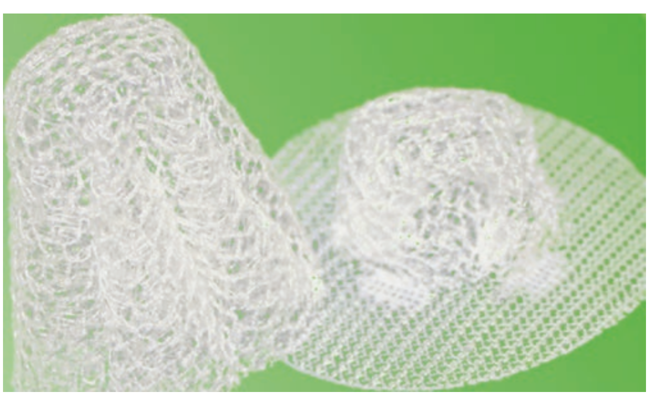

Fig. 7.147 TEC-T (left) and TB (right)

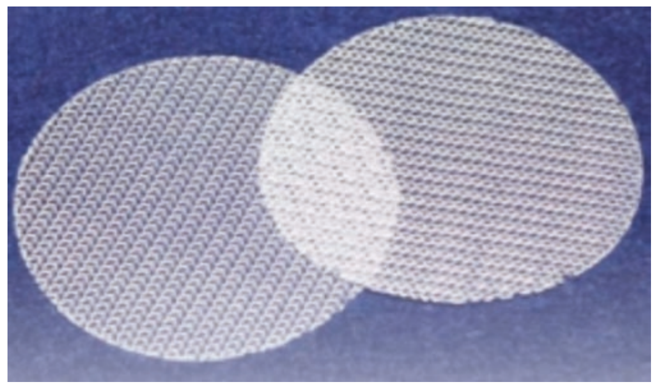

Fig. 7.148 TP

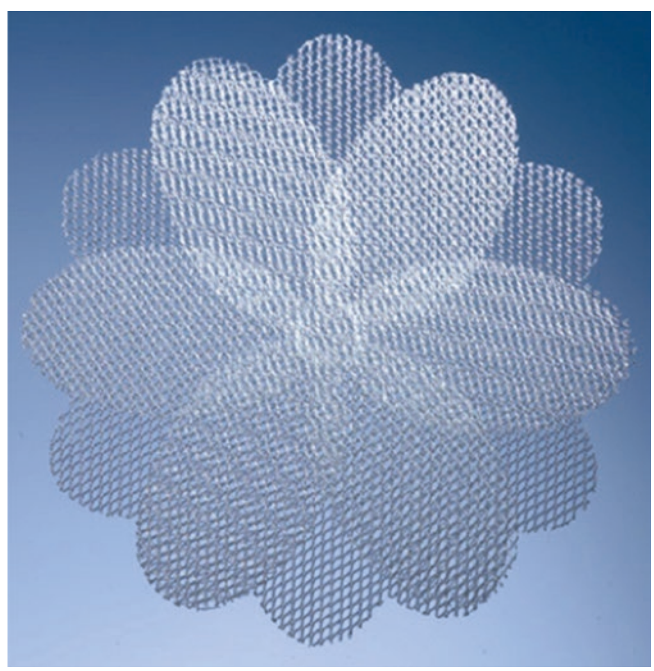

Fig. 7.149 TiLENE Plug

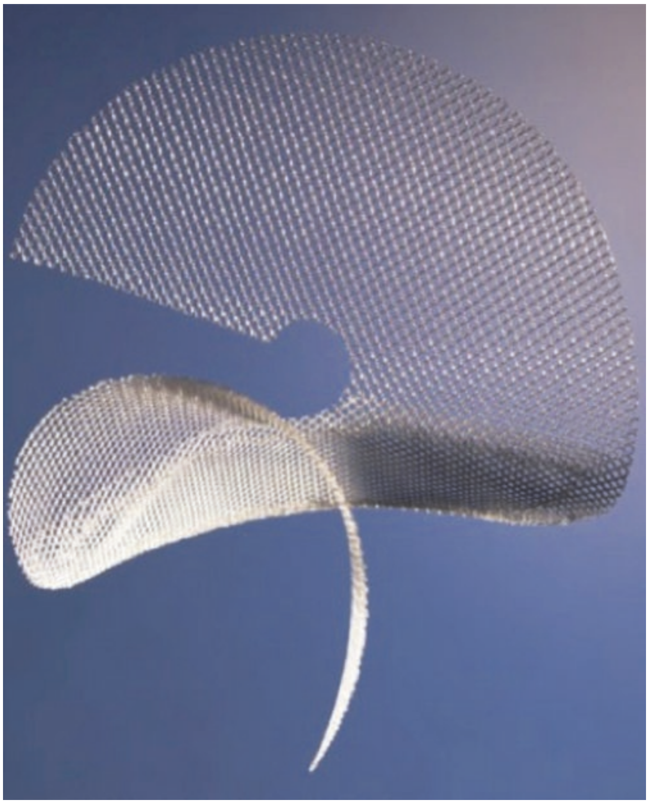

Fig. 7.150 TiPLUG

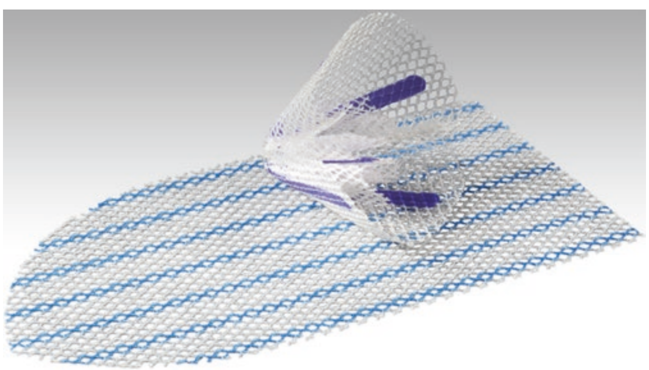

Fig. 7.151 Ultrapro comfort plug and patch (Image courtesy of Ethicon, Inc.)

Extraperitoneal Prosthetic Devices for Open Inguinal Hernioplasty

The posterior repair of open inguinal hernias is based upon the approach into the preperitoneal space. The use of a preformed prosthetic device in this space represents an emulation of the Stoppa repair and the giant prosthetic repair of the visceral sac of Wantz. The products that have been manufactured for this concept are not "giant" prostheses, however (Table 7.18).

Table 7.18 Extraperitoneal inguinal devices

Easy Prothes Preperitoneal Repair Patch, TransEasy Medical Tech. Co.Ltd, Beijing, China
Easy Prothes Light Preperitoneal Repair Patch, TransEasy Medical Tech.Co.Ltd, Beijing, China
Easy Prothes Partially Absorbable Preperitoneal Repair Patch, TransEasy Medical Tech. Co. Ltd, Beijing, China
Oval Preshaped Mesh, Herniamesh, Torino, Italy
OnFlex, Davol Inc., Warwick, RI, USA
Modified OnFlex, Davol Inc., Warwick, RI, USA
PB, Microval, Saint-Just-Malmont, France
Prolene Hernia System, Ethicon Inc., Somerville, NJ, USA
Prolene 3D Patch, Ethicon Inc., Somerville, NJ, USA
Rebound HRD Shield, ARB Medical, Minneapolis, MN, USA
*SM2+,*THT Bio-Science, Montpelier, France
T5 mesh, Herniamesh, Torino, Italy
Ultrapro Hernia System, Ethicon Inc., Somerville, NJ, USA

The *Easy Prothes Preperitoneal Repair Patch* also has an underlay portion but instead of the flat sheet of PP, there are petals that can be stitched to the fascial edges of the hernia itself (Fig. 7.152). This is similar to the plug and patch repair as the product is supplied with an onlay patch to place underneath the external oblique. There is a lightweight version as the *Easy Prothes Light Preperitoneal Repair Patch* that has straps and pockets to facilitate placement (Fig. 7.153). *Easy Prothes Partially Absorbable Preperitoneal Repair Patch* is similar to these products but is constructed of a partially absorbable material (PP and PGCL) that was described earlier in this chapter (Table 7.16). This is available as a round patch with four petals or with an oval base with pockets and a tether (Figs. 7.154 and 7.155).

Oval Preshaped mesh is to be used in the Kugel technique of extraperitoneal hernia repair (Fig. 7.156). It is a very heavy and rigid material. The *Onflex* is designed for placement exclusively in the preperitoneal space (Fig. 7.157). It has an added incomplete "ring" of polydioxanone. The mesh can be cut between this opening to allow for exit of the cord structures, if desired. It also is available as the *Modified Onflex* with an attached tether of PP and is to be used with an onlay (Fig. 7.158). Both of these are available in two different sizes.

The *Prolene Hernia System* is similar to the Easy Prothes (Fig. 7.152) in that it is designed as a connected another mesh product (Fig. 7.159). The difference between the two products is that the older Prolene Hernia System (PHS) has a connector piece that attaches the rounded underlay (extraperitoneal) portion and the elliptical (onlay) portion. There are three sizes of the PHS, medium, large, and extended. The choice of the size will depend upon the size and type of defect as well as the size of the patient and location of the hernia. These have also been used for umbilical and ventral hernias. *SM2+* has previously

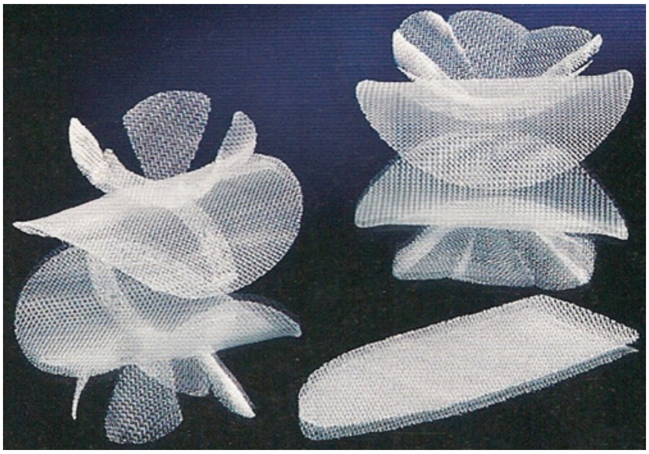

Fig. 7.152 Easy prothes preperitoneal repair patch

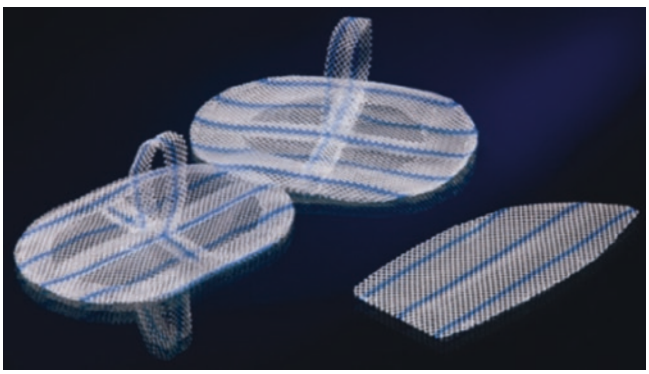

Fig. 7.153 Easy prothes light preperitoneal repair patch

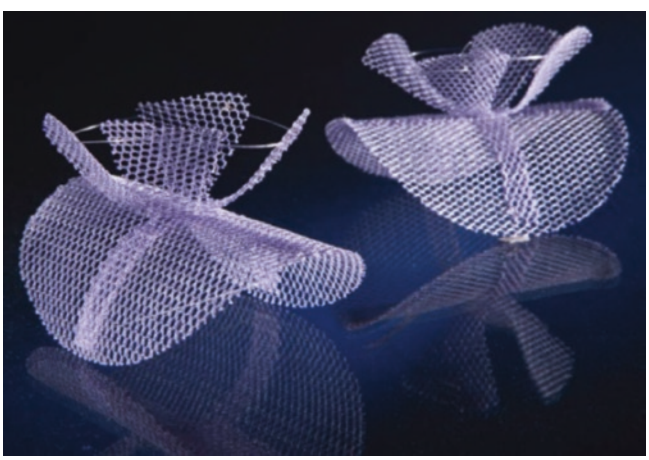

Fig. 7.154 Easy prothes partially absorbable preperitoneal repair patch—round

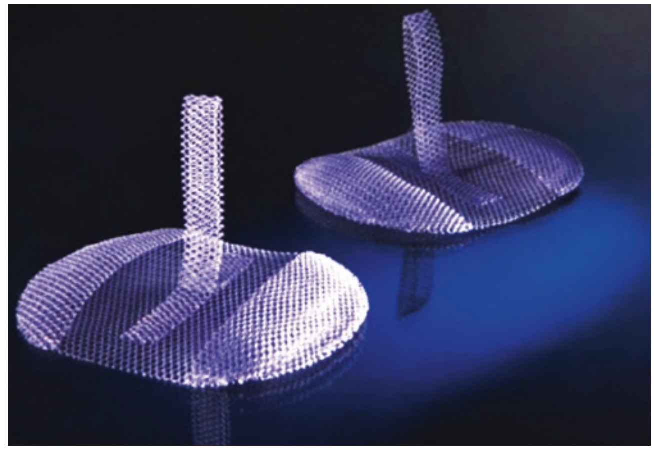

Fig. 7.155 Easy prothes partially absorbable preperitoneal repair patch—oval

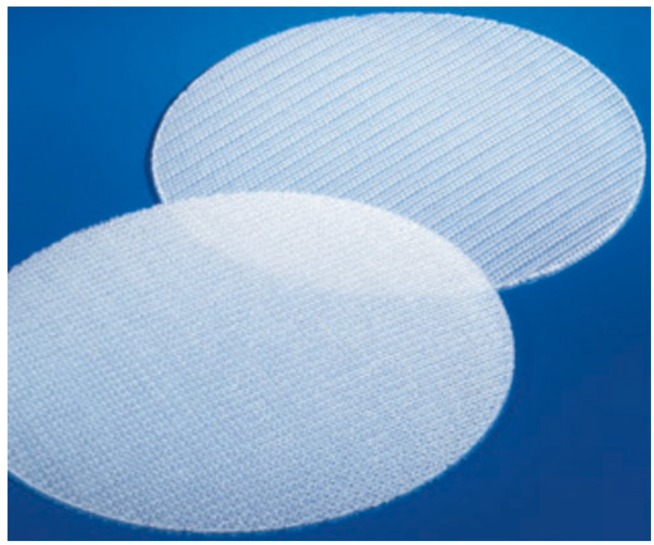

Fig. 7.156 Oval Preshaped

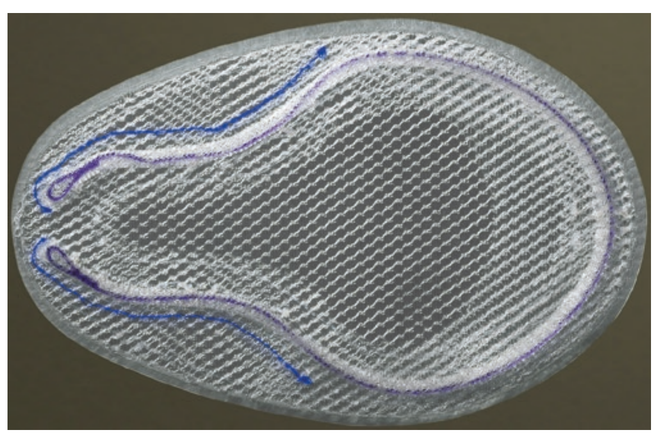

Fig. 7.157 Onflex

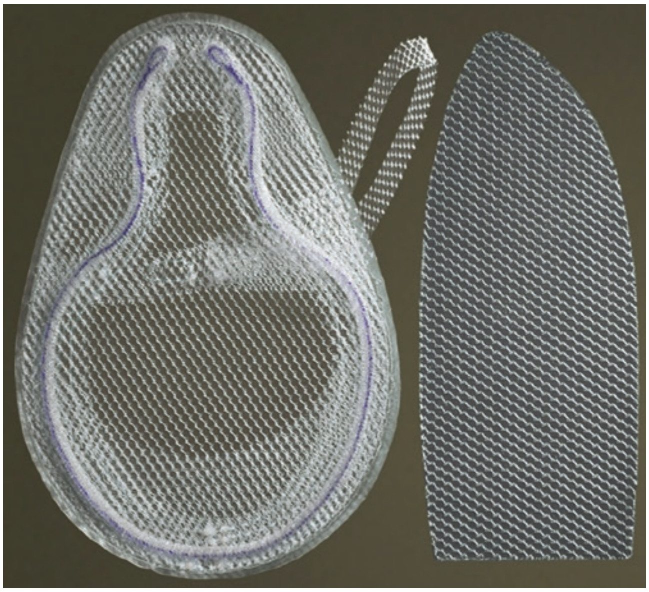

Fig. 7.158 Modified Onflex

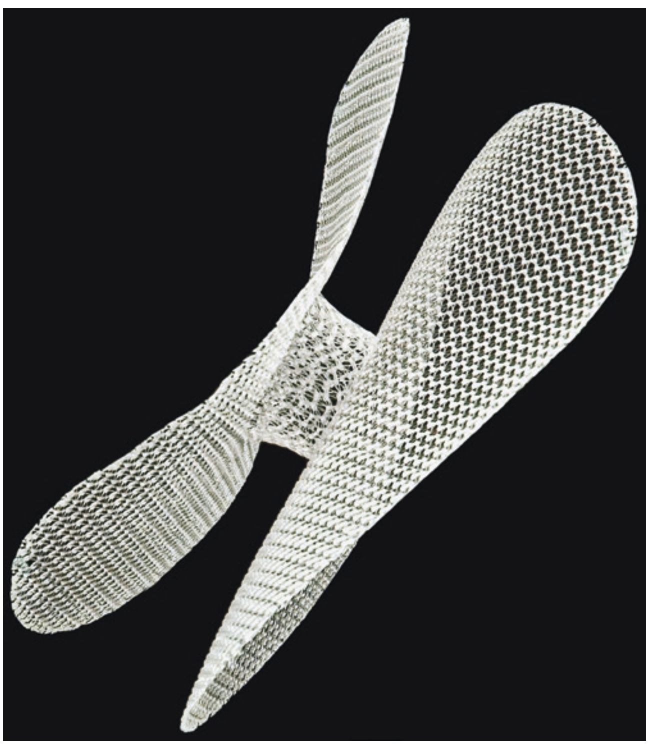

Fig. 7.159 Prolene hernia system (Image courtesy of Ethicon, Inc.)

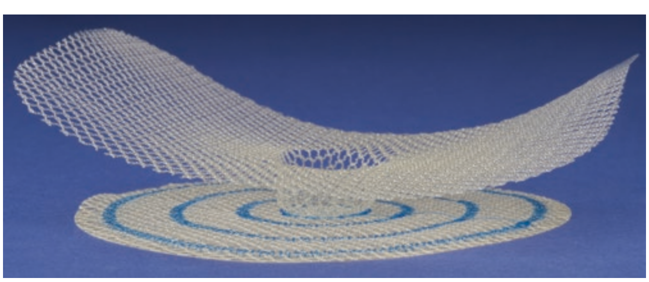

Fig. 7.160 Ultrapro hernia system (Image courtesy of Ethicon, Inc.)

been described in the flat mesh device section above. It is polyester and impregnated PUR (Fig. 7.87). The *Ultrapro Hernia System* is a combination product that is made from Ultrapro flat mesh that has the identical shape as the PHS that has additionally incorporated poliglecaprone-25 into the underlay portion (Fig. 7.101). This absorbable component of the Ultrapro material will leave behind a very lightweight PPM to repair the hernia (Fig. 7.160).

The *Prolene 3D Patch* is a three-dimensional device, which possesses two different portions of this product (Fig. 7.161). The diamond shaped portion is inserted into the preperitoneal space. The single pull of the suture causes the diamond to flatten out underneath the tranversalis fascia. The overlay portion is then secured as in the tension-free repairs. It is available in two sizes of the diamond portion and with or without a pre-shaped overlay. The *PB* inguinal implant possesses characteristics of the PHS and the Prolene 3D patch (Fig. 7.162). It is available in standard (90 gm/m^2) or light weight (60 gm/m^2) and in three different sizes. With these two corrections, this should not read "The *PB* inguinal implant possesses characteristics of the PHS and the Prolene 3D patch (Fig. 7.162). It is available in standard (90 gm/m^2) or light weight (60 gm/m^2) and in three different sizes. *Rebound HRD Shield* is a rather unique concept in hernia repair (Fig. 7.163). This device is designed to maintain the shape of the product after introduction into the preperitoneal space by the incorporation of a self-expanding nitinol alloy frame at the perimeter of the PP mesh. Because of the presence of this nitinol, this is the only prosthesis that can be visualized on radiologic studies postoperatively. *T5 mesh* is positioned in the extraperitoneal plane and is to be used with one of the other Hertra products (Fig. 7.164). It is preshaped with a keyhole to allow for passage of the cord structures.

Pre-Shaped Products for Laparoscopic/ Robotic Inguinal Hernioplasty

The history of laparoscopic repair of inguinal hernias involved flat meshes of one type or another. This continues to be a frequently used prosthetic product for this operation (Tables 7.11 and 7.12). There are, however, a number of devices that have been constructed for this procedure (Table 7.19). These all attempt to ease the placement of the prosthetic over the myopectineal orifice and/or serve to conform to the anatomic configuration at that site of the repair. These can be placed with either the transabdominal preperitoneal (TAPP) or totally extraperitoneal (TEP) approaches. A few are manufactured to make fixation with any type of fastener unnecessary.

The *3D Anatomic* implant has very deep curves that are designed to exactly fit the curves of the inguino-pelvic anatomy (Fig. 7.165). There is a mark in the inferior internal edge of the prosthetic to aid in positioning as there is a right and left product. For the TEP approach, no fixation required. The *3D Max* and *3D Max Light* products are similar in shape

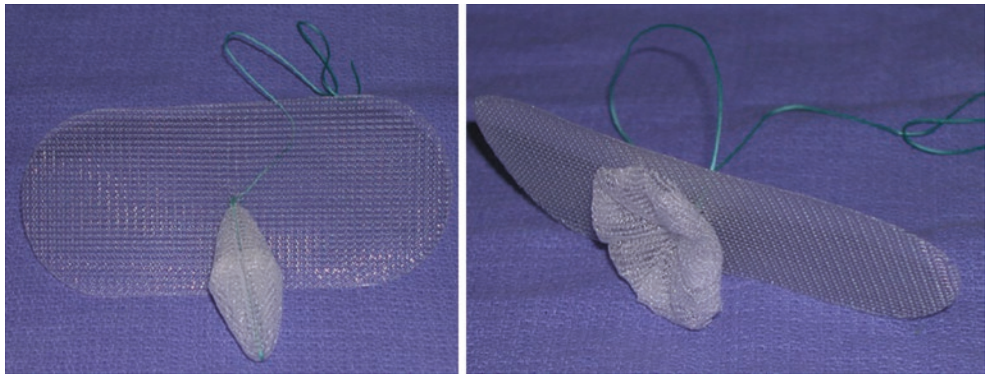

Fig. 7.161 Prolene 3D patch (Image courtesy of Ethicon, Inc.)

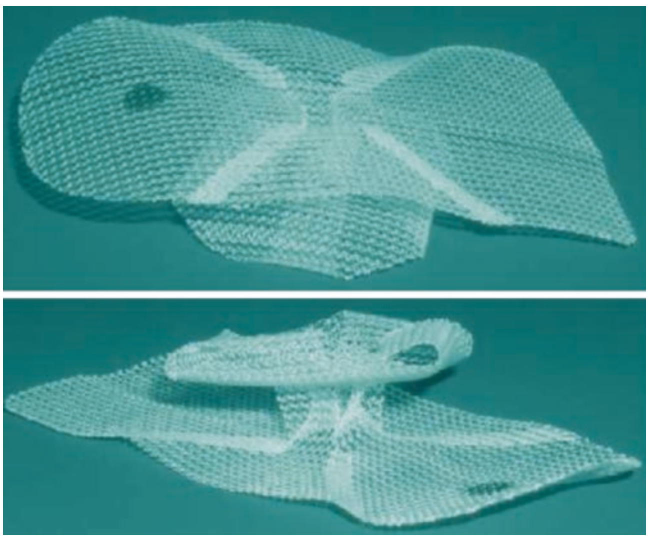

Fig. 7.162 PB inguinal implant

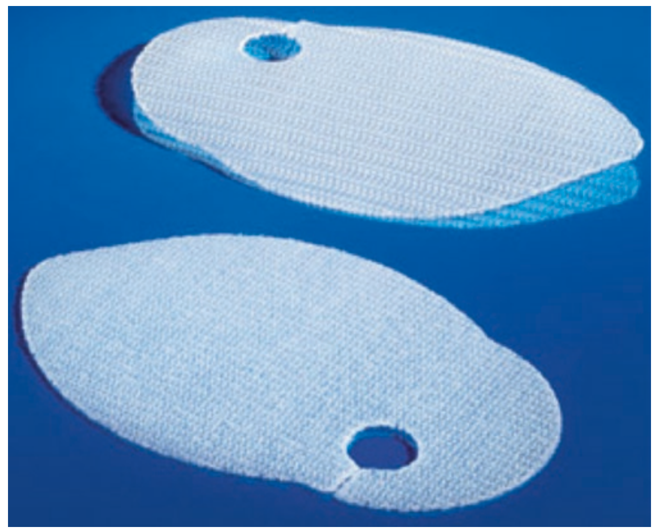

Fig. 7.164 T5 mesh

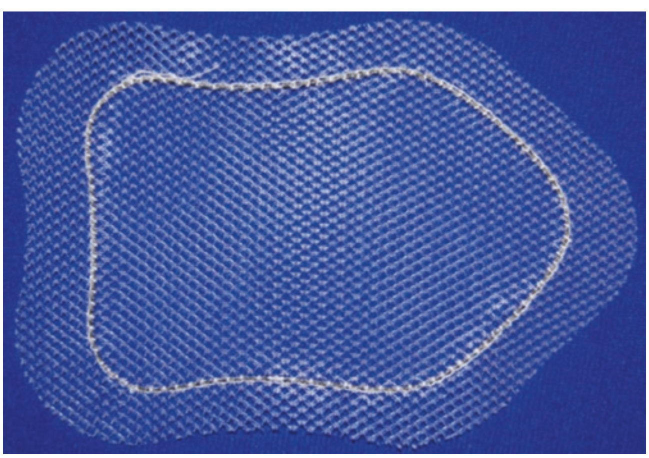

Fig. 7.163 Rebound HRB shield

and sizes (medium, large, and extra large). They differ in the weight of the PP within each product. The former is of the heavy weight Bard mesh and the latter is of the lighter Bard Soft Mesh. It is quite apparent in the figure that the lower product is the lighter one (Fig. 7.166). Both have an "M" and an arrow on the medial aspect of the product to indicate the positioning of the prosthesis. These are curved to conform to the shape of the pelvis. Because of this curved shape, there is a right and left product. There is also an indentation on the inferior aspect of the product to indicate the location of the iliac vessels. There is no required fixation with the heavier weight product in either the TAPP or TEP approaches.

The 4D Mesh product has been described above but they have manufactured a product for laparoscopic repair of these hernias (Fig. 7.167). It is of the same composition of the other product but is shaped for this technique. *CO3A* and *CO3+* are of similar material that has been previously described in other sections (Table 7.12) in the chapter (Fig. 7.83). They both are POL with impregnated PUR and have knitted grips to hold the products in place. These have been configured in many different shapes for laparoscopic inguinal and ventral hernia repair. *CO3+* is a flat sheet but *CO3A* is recommended for laparoscopic inguinal hernia repair due its specific configuration (Fig. 7.168).

C-QUR FX has a light coating of the Omega 3 fatty acid that the other C-QUR products possess (Fig. 7.169). *C-QUR CentriFX* is made in a laparoscopic shape (Fig. 7.170). *C-QUR CentriFX* is also part of the ProLite materials coated with O3FA but is shaped for use in either a left or right laparoscopic repair of inguinal hernias. It is one of the few products that can be interchanged in such a fashion. The only one of these materials that is partially absorbable is that of the *Easy Prothes Partially Absorbable 3D Mesh* (Fig. 7.171). It is made of the same material as the Easy Prothes Partially Absorbable Flat product PAS noted above (Fig. 7.115). The *JG inguinal* implant also has an anatomic shape that includes a raised edge for the cord structures (Fig. 7.172). There is a round black mark to indicate the inferior internal edge, as there is a left and right product. This is available in a standard or lightweight version.

Parietex Lap ProGrip Anatomic is POL with microgrips that has been described above but it is configured as either the left or right for laparoscopic repair specifically (Fig. 7.173). *Parietex Anatomical Mesh* is of the same three-dimensional weave of POL as the other Parietex products on the lower portion of the product making if softer and is designed to lie on the iliac vessels (Fig. 7.174). Its shape is similar to the ProGrip Anatomic but it does not have the micrograps. The portion that is placed on the posterior aspect of the inguinal floor is a more rigid two-dimensional weave to aid in handling. It is generally used with the application of some type of fixation but some surgeons do not see the need to add these fasteners. It has a left and right design. It is available with an embedded suture to ease insertion and an included flap to place the cord structures (Fig. 7.175). The *Folding Mesh with Suture* is shaped as a flat polyester mesh with rounded edges (Fig. 7.176). To aid in the insertion and deployment of this mesh in the preperitoneal space during the laparoscopic repair there is a suture that is woven through the material. This suture is placed such that when it is pulled tight the mesh will be drawn into a small somewhat cylindrical shape. It is then placed into the preperitoneal space whereupon the suture is cut, allowing the mesh to resume its original shape. It can then be positioned appropriately. This device is also available with a slit if one desires to place the cord structures within the slit.

PS implant is a nonwoven PP material that is rather ovoid in shape (Fig. 7.177). It can be used in the repair of either the left or right inguinal hernia. It can be used with or without

Table 7.19 Pre-shaped products for laparoscopic inguinal hernia repair

3D Anatomic, Microval, Saint-Just-Malmont, France
3D Max, Davol, Inc., Warwick, RI, USA
3D Max Light, Davol, Inc., Warwick, RI, USA
4D Laparoscopic Mesh, Cousin Biotech, Wervicq-Sud, France
CLAP, Di.pro Medical Devices, Torino, Italy
*CO3A,*THT Bio-Science, Montpelier, France
*CO3+,*THT Bio-Science, Montpelier, France
C-QUR FX, Getinge Group, Wayne, NJ
C-QUR CentriFX, Getinge Group, Wayne, NJ
Easy Prothes Partially Absorbable 3D Mesh, TransEasy Medical Tech.Co.Ltd, Beijing, China
JG Inguinal, Microval, Saint-Just-Malmont, France
Parietex ProGrip Anatomical, Medtronic, Minneapolis, MN, USA
Parietex Anatomical Mesh, Medtronic, Minneapolis, MN, USA
Parietex Anatomical Mesh with Suture, Medtronic, Minneapolis, MN, USA
Parietex Folding Mesh with Suture, Medtronic, Minneapolis, MN, USA
PS, Microval, Saint-Just-Malmont, France
Premium, Cousin Biotech, Wervicq-Sud, France
SMA, THT Bio-Science, Montpelier, France
SM2+, THT Bio-Science, Montpelier, France
SMH2+, THT Bio-Science, Montpelier, France
SMH2A, THT Bio-Science, Montpelier, France
SM3, THT Bio-Science, Montpelier, France
SM3+, THT Bio-Science, Montpelier, France
SurgiMesh WN, Aspide Medical, St. Etienne, France
Visilex, Davol, Inc., Warwick, RI, USA

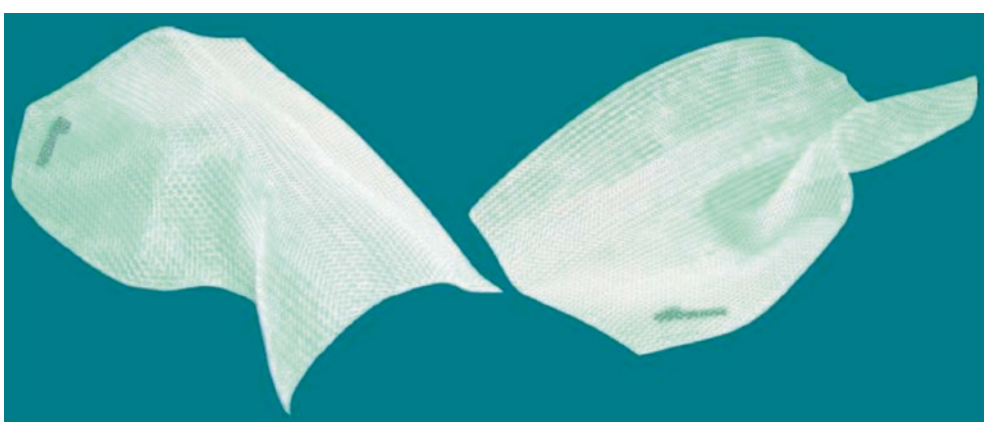

Fig. 7.165 3D anatomic

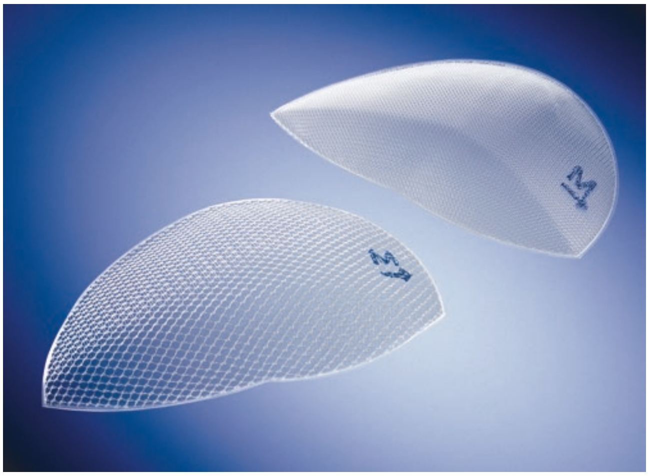

Fig. 7.166 3D Max regular (right) and light (left)

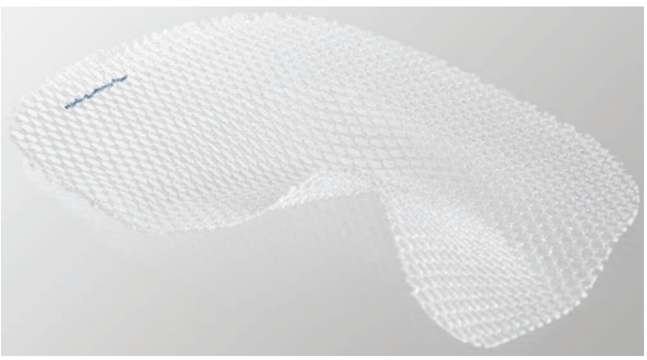

Fig. 7.167 4D laparoscopic

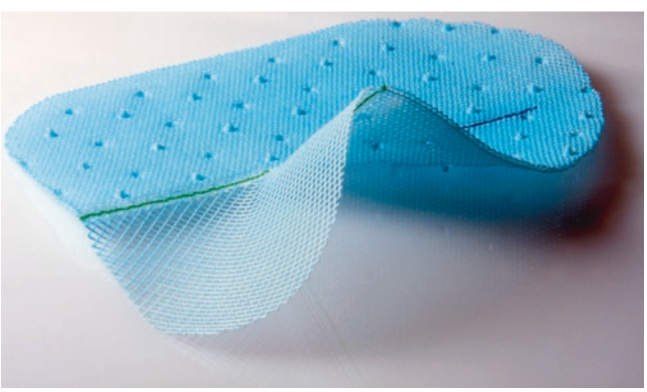

Fig. 7.168 CO3A

Fig. 7.169 C-Qur FX

Fig. 7.170 C-Qur CentriFX

fixation. *Premium* mesh has also been described above for open inguinal but it is available in various shapes for the laparoscopic repair (Fig. 7.178). There is a blue polypropylene suture to mark the medial side of the product. *SMA* and *SMH2* products are similar products. They are both anatomically shaped but the *SMA* is made of polyester and impregnated PUR (Fig. 7.179). It is preferably used in the TEP repair. *SM2+* has previously been described in the flat mesh device section above. It is polyester and impregnated PUR and shaped for this repair (Fig. 7.180). *SMH2+* is a product that has a shape similar to the 3D Max and the Easy Prosthes 3D Mesh (Fig. 7.181). It differs in that it is a combination product of permanent material, PP, and impregnated polyurethane (PUR). *SMH2A* is also made of PP and PUR but

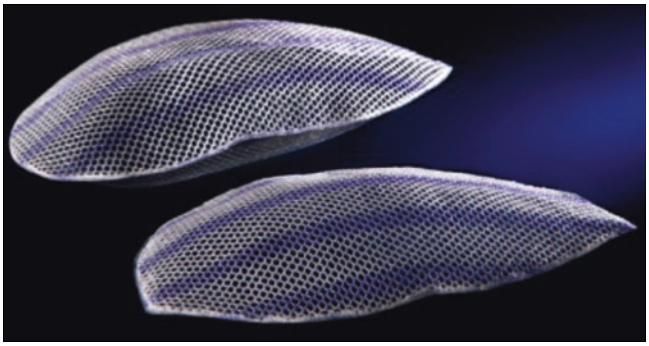

Fig. 7.171 Easy prothes 3D

Fig. 7.172 JG inguinal

Fig. 7.173 Lap ProGrip anatomic (All rights reserved. Used with Permission of Medtronic)

like the *SMA*, it should be used preferably in the TEP approach to inguinal hernia repair due to its shape (Fig. 7.182). *SM3* and *SM3+* have been described in the flat mesh section above (Figs. 7.88 and 7.89). They are configured for use in the laparoscopic repair of inguinal hernias.

SurgiMesh WN has the same structure as that of most of the SurgiMesh products listed in the prior tables (Fig. 7.67).

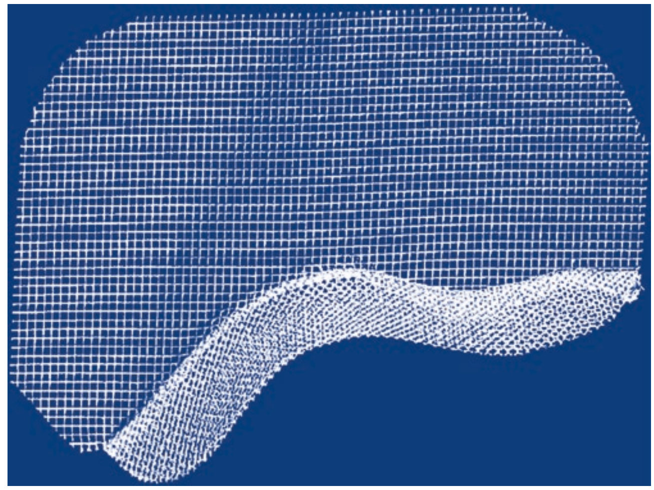

Fig. 7.174 Parietex anatomic (All rights reserved. Used with Permission of Medtronic)

Fig. 7.175 Parietex anatomic with suture (All rights reserved. Used with Permission of Medtronic)

There are two laparoscopic products. One is a single flat square sheet with a rounded portion cutout on one corner. This is to be placed at Cooper's ligament. The other product has a keyhole and a flap to allow the product to be placed onto the posterior wall of the inguinal canal with the cord structures placed in the keyhole. The flap then covers the slit and keyhole to seal this defect in the mesh. *Visilex* is flat Bard mesh that has a stiffer border designed to ease the manipulation of the product in the preperitoneal space (Fig. 7.183).

Prostheses for Incisional and Ventral Hernioplasty with an Absorbable Component

The original impetus behind the development of these products was the popularity of the laparoscopic methodology. In general, however, all of these prosthetic devices can or have been used in both open and laparoscopic

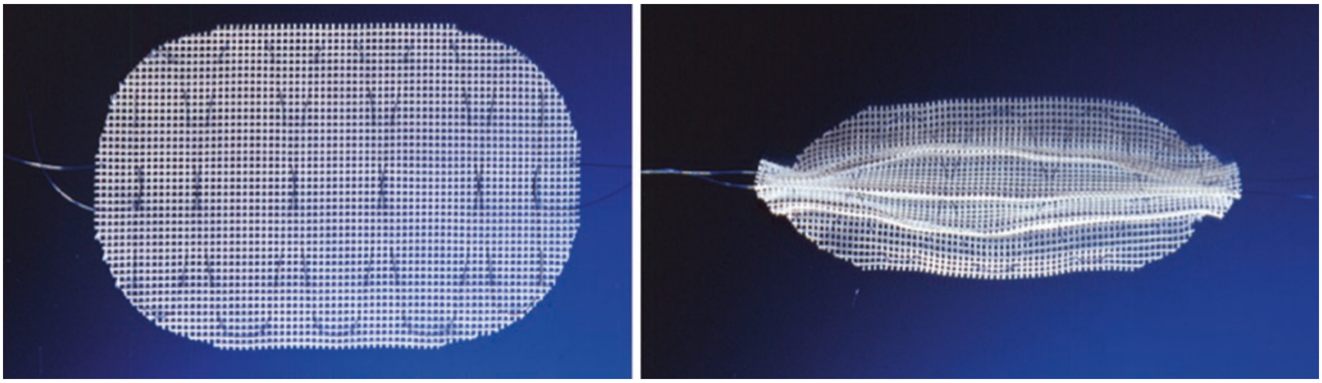

Fig. 7.176 Folding mesh with suture (All rights reserved. Used with Permission of Medtronic)

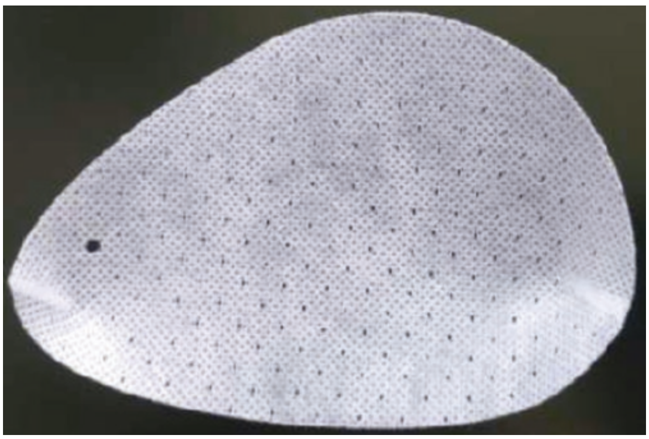

Fig. 7.177 PS

Fig. 7.178 Premium laparoscopic

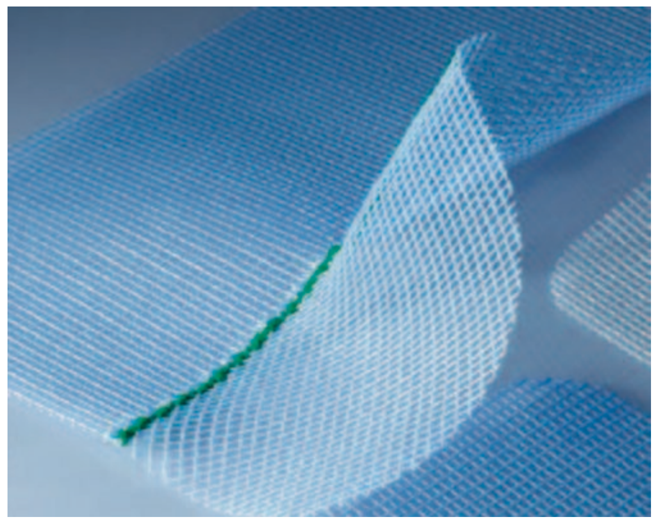

Fig. 7.179 SMA

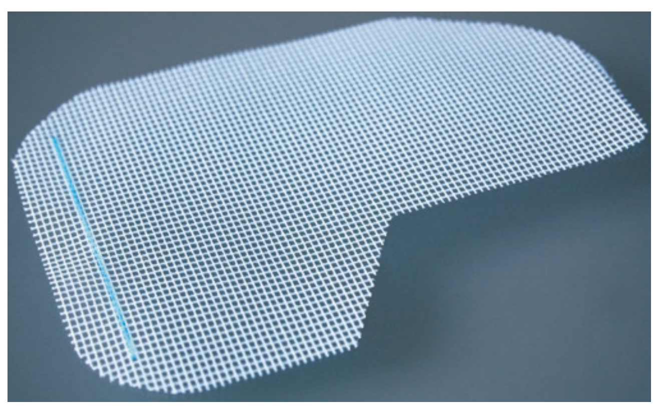

Fig. 7.180 SM2+

incisional hernioplasties. All of these have the common purpose to repair the hernia and prevent the development of adhesions with the attendant complications associated with this result of the healing processes. These are generally referred to as "tissue-separating" meshes as they create an absorbable barrier between the permanent product and the viscera (Table 7.20). They are available in a variety of shapes and sizes, which are too many to enumerate here. The reader is referred to the individual company for further information.

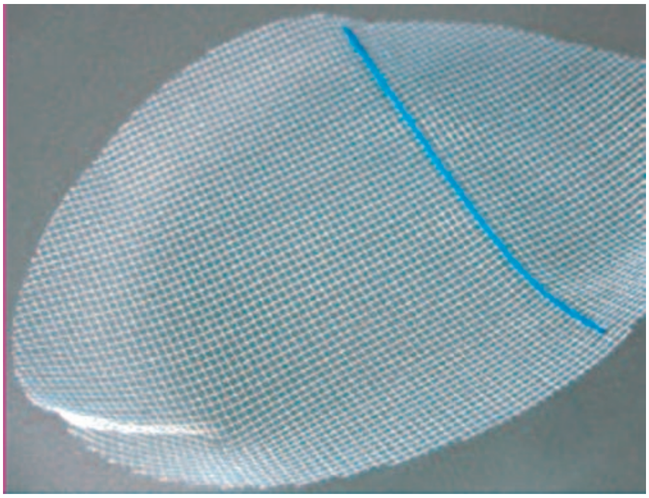

Fig. 7.181 SMH2+

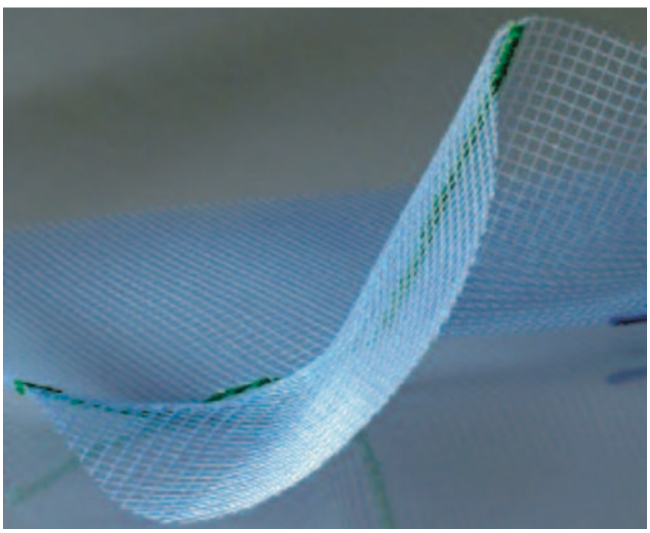

Fig. 7.182 SMH2A

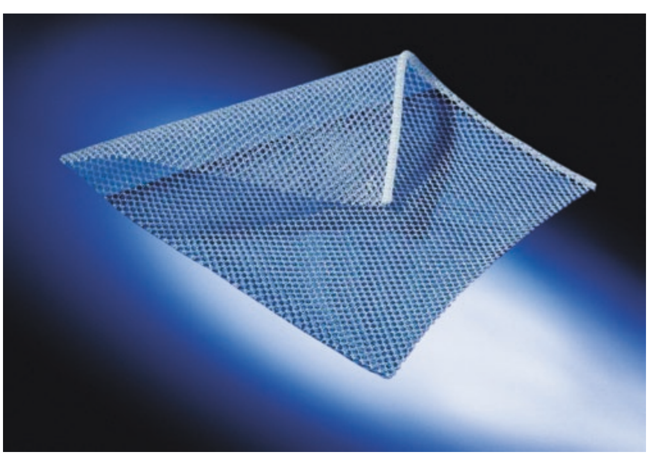

Fig. 7.183 Visilex

Table 7.20 Prostheses with an absorbable component

Adhesix, Davol, Inc., Warwick, RI, USA
CA.*B.S.'air SR*, Cousin Biotech, Wervicq-Sud, France
C-QUR FX, Getinge Group, Wayne, NJ, USA
C-QUR Mosiac, Getinge Group, Wayne, NJ, USA
C-QUR TacShield, Getinge Group, Wayne, NJ USA
C-QUR V-Patch, Getinge Group, Wayne, NJ, USA
Easy Pro Composite Mesh, TransEasy Medical Tech.Co.Ltd, Beijing, China
Parietene Composite, Medtronic, Minneapolis, MN, USA
Parietex Composite Ventral Patch, Medtronic, Minneapolis, MN, USA
Parietex Optimized Composite (PCO$_x$), Medtronic, Minneapolis, MN, USA
Parietex Optimized Composite (PCO$_x$) Skirted Mesh, Medtronic, Minneapolis, MN, USA
Parietene DS, Medtronic, Minneapolis, MN, USA
Parietene ProGrip, Medtronic, Minneapolis, MN, USA
Parietex ProGrip, Medtronic, Minneapolis, MN, USA
Physiomesh Open, Ethicon, Inc., Somerville, NJ, USA
Proceed, Ethicon, Inc., Somerville, NJ, USA
Proceed Ventral Patch, Ethicon, Inc., Somerville, NJ, USA
SepraMesh IP, Davol, Inc., Warwick, RI, USA
Symbotex, Medtronic, Minneapolis, MN, USA
Ventralight ST, Davol, Inc., Warwick, RI, USA
Ventralex ST, Davol, Inc., Warwick, RI, USA
Ventrio ST, Davol, Inc., Warwick, RI, USA

The resorption of that nonpermanent substance leaves a permanent layer of mesh that will incorporate into the tissues of the patient. The controversial part of this idea is the fact that the problems that are related to the development of adhesions following the implantation of a synthetic biomaterial do not become manifest for many years post-implantation. Therefore, the late effects of these products will necessitate many years of follow-up to validate these claims. At the present time, however, these meshes do seem to live up to their expectations. There have been some central failures due to materials that were too lightweight and/or macroporous. These generally are no longer available.

Adhesix is the same product that was listed in Table 7.16 (Fig. 7.113). It is touted that this can be used in the preperitoneal position, the retrorectus space or as an onlay but it is not designed for use in with contact with the viscera. CA.*B.S.'air SR* has a permanent component of 45% lightweight PP and 55% resorbable poly-L-lactic acid (PLLA) (Fig. 7.184, left). It differs from all of the other products in that it has two permanent sutures with needles that are attached and it is also accompanied by a balloon dissection device as is the CA.B.S.'Air described below. The attached sutures are ePTFE and polyester. This device is designed for use in umbilical and ventral hernia repair. The entire product is inserted; the balloon is used to dissect the tissues and is

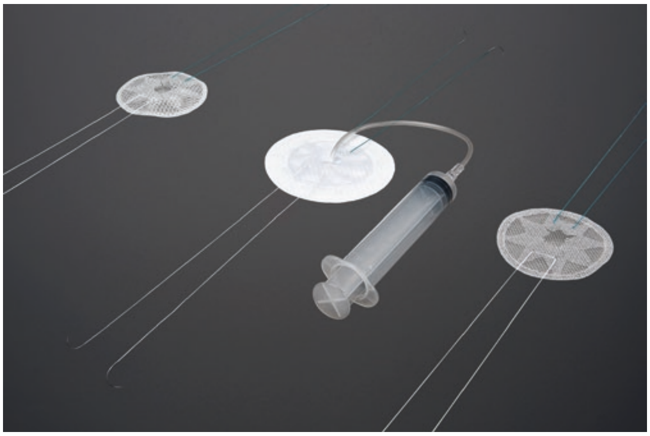

Fig. 7.184 CA.B.S.'air SR (left), CA.B.S.'air composite (middle), CA.B.S.'air light (right)

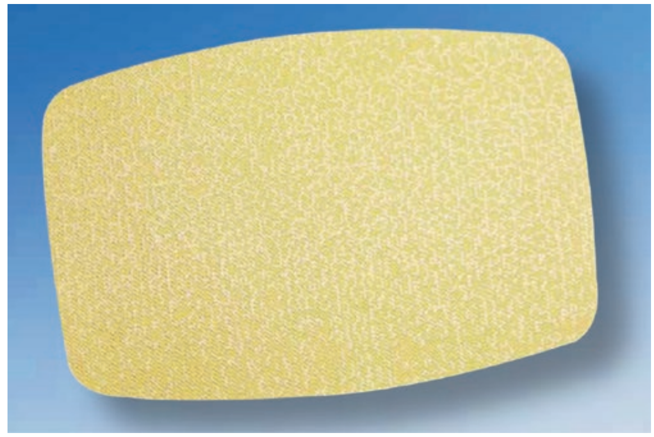

Fig. 7.185 C-Qur Mosaic

then removed leaving behind the prosthesis with the attached sutures to fixate it. The figure shows the balloon in only one of the products.

C-QUR Mosiac is made of a lightweight ProLite mesh onto which Omega-3 Fatty Acid (O3FA) has been coated onto the product (Fig. 7.185). These fatty acids are in a cross-linked gel that covers both sides of the material and impart a characteristic dark yellow color. O3FA will absorb over a period of 3–6 months. It is to be used when tissue-separating capabilities are required in the repair of hernias. *C-QUR FX* has a light spray of O3FA so that the product is to be used in the situations where tissue separation is not required (Fig. 7.169). As such it is also configured for use in open and laparoscopic inguinal hernia repair. *C-Qur TacShield* is designed for open repair of incisional and ventral hernias (Fig. 7.186). The apron on it is made to avoid contact of fixation devices to the intestine. The *C-QUR V-Patch* is designed for umbilical hernia repair and trocar site defects but one could see its use for smaller incisional hernias as well (Fig. 7.187). It combines the ProLite material such that there is one layer of the C-Qur FX and one layer of the C-Qur mesh itself that are sewn together around an O3FA coated mesh stabilizing ring. The fixation straps can be secured to the edge of the defect, if desired.

EasyPro Composite Mesh is constructed of lightweight PP with a barrier coating of poly-lactide-co-caprolactone (Fig. 7.188). It is usage. It has an "F" on the visceral surface to identify the orientation toward the intestine. It is also available in a precut size for complicated inguinal hernia repair.

Parietene Composite is PP coated with the hydrophilic collagen and other substances that are used in the better-known Parietex Composite discussed below. *Parietex Composite Ventral Patch* is designed for the smaller defects in the abdominal wall such as umbilical or epigastric hernias (Fig. 7.189). It is supplied with a deployment system that

Fig. 7.186 C-Qur TacShield

Fig. 7.187 C-Qur V-Patch

Fig. 7.188 EasyPro composite mesh

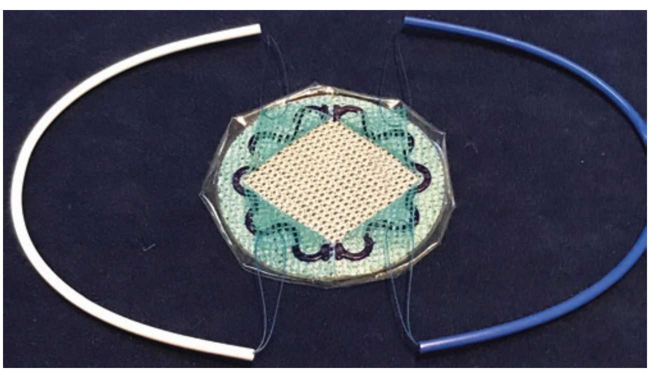

Fig. 7.189 Parietex composite ventral patch (All rights reserved. Used with Permission of Medtronic)

consists of a PGLA structure that is implanted and two nylon suture "positioning" arms that are removed after it is secured in place. It has an incorporated hydrophilic layer of a mixture of oxidized Type I atelocollagen, polyethylene glycol, and glycerol, which is absorbable. *Parietex Optimized Composite* is the same POL biomaterial that is described earlier in this chapter (Fig. 7.190). It is supplied with or without preplaced sutures. It can be purchased with the *AccuMesh Positioning System* (Fig. 7.191). It is also available for open repair as *Parietex Optimized Composite Skirted Mesh* (Fig. 7.192). The skirt is a second layer placed over the larger mesh itself

Fig. 7.190 Parietex composite optimized (All rights reserved. Used with Permission of Medtronic)

Fig. 7.191 AccuMesh positioning system (All rights reserved. Used with Permission of Medtronic)

Fig. 7.192 Parietex optimized skirted mesh (All rights reserved. Used with Permission of Medtronic)

to allow for easier placement of the fixation devices that can be used to fix the product to the anterior abdominal wall in the open technique. *Parietene DS* should be available at the time of publication. It is a dual sided product that has Parietene macroporous PP that is coated on one side with glycolide, caprolactone, trimethylene carbonate, and lactose. *Parietene ProGrip* and *Parietex ProGrip* also differ in that the former is of PP and the latter is of POL (Fig. 7.114). Both have the polylactic acid grippers (described earlier in this chapter) so that they do not need fixation potentially. The coating on these products is very minimal so it is not recommended that these products should contact the viscera.

Physiomesh Open is a skirted product (Fig. 7.193). It is a macroporous mesh of knitted polydioxanone (PDO) and PP fibers that is then laminated to absorbable poliglecaprone-25 film. There is a larger PDO fiber that is sewn into the center of the long axis of the product as an orientation marker. It is designed for open not laparoscopic use and cannot be trimmed or cut. *Proceed* is composed of an oxidized regenerated cellulose (ORC) fabric and Prolene Soft Mesh which is encapsulated by a polydioxanone polymer that holds this together (Fig. 7.194). The fabric acts as a barrier to separate the PP from the tissue. The ORC is absorbed within 4 weeks.

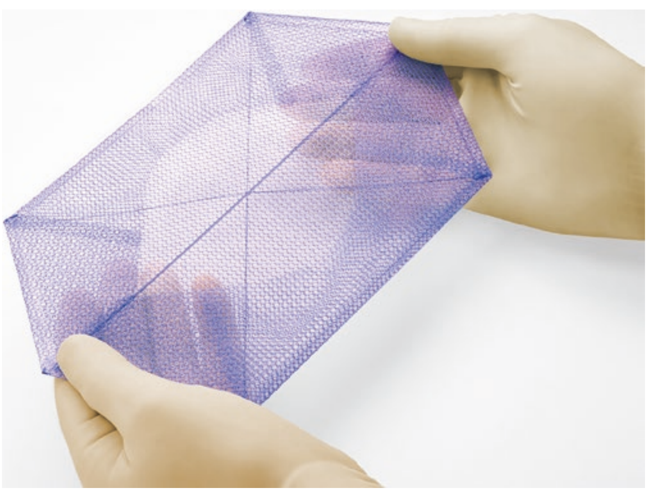

Fig. 7.193 PHYSIOMESH open (Image courtesy of Ethicon, Inc.)

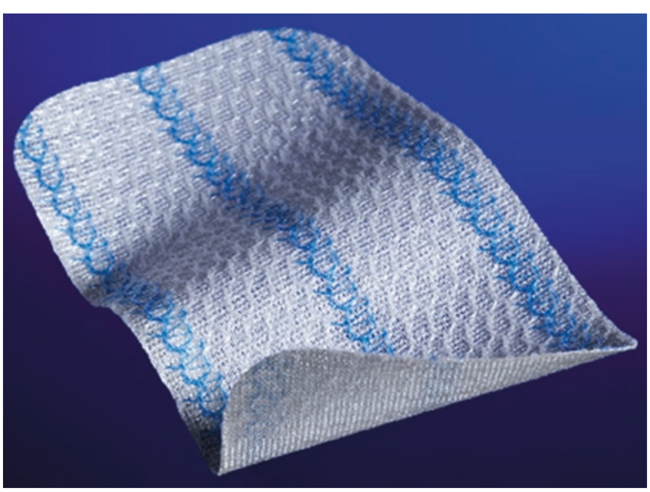

Fig. 7.194 Proceed (Image courtesy of Ethicon, Inc.)

It should be noted that the instructions for use state “Proceed Mesh has an ORC component that should not be used in the presence of uncontrolled and/or active bleeding as fibrinous exudates may increase the chance of adhesion formation.” The *Proceed Ventral Patch (PVP)* is another version that also has an ORC layer that is placed toward the intestine (Fig. 7.195). In this product, there is an additional layer of polydioxanone polymer and a positioning ring to provide memory. Vicryl mesh (polyglactin 910) is placed on top of the polydioxanone and is encapsulated with a polydioxanone film. The sutures that are seen in the photo are of polyester.

SepraMesh IP is a single layer of polypropylene and is covered by barrier that is a combination of carboxymethylcellulose and hyaluronic acid (Fig. 7.196). It is bound together with polyglycolic acid fibers and a hydrogel. This product requires brief immersion into saline solution prior to its use to activate the gel. This hydrogel swells following implantation to cover the fixation devices that are used. This portion of the product is stated to last approximately 4 weeks, at which point, it has been resorbed. There is a lighter weight version that is *Ventralight ST* (Fig. 7.197). The “Sepra” technology has been extended to the original Ventralex and Ventrio products (Table 7.21). The ePTFE surface has been replaced with the tissue-separating material that is used on the SepraMesh IP and Ventralight ST prostheses. These products are called *Ventralex ST* and *Ventrio ST* (Figs. 7.198

Fig. 7.195 Proceed ventral patch (Image courtesy of Ethicon, Inc.)

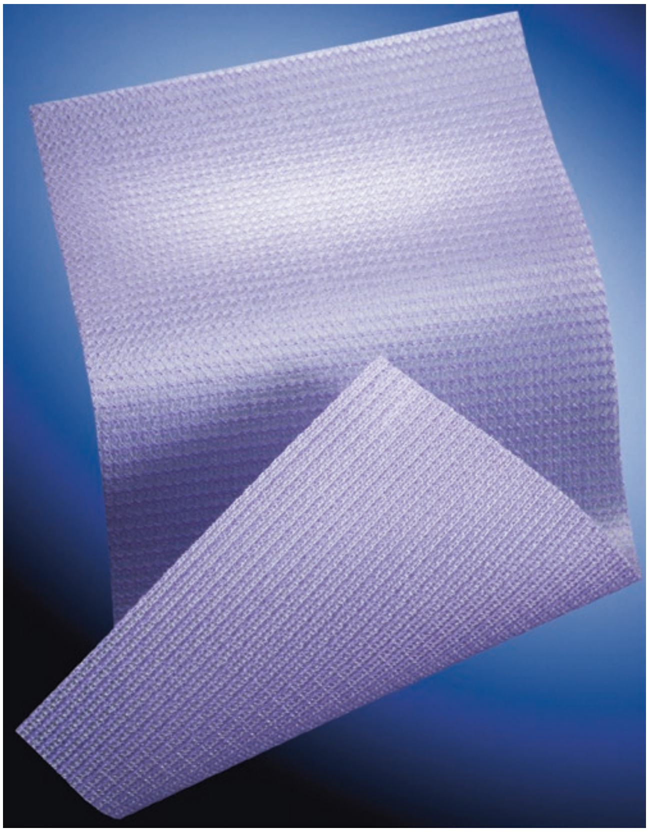

Fig. 7.196 SepraMesh IP

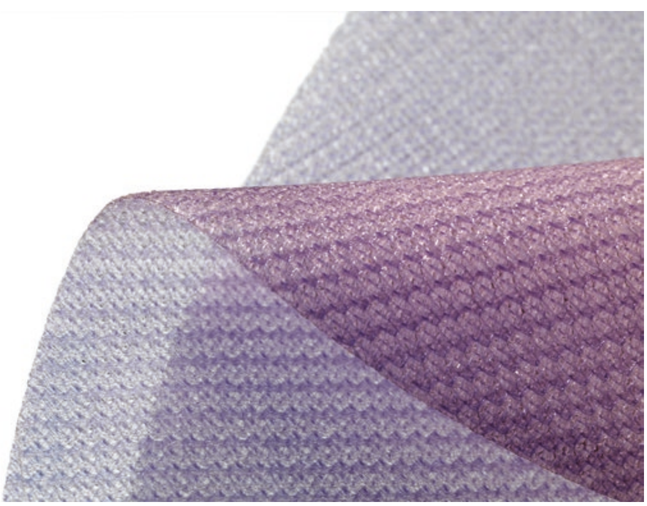

Fig. 7.197 Ventralight ST

Fig. 7.198 Ventralex ST

Fig. 7.199 Ventrio ST

and 7.199). *Symbotex* is a polyester material that is lighter in weight than the Parietex PCO (Fig. 7.200). It has the same barrier material as the PCO product described above (i.e., Type I atelocollagen, polyethylene glycol and glycerol). The green marker is 2D polyester. It is also available with a skirted design to facilitate open repair (Fig. 7.201).

Combination Permanent Materials for Incisional and Ventral Hernioplasty

These products are a combination of a single product that is manufactured in two different forms or, more commonly, a combination of two different products (Table 7.21). The method of fixation of these products differs from each manufacturer. There are some that have been described earlier in this chapter that are single products (ePTFE, cPTFE, or PVDF) and are not described again here (Tables 7.13 and 7.14). What is consistent

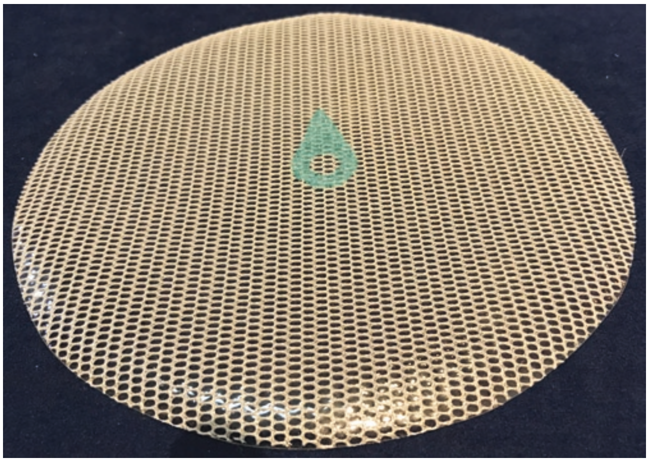

Fig. 7.200 Symbotex (All rights reserved. Used with Permission of Medtronic)

Fig. 7.201 Symbotex skirted mesh (All rights reserved. Used with Permission of Medtronic)

Table 7.21 Ventral hernia products entirely of permanent material

CA.*B.S 'air Composite*, Cousin Biotech, Wervicq-Sud, France
CA.*B.S 'air Light*, Cousin Biotech, Wervicq-Sud, France
ClearMesh Composite (CMC), Di.pro Medical Devices, Torino, Italy
CO3+, THT-Bio-Science, Montpelier, France
Combi Mesh Plus, Angiologica, S. Martino Sicc., Italy
Composix E/X Mesh, Davol, Inc., Warwick, RI, USA
Composix L/P Mesh, Davol, Inc., Warwick, RI, USA
Composix L/P Mesh with ECHO PS, Davol, Inc., Warwick, RI, USA
DualMesh, W. L. Gore & Associates, Elkhart, DE, USA
DualMesh Plus, W. L. Gore &Associates, Elkhart, DE, USA
DualMesh Plus with Holes, W. L. Gore &Associates, Elkhart, DE, USA
Dulex, Davol, Inc., Warwick, RI, USA
DynaMesh IPOM, FEG Textiltechnik mbH, Aachen, Germany
Intra, Microval, Saint-Just-Malmont, France
IntraMesh T1, Cousin Biotech, Wervicq-Sud, France
IS 180, THT Bio-Science, Montpelier, France
Omyra Mesh, B. Braun Melsungen AG, Melsungen, Germany
MotifMESH, Proxy Biomedical Ltd, Galway, Ireland
MycroMesh, W. L. Gore &Associates, Elkhart, DE, USA
MycroMesh Plus, W. L. Gore &Associates, Elkhart, DE, USA
Prefix, THT Bio-Science, Montpelier, France
Plurimesh (PCMC), Di.pro Medical Devices, Torino, Italy
Rebound HRD V, ARB Medical, Minneapolis, MN, USA
Relimesh, HerniaMesh, Torino, Italy
SMH2+, THT Bio-science, Montpelier, France
SM3+, THT Bio-Science, Montpelier, France
Soft Tissue Patch, W. L. Gore &Associates, Elkhart, DE, USA
SurgiMesh XB, Aspide Medical, St. Etienne, France
TiMesh, GfE Medizintechnik, Nuremburg, Germany
TiO_2 Mesh, Bayreuth, Germany
Umbilical—CMC, Di.pro Medical Devices, Torino, Italy
Ventralex, Davol, Inc., Warwick, RI, USA
Ventrio Hernia Patch, Davol, Inc., Warwick, RI, USA
Ventrio-S, THT Bio-Science, Montpelier, France

in all of the prostheses is the creation of some type of a barrier to adhesion formation while allowing for ingrowth on the parietal side of these meshes to repair a hernia effectively.

The CA.*B.S. 'air Composite* is similar to the *CA.B.S.' air SR* (Fig. 7.184, left) device described above. They both are constructed of two materials and inserted with the aid of a balloon dissection device that is removed (Fig. 7.184, middle). The SR device is semi-resorbable while the CA.B.S.'air is totally made of permanent material. These materials are PP on the parietal surface and ePTFE on the visceral surface. It is the only one of these CA.B.S.' air products that can be used in the intraperitoneal position. The CA.*B.S.' air Light* is similar to the SR but there is no absorbable component and it is pure polypropylene (Fig. 7.184, right). *CO3+* has been described in the flat mesh section (Fig. 7.83). It is a combination of POL and PUR with grips.

ClearMesh Composite (CMC) is a pure PP mesh (Fig. 7.202). There is a textured side that is composed of a single filament macroporous weave and a non-adhesive side that is composed of a non-porous smooth PP film. It is for use in the intraperitoneal space. It is further designated as *CMC 2P*, which is elliptical in shape and the *CMC 2P–C,* which is round. *Plurimesh (PCMC)* is a similar concept as the CMC except that it is designed for incisional or parastomal hernia repair (Fig. 7.203). It has sewn seams that can be used to cut the mesh to conform to the needs of the hernia treated. The CMC product line also includes an umbilical version. *Umbilical CMC* is round and includes blue stitching and tethers to aid in positioning (Fig. 7.204). *Combi Mesh Plus* is a combination of PP and polyurethane to allow usage intrabdominally (Fig. 7.205). There is an attached suture to delineate the parietal surface. The polyurethane layer faces the viscera.

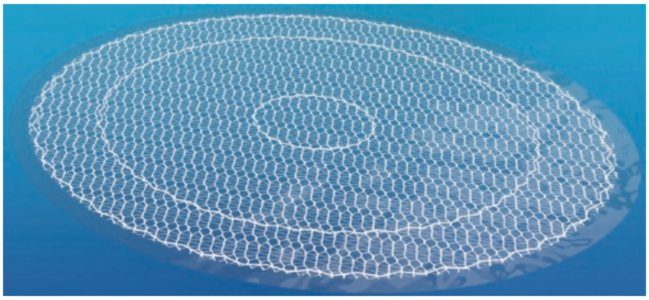

Fig. 7.202 ClearMesh composite (CMC)

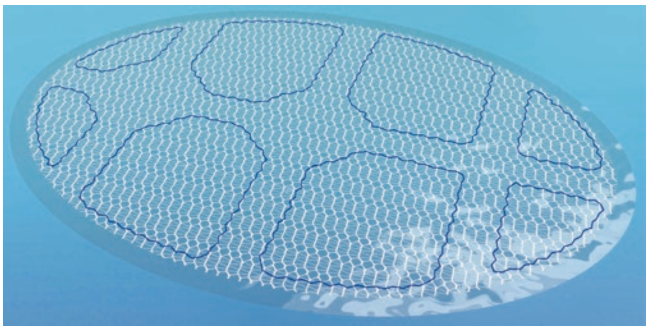

Fig. 7.203 Plurimesh (PCMC)

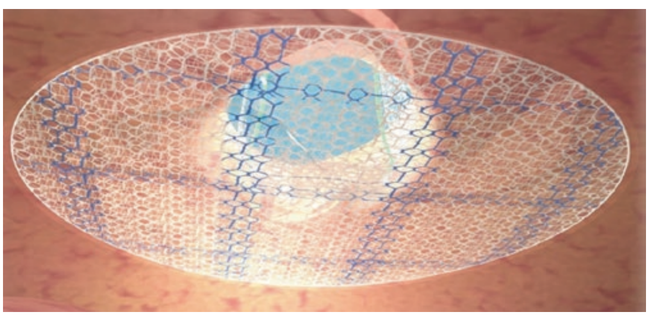

Fig. 7.204 Umbilical CMC

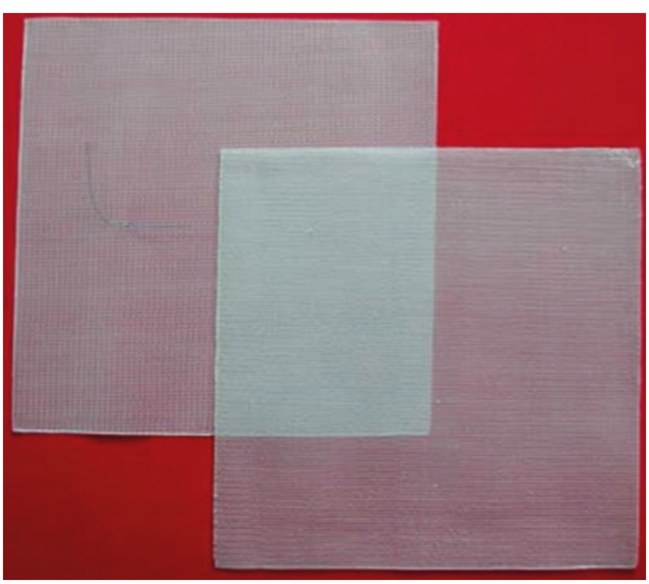

Fig. 7.205 Combi Mesh Plus

Composix E/X Mesh is flat Bard mesh on one side and ePTFE on the other side (Fig. 7.206). The edge of the perimeter of the elliptically shaped product is sealed to prevent contact of viscera to the PP. It is a low profile mesh. *Composix L/P* is very similar to the Composix E/X except that the former uses the lighter Bard Soft of silicon (Fig. 7.207). It is specifically designed for laparoscopic usage and can be used with a supplied introduction tool. The two mesh layers are sutured together with ePTFE suture. The Composix L/P is also available with the ECHO PS (Fig. 7.208). The green balloon shown in the figure will be inflated to firm up the mesh to allow for accurate positioning and fixation. There is an attached blue tubing on the opposite side that is not seen in the figure that is pulled through the abdominal wall to center the mesh. It is then cut and attached to a syringe that is used to inflate the balloon. Once fixation is completed, the balloon is deflated and removed. There is a newer version, ECHO2 PS, that has a nitinol core rather than the balloon.

DynaMesh IPOM is a similar PP weave as the DynaMesh described earlier in this chapter but it is slightly lighter than the latter product (Fig. 7.209). This version is intertwined with polyvinylidene fluoride (PVDF), which is also a monofilament. Because of this PVDF tissue-separating component it can be placed onto the viscera. The suture noted in the figure signifies which side should be placed against the abdominal wall as it is impossible to be certain with the naked eye which side should go up. *Intra* mesh is a combination of nonwoven PP on one side with a layer of silicone on the other as a tissue separating material (Fig. 7.210). It is one of the few materials available with this silicone barrier. This side is marked with a cross and "intra side" in black silicone ink. *IntraMesh T1* is similar to the Composix product line in that it is composed of one layer of PP and a second layer of ePTFE (Fig. 7.211). It is the only material that possesses lines on the product to delineate the midportions of each side to ease positioning for the laparoscopic approach. Cousin Biotech also sells a "mesh roller" which is a device to aid in the rolling of these materials to ease insertion via a trocar. *IS 180* is part of the intra-swing composite family, which is a macroperforated three-dimensional POL that has a coating of PUR on one surface. The latter is the tissue-separating component (Fig. 7.212). It is configured in a variety of shapes with or without PP sutures to aid in fixation. The company also has an available *Easy-Catch EC* device to be used for laparoscopic introduction of the material into the abdominal cavity. *Prefix* is similar in concept to the IS 180 but, as shown in the photo, there are preplaced sutures to allow for positioning of the product (Fig. 7.213). It is one of the few products that include pre-attached sutures with straight needles on them.

Rebound HRD V has previously been described in miscellaneous flat mesh section above (Fig. 7.101). It is designed for use in the preperitoneal space. *Relimesh* is another product that incorporates the PP on one surface and

Fig. 7.206 Composix E/X

Fig. 7.207 Composix L/P

Fig. 7.208 Composix L/P with ECHO PS

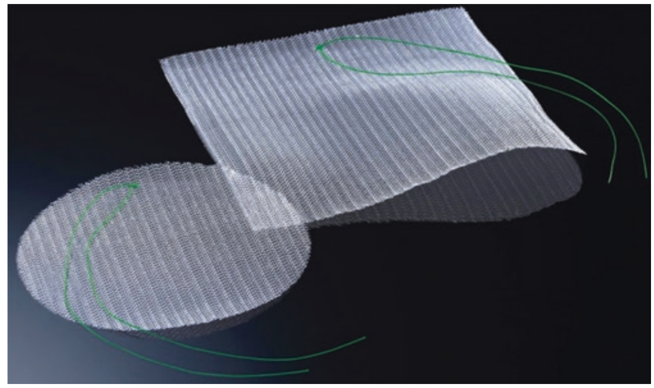

Fig. 7.209 DynaMesh IPOM

Fig. 7.210 Intra

Fig. 7.211 IntraMesh T1

ePTFE on the other to allow placement against the viscera (Fig. 7.214). It is a lighter weight product compared to other HerniaMesh products. Because of this, it can be rolled for insertion via a trocar. It is marked to aid in positioning and fixation. *SMH2+* has been previously described in the preformed inguinal hernia mesh section and is PP and PUR. It is also indicated for ventral hernias as well (Fig. 7.181). *SM3+* has been described in the flat mesh section of the chapter and has also been noted in other sections (Fig. 7.89). It is made of polyester and impregnated polyurethane and can be used in open or laparoscopic methods.

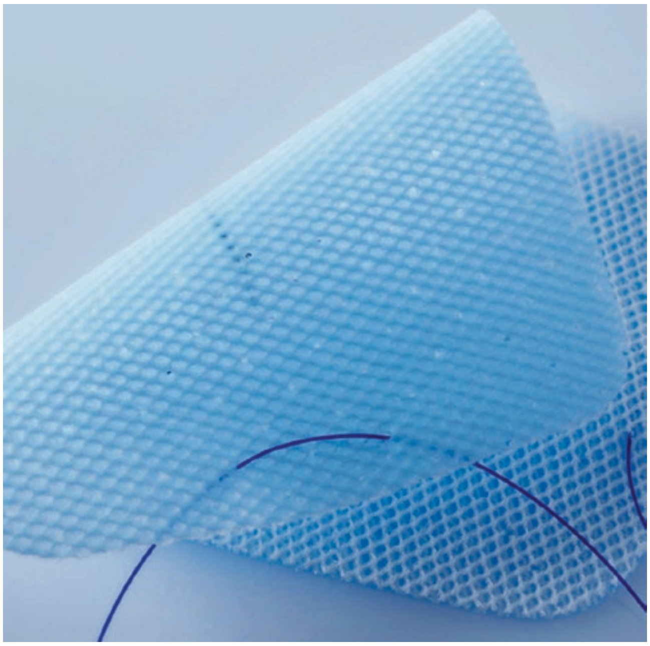

Fig. 7.212 IS 180

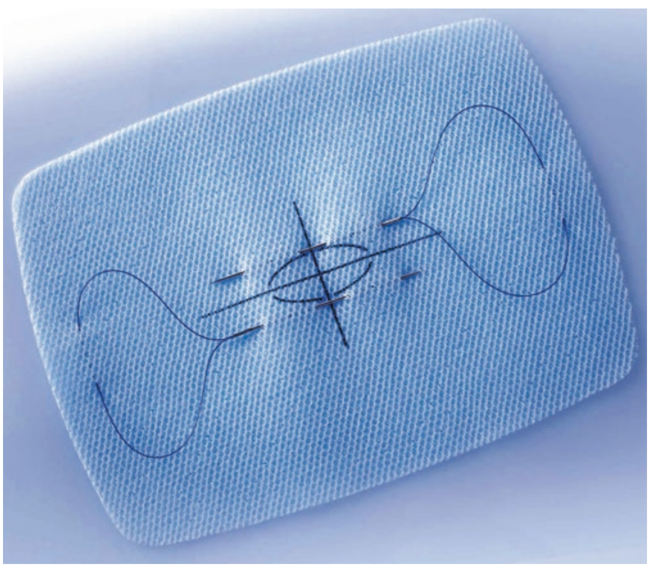

Fig. 7.213 Prefix

SurgiMesh XB has a non-woven, non-knitted structure as does the SurgiMesh WN described earlier (Fig. 7.215). It has an additional layer of silicone to allow contact with the viscera and is microperforated. This product is available in different shapes. There is a circular one that has an attached suture as a positioning aid (Tintra C). There is also a circular and an oval one with a skirt for fixation during open repair (Tintra CK or OK). *TiMesh* is the same material that has been described in several locations within this chapter (Fig. 7.120). The titanized PPM can be used in the intraperitoneal location (per the manufacturer). Another

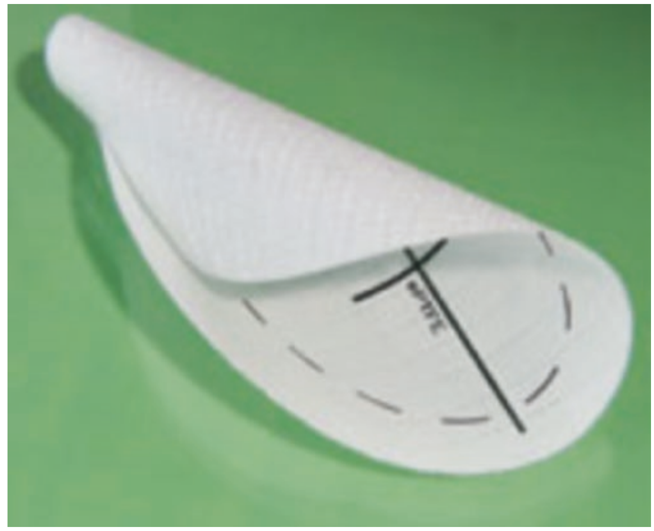

Fig. 7.214 Relimesh

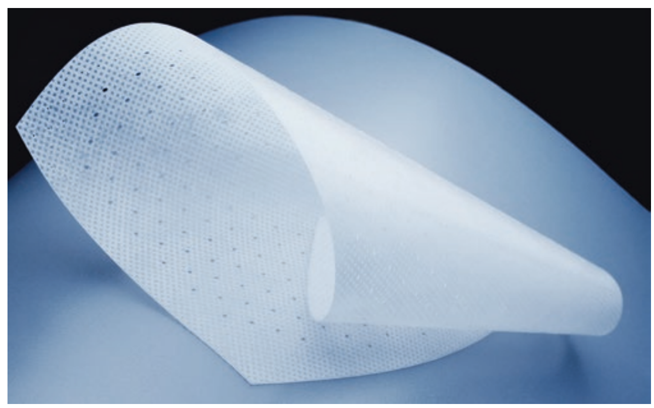

Fig. 7.215 SurgiMesh XB

titanized PPM is that of *TiO_2 Mesh* (Fig. 7.102). This is described in the Miscellaneous Flat Mesh section above.

Ventralex is a self-expanding PP device (because of the outer ring of polydioxanone) that has ePTFE on one side to allow placement adjacent to viscera (Fig. 7.216). It is round but smaller than the larger products such as the Composix products described above. It is intended for use in the smaller defects of the abdominal wall such as trocar or umbilical hernias. There is a pocket to allow for a finger to be inserted for placement. Two long straps are attached that can be used for fixation to the fascia. They are very long as this product can be inserted through a laparoscopic trocar to aid in the prevention of trocar hernias. The *Ventrio Hernia Patch* is comprised of two layers of PP that are stitched to an ePTFE layer as the tissue-separating component (Fig. 7.217). Within the PP surface there are “tubes” that house the absorbable polydioxanone (PDO) monofilament rings to give the mesh rigidity to aid in positioning and fixation. The purple PDO ring is absorbed within 6–8 months. *Ventro-S*

Fig. 7.216 Ventralex

Fig. 7.217 Ventrio hernia patch

Fig. 7.218 Ventro-S

Table 7.22 Stomal prostheses

Colostomy Mesh, HerniaMesh, Torino, Italy
DynaMesh-IPST, FEG Textiltechnik mbH, Aachen, Germany
Parietex Composite Parastomal Mesh, Medtronic, Minneapolis, MN
Polyvalent Clear Mesh Composite (PCMC), Di.pro Medical Devices, Torino, Italy
TiLENE Guard, GfE Medizintechnik, Nuremburg, Germany

is a member of the intra-swing family. It has the three-dimensional POL that is coated with PUR but has an additional skirt of two-dimensional POL impregnated with PUR (Fig. 7.218). As is common to the skirted meshes, it is to be used in open surgery.

Stomal Hernia Prevention and Repair Products

The development of a hernia wherever a stoma is created has been the challenge in the life of all patients with some type of an ostomy. Traditionally, relocation or primary closure was used to repair these hernias. It is now recognized that this is fraught with failure in most cases. Consequently, the use of a prosthetic material has become nearly standard to repair these hernias. In fact, recent trends indicate that the use of a mesh of some type when the stoma is created may be the preferred option. Prevention has become the new effort in mesh construction (Table 7.22). Many of these involve the use of one of the biologic, synthetic absorbable or permanent products described earlier in this chapter. As with many of the other products in this chapter, these can generally be used with the open or laparoscopic technique.

Colostomy Mesh is a single layer PP product (Fig. 7.219). It has a five-centimeter hole in the center of the material through which the intestine can be placed during stomal creation. Of course, the mesh can be cut if this product is used to repair a parastomal hernia. It is available in a "rigid" and a "semi-rigid" construction.

DynaMesh-IPST, like its parent material, is made of both PVDF and PP (Fig. 7.220). It is preshaped and three-dimensional. *Parietex Composite Parastomal Mesh* is of the same material as that described previously. This is supplied in two sizes and is available with a hole or without a hole and a central band (Figs. 7.221 and 7.222). The available opening of the hole can either be 3.5 cm or 5.0 cm. *Plurimesh (PCMC)* has already been described for incisional and ventral hernia repair. It can also be used for parastomal hernia repair (Fig. 7.203). It is supplied in such a manner that it can be cut to confirm to whatever the size the surgeon chooses.

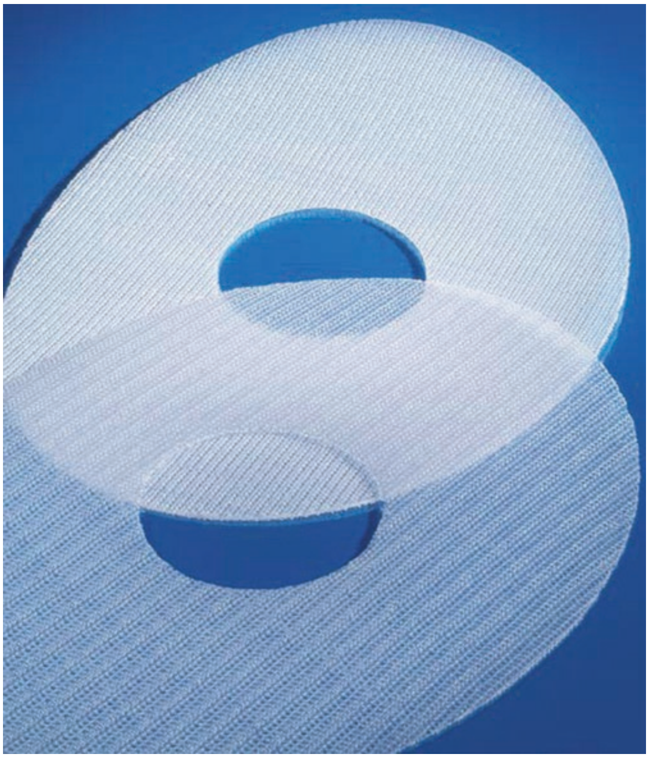

Fig. 7.219 Colostomy mesh

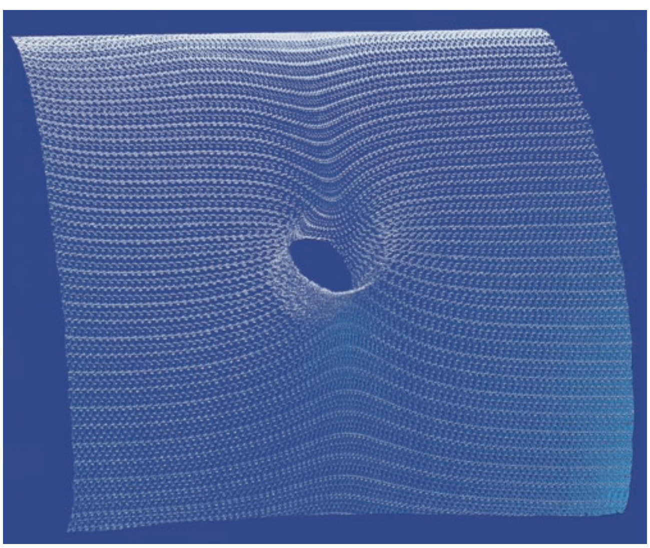

Fig. 7.220 DynaMesh-IPST

TiLENE Guard is of titanized PP (Fig. 7.223). It is supplied with a flap, which is closed after the intestine is placed through the central hole. It is supplied in the light and dual-weight (light and medium) meshes. There is a set, which contains *TiLENE* mesh that is to be applied as a "sandwich" technique to repair or prevent herniation through the stoma location.

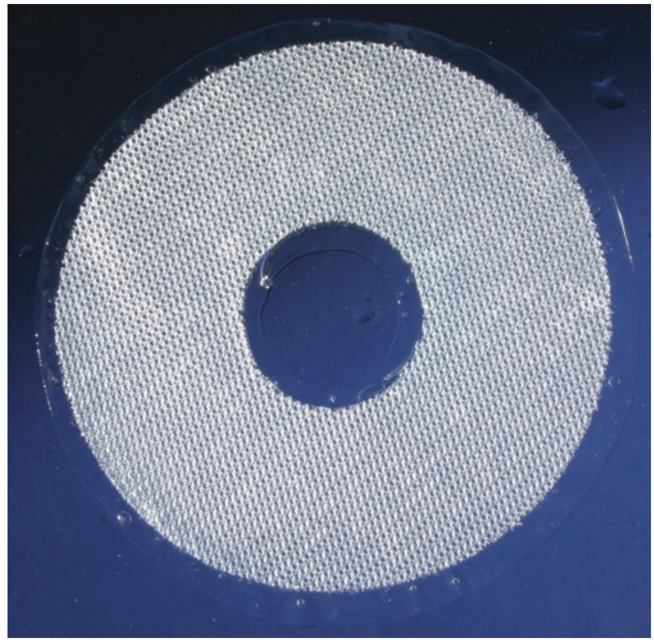

Fig. 7.221 Parietex parastomal with hole (All rights reserved. Used with Permission of Medtronic)

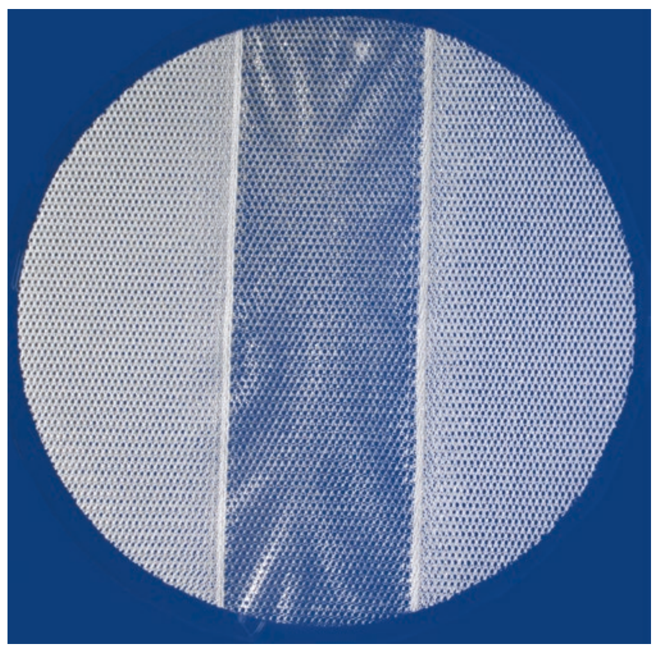

Fig. 7.222 Parietex parastomal without hole (All rights reserved. Used with Permission of Medtronic)

Hiatal Hernia Repair Products

The use of permanent meshes to repair hiatal hernias has been commonplace for many years. The introduction of the biologic products has resulted in a decline in the application of the permanent products at this position. The real concern is of erosion of the product into the esophagus or infection

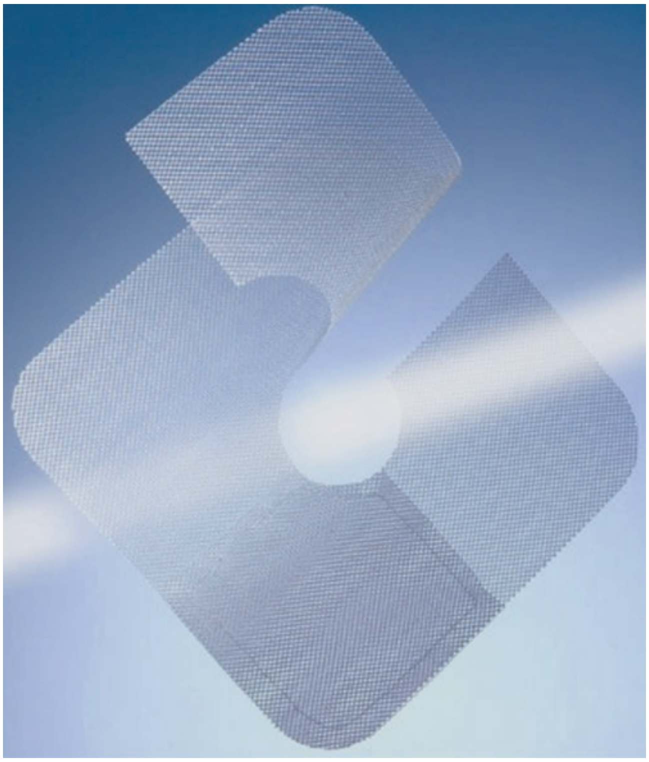

Fig. 7.223 TiLENE guard

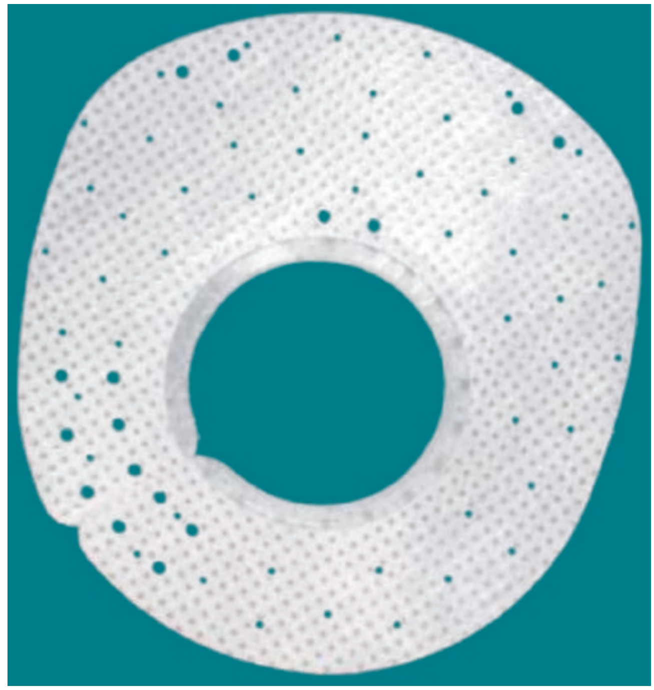

Fig. 7.224 RH implant

Table 7.23 Permanent hiatal hernia repair products

RH Implant, Microval, Saint-Just-Malmont, France
Parietex Composite (PCO) Hiatal Mesh, Medtronic, Minneapolis, MN, USA
TiLENE Hiatus, GfE Medizintechnik, Nuremburg, Germany
TiSURE, GfE Medizintechnik, Nuremburg, Germany

with a permanent prosthesis. While the application of flat meshes such as unprotected PP or POL has been used, these products were designed to mitigate against these concerns (Table 7.23).

The *RH Implant* is of the similar material of the other products from Microval (Fig. 7.224). It is non-woven PP coated on one side with silicon as the tissue-separating component. The larger perforations are used to suture the mesh in place.

Parietex Composite Hiatal Mesh is made of the same material as the parent PCO product (Fig. 7.225). It possesses a U-shaped defect that is slightly off-center that is to be positioned below the esophagus. The legs of the product will lie on the crura. It is available in two other shapes, a heart shape and a horseshoe shape.

TiLENE Hiatus is made of the titanized PP but in either a rectangle shape with a curve on one side or in an "hourglass" configuration. *TiSURE* is a rectangular mesh that has a central hole and a flap made from TiMESH (Fig. 7.226). It differs from the other products listed in that it possesses that flap which mandates complete encirclement of the esophagus. It can be fixed with either fibrin glue or sutures. It is not recommended to use metal fixation devices on this product because of the risk of complications from these devices.

Fig. 7.225 Parietex composite hiatal mesh (All rights reserved. Used with Permission of Medtronic)

Fixation Devices

Fixation devices became prevalent early in the development of the laparoscopic repair of hernias. They are mostly available as 5 mm versions as these have become

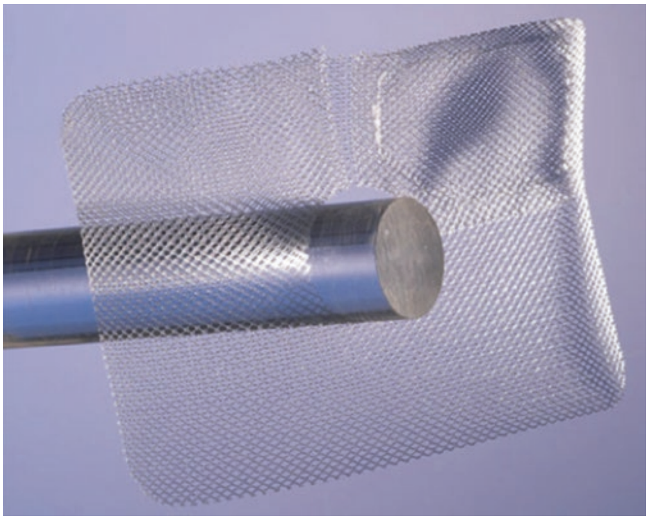

Fig. 7.226 TiSURE

Table 7.24 Fixation devices for hernia repair

AbsorbaTack, Medtronic, Minneapolis, MN, USA
CapSure, Davol, Inc., Warwick, RI, USA
DegraTack, TransEasy Medical Tech.Co.Ltd, Beijing, China
Endo Universal Stapler, Medtronic, Minneapolis, MN, USA
FasTouch, Via Surgical, Tel Aviv, Israel
iMesh Tacker, Corregio (RE), Italy
Multifire Endo Hernia Stapler, Medtronic, Minneapolis, MN, USA
Multifire VersaTack Stapler, Medtronic, Minneapolis, MN, USA
Optifix, Davol. Inc., Warwick, RI, USA
PermaFix, Davol, Inc., Warwick, RI, USA
ProTack, Medtronic, Minneapolis, MN, USA
ReliaTack, Medtronic, Minneapolis, MN, USA
SecureStrap, Ethicon Inc., Somerville, NJ, USA
SorbaFix, Davol, Inc., Warwick, RI, USA
Spire' it, Microval, Saint-Just-Malmont, France
Stat Tack, Medtronic, Minneapolis, MN, USA
Tacker, Medtronic Minneapolis, MN, USA
TiTack, TransEasy Medical Tech.Co.Ltd, Beijing, China

the most popular. Most recently, recognition of the fact that these fasteners are only needed on a temporary basis has led to the introduction of absorbable platforms. Currently, there is a variety of these devices that one may choose to fixate the meshes placed in hernia repair, whether inguinal or ventral and via an open or laparoscopic technique (Table 7.24). Surgeon preference and the mesh chosen will dictate the decision. One should consider the total length of these fasteners, as the depth of penetration will be dependent upon the thickness of the mesh used to repair the hernia. For example, a 5 mm fastener will provide no more of tissue penetration than 4 mm when used with 1 mm prosthesis. The reader is referred to the specific manufacturer of these products for more in-depth information.

Fig. 7.227 Absorbatack (All rights reserved. Used with Permission of Medtronic)

AbsorbaTack is a 5 mm fixation device and provides an absorbable synthetic polyester copolymer screw-like fastener derived from PGLA (Fig. 7.227). It measures 5.1 mm in length. It is offered in a short version for open repair with a 20-tack configuration. It is also available in a laparoscopic version with either 15 or 30 tacks. The tacks are significantly absorbed within 3–5 months with complete absorption within 1 year. *CapSure* is a permanent product, which has a smooth polyetheretherketone (PEEK) cap and screw threads that are made of 316 L stainless steel (Fig. 7.228). The *DegraTack* is an absorbable screw like tack and is also made of polylactide-co-glycolide (PGLA), which is also totally degraded in 12 months (Fig. 7.229). The iMesh tack is also an absorbable PGLA device (Fig. 7.230). The fasteners of this device have a depth of purchase of 5.2 mm. It has a large variety of loads of 10, 15, 20, 25, 30, or 38 tacks. The tip of the delivery device can articulate up to 60°.

FasTouch is a unique 5 mm device in that it does not employ any of the screw-like fasteners listed in this section (Fig. 7.231). It delivers a suture-like closed "locked" loop (Fig. 7.232). Its shape and size delivers the lowest amount of foreign body to fixate the mesh than any other available product. The permanent fastener is made of poly-carbonate-urethane (PCU). Although not available at the time of this writing, there will be an absorbable fastener available soon. It can be reloaded with either a 10 or 25 reload. The *Endo Universal Stapler* is to be used via a 10 or 12 mm trocar (Fig. 7.233, middle). It delivers a "box-type" staple of titanium and can be rotated 360° and has 65% of articulation. It can be used in four different positions. The *MultiFire Endo Hernia Stapler* is introduced through a 12 mm trocar (Fig. 7.233, upper). It also fires "box-shaped" staples that will fixate the prosthesis into which it is fired. They are both reloadable either 4.0 mm or 4.8 mm staples (Fig. 7.233, lower). The obvious difference is that the former product will articulate up to 65° while the latter does not. The *MultiFire VersaTack Stapler* is designed for usage during open hernia repair (Fig. 7.234). It, too, can be rotated 360° and is available with either the 4.0 or 4.8 mm staples with ten staples. These staples are usually acceptable for use with MRI and NMR up to 3 Tesla.

Fig. 7.228 CapSure

Fig. 7.229 DegraTack

Fig. 7.230 iMesh tack

Fig. 7.231 FasTouch device

Fig. 7.232 FasTouch suture-like fastener

Fig. 7.233 Endo Universal Stapler (middle), MultiFire Endo Hernia Stapler (upper), Reload cartridge (lower) (All rights reserved. Used with Permission of Medtronic)

Fig. 7.234 Multifire Versatack (All rights reserved. Used with Permission of Medtronic)

The *OptiFix* device delivers a poly(D,L)–lactide (PDLLA) fastener that has two barbs on the end of it and two on the shaft (Fig. 7.235). They are delivered over an introducer needle. This product is available in either a 15 or 30 shot shaft. These fasteners are fully absorbed at 16 months. *PermaFix* and *SorbaFix* each deliver the same size (6.7 mm) screw-type fasteners by an identical delivery mechanism with a pilot tip and mandrel (Fig. 7.236). Both of these fasteners are available in either 15 or 30 devices delivered via a 5 mm product. Permafix is made of a grey molded permanent (non-absorbable) polymer. SorbaFix is made of the same purple absorbable material as OptiFix.

The *ProTack* was one of the older products that delivers a permanent titanium helical fastener by a 5 mm device (Fig. 7.237). It is available with 30 tacks. These are the easiest fixation products to visualize on a plain radiologic study. They are 3.9 mm in total length. *ReliaTack* is an articulating 5 mm device that also delivers a similar screw like absorbable tack (Fig. 7.238). It can be reloaded with a cartridge that contains either 5 or 10 fasteners. It is supplied with either a standard 5.1 mm device or the deep purchase tack that is 7.0 mm in length (Fig. 7.239). It is the only fastener that is available with two different lengths of tacks from which to choose.

The *SECURESTRAP* is pre-loaded with *25* absorbable straps (Fig. 7.240). The straps are composed of a blend of polydioxanone and L(−)-lactide and glycolide dyed with D&C Violet No. 2. This product does not screw into the tissues and has two legs similar to the staplers. The ends of these straps are barbed to aid in fixation. The width between the points is 3.5 mm. The entire device's length is 6.7 mm but the distance from the inner portion of the strap to the point of fixation of the strap is 4.9 mm (i.e., the "grip"). It also is available with a curved shaft for open repair (Fig. 7.241). *Spire' It* is a different device in that it is made of nitinol and advances in the shape of a ring once fully formed (Fig. 7.242). There are two turns of the ring with a final form of 4 mm. It is re-loadable and is available in a 7 cm length for open surgery or a 30 cm length for laparoscopic surgical applications.

Fig. 7.235 OptiFix

Fig. 7.236 PermaFix (left), Sorbafix (right)

Fig. 7.237 ProTack (All rights reserved. Used with Permission of Medtronic)

Fig. 7.238 Reliatack (All rights reserved. Used with Permission of Medtronic)

The *Stat Tack* and *Tacker* devices deliver helical titanium tacks virtually identical to the ProTack (Figs. 7.243 and 7.244). The former device is shorter and designed for open hernia repair, delivering only 15 tacks. The *Tacker* is longer as it is designed for laparoscopic techniques and delivers 30

Fig. 7.239 Reliatack standard or deep purchase tack (All rights reserved. Used with Permission of Medtronic)

Fig. 7.240 SECURESTRAP (Image courtesy of Ethicon, Inc.)

Fig. 7.241 SECURESTRAP Open (Image courtesy of Ethicon, Inc.)

Fig. 7.242 Spire' it

Fig. 7.243 Stat tack (All rights reserved. Used with Permission of Medtronic)

Fig. 7.244 Tacker (All rights reserved. Used with Permission of Medtronic)

tacks in the single use device. There is an available multi-use handle of the *Tacker* that can be attached to an available tube of 20 tacks. The multiuse product has a shorter tube than the single use product. The *TiTack* is another permanent titanium screw like device that has a similar appearance to the devices listed above (Figs. 7.245 and 7.246). There are significant differences in configuration, depth of penetration and exposed "head" of these devices (Fig. 7.247). These variations should influence the choice of product to fixate any mesh material.

Fig. 7.245 TiTack device

Fig. 7.246 TiTack fasteners

Fastener Comparison

Fas Touch Secure Strap OptiFix Relia Tack Pro Tack Capsure

Fig. 7.247 Comparison of fixation fasteners

Conclusion

The use of a prosthetic material for all hernia repairs is generally considered the standard of care unless there are extenuating circumstances. The purpose of this chapter is to identify and differentiate the products that can be used in hernioplasties. It is as complete as I could make this at this time. Undoubtedly by the time of the printing of this textbook others will have become available. The surgeon should choose carefully.

I believe that the ideal material has not yet been developed. There are, however, many that have been described above that do function quite well for the surgeon and the patient. Perhaps in the future, the use of genetic engineering will produce a product that is based from the protein of the patient and will allow the patient to incorporate a "natural" and "native" product into the tissues without fear of infection or adhesions. A permanent solution to the quest of the perfect biomaterial may be the result.

Acknowledgement Although it is not designated on the propriety names of most of the products listed in this chapter, it should be acknowledged to the reader that all manufacturer names and products are either registered trademarks, copyrighted or exclusive to that company. These cannot be used without the permission of the respective company.

Many of these photos were taken by myself or provided by the company itself. I wish to thank all of these companies for their invaluable assistance in putting the most accurate information into this chapter that I could not have obtained without their assistance.

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8 Progress in Synthetic Prosthetic Mesh for Ventral Hernia Repair

Sheila Grant and Bruce Ramshaw

Background on Hernia Mesh for Ventral Repair

In the United States, there are over 250,000 ventral hernia repairs each year [1]. Most ventral hernias are repaired using a mesh of some type in the repair, but prior to 1970, tension type (tissue only) repair was common, which led to many complications, such as pain, discomfort, and recurrences [2–8]. Today's tension-free type of repairs reduces complications by utilizing a scaffold or surgical mesh that bridges the defect and/or reinforces the abdominal wall. Usher and colleagues are credited with the modern introduction of mesh use in inguinal hernia repair (1958–59) when they utilized a synthetic material, polypropylene monofilament mesh known as Marlex (now called Bard Mesh). However, this need for reinforcement materials was noted as far back as the 1900s. Much earlier mesh material designs were investigated such as silver mesh (1900 and 1940s), tantalum (1948), and stainless steel (1950s) [8]. The problems stemming from these metallic meshes were corrosion of the metal, metallic fatigue, and fracture, and thus metallic meshes were discontinued.

The utilization of mesh to bridge the hernia defect led to the reduction of recurrences and alleviated some complications. Many studies have been performed detailing the ability of hernia mesh to reduce complications and recurrences [9–13]. For example, in a 5-year follow-up study of laparoscopic ventral hernia repairs using a composite polypropylene surgical mesh, the recurrence rate was only 7% [14]. Factors such as defect size and significant comorbidities may contribute the onset of early or late recurrence. In another laparoscopic ventral hernia repair prospective study, recurrence rate was 9.8% when using a mesh [15]. The authors stated that recurrence prevention will rely, in part, on standardization of surgical techniques and eradication of preoperative predisposing factors.

While factors such as surgical technique and patient comorbidities can contribute to a hernia recurrence, other factors such as the foreign body response to the surgical mesh also can contribute. Numerous studies have shown shrinkage, contraction, and distortion of the hernia mesh that have led to pain and recurrences [16–20]. Many of the complications presented with synthetic mesh are the result of the body's foreign body response. Initially, an aggressive foreign body reaction was touted as necessary since it resulted in scar plate formation that, for all intents and purposes, reinforced the abdominal wall. However, it has since been discovered that this response may also lead to mesh degradation and other complications. Figure 8.1 displays an explanted hernia mesh. Scar tissue, contraction, and distortion of the mesh are apparent, which may be due to aggressive foreign body reactions, mismatch of material-tissue properties, and/or non-inertness of the mesh (oxidation, hydrolysis, etc.), which all could be exasperated by particular patient demographics, surgical repair techniques, etc. [16, 17].

Fig. 8.1 Explanted polypropylene mesh

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A biocompatible mesh would elicit a benign physiological response, such as no adhesion formation on the visceral side, no infection, no allergic or hypersensitivity reaction, limited foreign body reaction, and adequate recapitulate of tissue. Additionally, surgical mesh material must also possess the essential engineering properties such as strength, ease of handling, proper mechanical strains (similar to the abdominal wall), sterilization, chemical inertness (if nondegradable), nontoxic by-products (if degradable), and capability to be fabricated in different forms (knits, monofilaments, etc.). Unfortunately, there is no surgical mesh that has been engineered at the present time with all of these desired properties.

Today's commercially available mesh can be broadly classified as synthetic, biologic, resorbable, or a combination thereof. This chapter provides an update on the state of the current synthetic mesh used in ventral hernia repair, including new designs in order to improve the overall biocompatibility.

Current Mesh Materials

The three main types of hernia mesh materials that are available in the United States include polypropylene, polyethylene terephthalate (PET), and expanded tetrafluoroethylene (ePTFE). Polypropylene is a semicrystalline material with hydrophobic tendency. Polypropylene can be extruded and then woven or knitted into monofilament or multifilament designs where the designs dictate the overall mechanical properties such as compliance, strength, and strain of the mesh. There are three basic polypropylene mesh designs, heavyweight, midweight, and lightweight. The "heavyweight mesh" has small pores and a surface area greater than 90 g/m^2 area of material, which results in an intense foreign body reaction. A rigid scar plate usually formed due to granuloma bridging between the small pores, leading to a less compliant, integrated mesh. Numerous clinical problems such as mesh extrusion and bowel fistulas, which have occurred with heavyweight polypropylene, have been well documented in literature [21].

To reduce the foreign body response and granuloma bridging [22], mid- and lightweight polypropylene mesh with larger pores (>1 mm) and smaller filaments were designed. These designs still could withstand the intra-abdominal pressures but also would have less material per square meter. While clinical evidence has demonstrated that the efficacy of most lightweight meshes is an improvement over the heavyweight mesh, granulomas and scar tissue formation still occur [23]. Additionally, a few of the lighter weight mesh with larger, open pore design suffered from premature failure due to mesh displacement or rupture [24]. The midweight designs have performed better. A recent study analyzed polypropylene mesh utilized in open ventral hernia repair [25]. The midweight mesh demonstrated a significant improvement in the quality of life at 6 months and significantly less symptomatic pain after 12 months compared to lightweight mesh.

Polyethylene terephthalate, commonly known as PET or polyester, is another popular hernia mesh. Like polypropylene, PET can also be extruded into synthetic fibers wherein it can be woven into a variety of mesh designs; PET is also less hydrophobic than polypropylene. Clinical evidence has also shown foreign body reactions with gross tissue ingrowth into the macroporous interstices of the mesh, causing variable degrees of scar formation.

Polytetrafluoroethylene (PTFE) is a fluorocarbon-based polymer and is a commonly utilized mesh material. Unlike polypropylene and PET, PTFE is extremely hydrophobic and one of the most chemically inert polymers. Also utilized as a hernia mesh material is expanded PTFE (ePTFE), which is produced by stretching a sheet of PTFE, creating micropores. Clinical data has shown that the microporous structure results in poor integration and scar tissue formation, resulting in mesh contraction and shrinkage [26]. To allow better tissue integration, PTFE mesh is available in an open macroporous, monofilament design (Synecor by W.L. Gore and Associates). Another macroporous PTFE mesh is MotifMESH™ (Proxy Biomedical).

Coatings: To improve the overall biocompatibility, coatings have been incorporated onto the synthetic mesh materials. These coatings provide a protective layer to reduce the severity of the inflammatory response, reduce adhesions, and lead to less fibrosis and contraction of the mesh [27]. There are many mesh products on the market that have been coated with absorbable or permanent coatings. Studies have shown that these coatings help reduce adhesions and the severity of the inflammatory response. However, clinical evidence has also shown that some of the coatings are unstable over time and disintegrate, thus potentially leaving the underlying material susceptible to adhesion formation and material degradation [28, 29]. New, longer-lasting coatings are now available for better long-term clinical outcomes [30]. Table 8.1 provides a partial list of some of the currently available coated mesh.

Resorbable Mesh Materials: An alternative to permanent synthetic mesh is the resorbable or degradable mesh. Resorbable meshes are attractive due to their reduced risks of adhesion formations and the absence of long-term foreign body responses. The resorbable mesh is typically composed of copolymerized forms of polylactic acid, polyglycolic acid, polyglactin, and/or polycaprolactone. The challenge for absorbable mesh is the degradation rate; degradation that occurs too fast could result in loss of mesh strength, potentially contributing to an early hernia recurrence. Degradation that occurs too slowly could result in long-term foreign body reactions. There are only a few resorbable mesh products

Table 8.1 A partial list of coated mesh

Brand	Coating/mesh
C-Qur (Getinge Group)	Omega-3 fatty acid over lightweight polypropylene
Parietex composite (PCO_x) (Medtronic)	Collagen-polyethylene glycol-glycerol over PET
Proceed (Ethicon)	Oxidized regenerated cellulose over polypropylene encapsulated by polydioxanone
Sepramesh IP Composite (Bard)	Hydrogel layer (sodium hyaluronate, carboxymethylcellulose, polyethylene glycol) over polypropylene co-knitted with polyglycolic acid fibers
TiMESH (GfE Medizintechnik)	Covalently bonded titanized surface over polypropylene (light to medium weight)
PolyPro[a] (soft tissue science)	Polyether urethane urea over polypropylene
Physiomesh™[a] (Ethicon, Johnson & Johnson)	A monofilament polypropylene mesh coated with a monocryl (polyglecaprone 25) layer on its peritoneal and subcutaneous sides. A polydioxanone film binds the polyglecaprone 25 to the PP mesh
Ventralight ST™ (Bard, Davol Inc.)	A monofilament polypropylene mesh with a hydrogel barrier (chemically modified sodium hyaluronate/carboxymethylcellulose absorbable adhesion barrier) and resorbable polyglycolic acid (PGA) fibers

[a]Not currently commercially available

currently on the market. TIGR Matrix Surgical Mesh (Novus Scientific) is a knitted mesh made from two polymers with different resorption rates; one has a fast and one a slow degradation rate so that that strength and integrity of the mesh is secured while reducing inflammatory response and adhesions. Another resorbable mesh product that has become available in the past decade is BioA (WL Gore and Associates). BioA is made from absorbable glycolic acid/trimethylene carbonate synthetic mesh and resorbs by hydrolytic and enzymatic mechanisms over a period of approximately 6 months. A third more recently introduced resorbable mesh is sold by Bard, Davol Inc., called Phasix™. This is a knitted monofilament mesh composed of a degradable material called poly-4-hydroxybutyrate, a naturally occurring metabolite.

Because premature loss of strength is a concern for resorbable mesh, composite mesh that consists of both resorbable and non-resorbable polymers has been developed. For example, poly-L-lactic acid (PLLA) has been used in complement of PET or polypropylene yarns in the manufacture of semi-resorbable parietal implants. While resorbable and/or partially resorbable mesh may not be applicable to every hernia procedure, there may be some procedures where these mesh products will be the surgical mesh of choice.

New Research in Mesh Materials

Almost all synthetic materials will initiate a foreign body reaction leading to possible adverse effects, such as inflammation, fibrosis, and/or infection; no material is completely inert in the body. Inflammation is a typical response upon mesh placement, and the severity of inflammation is related to the material properties, such as surface chemistry, porosity, texture, etc. as well as the surgical techniques and skill of the surgeon. To improve the overall biocompatibility of hernia mesh as well as clinical outcomes, new materials, coatings, and/or designs that induce desired tissue responses are needed.

Surface modification is a technique that can alter the surface chemistry of the material without altering the bulk physicomechanical properties. Current hernia materials such as polypropylene and PTFE are classified as hydrophobic materials due to their nonpolar groups, which give rise to low surface energies. Low surface energy materials attract proteinaceous materials, driven in part by the thermodynamically favorable high interfacial energy gain upon binding. Surface modifications could be performed to achieve desired tissue effects such as a reduction in unwanted protein: surface interactions. For example, mesh surfaces could be functionalized with polar groups such as hydroxyl or amine groups to render the surface more resistant to protein adsorption. Covalent attachment of polymeric brush polymers such as polyethylene oxide or polyethylene glycol which kinetically and thermodynamically repel proteins is another alternative. These protein-resistant functional groups are usually hydrophilic in nature and possess a neutral charge with the presence of hydrogen bond acceptors with no hydrogen bond donors.

There are numerous examples in literature where the surface of polymeric materials is altered in order to achieve a particular tissue response. For example, Rivolo et al. [31] utilized a plasma-enhanced chemical vapor deposition (PECVD) system to functionalize polypropylene with polyacrylic acid groups. The polyacrylic acid plasma-polymerized surface modification transformed the polypropylene mesh into an adhesive tissue gripping mesh. In another example, polyester and polypropylene mesh were plasma treated to allow the deposition of polysiloxane and subsequent heparin to prevent tissue adhesions. Plasma treating the mesh with polysiloxane provided functional groups on the surface of polymers for the covalent attachment of heparin [32]. Other surface modifications have been performed. For example, Whelove et al. [33] used chemical modifications to covalently attached gold nanoparticles to PET mesh in order to improve tissue integration. The study demonstrated enhanced cellularity, reduced reactive oxygen species, and reduced bacteria adhesion to PET mesh. In addition, Grant et al. [34] successfully chemically modified polypropylene mesh with AuNPs and achieved similar improved results.

Besides chemically modifying the surface of existing hernia mesh materials, new coating and composite materials are in development. For example, monofilament polyester 3D mesh with an absorbable layer of oxidized collagen and chitosan on its peritoneal side has been developed [35]. This new coated mesh may be able to improve clinical outcome by lowering the development of seromas and minimizing pro-inflammatory cytokine response. Research has also shown that coating mesh with polyethylenimine (PEI) can also improve the material characteristics of implants [36]. Polypropylene, polyester, and ePTFE have all been coated with PEI and have indicated promising results.

Another modification to attempt to improve biocompatibility is to change the manufacturing process of the mesh. Most meshes are woven, but one type of mesh is made from randomly oriented microfibers of polypropylene (Aspide Medical, France). The random orientation is theoretically more biocompatible compared with a mechanical weave; however the polypropylene is still at risk of oxidation from the foreign body response. This particular mesh product is further described in Chap. 10.

The development of drug-eluting mesh or cell-coated mesh is being investigated as potential new hernia mesh materials. Vermet et al. [37] developed a resorbable knitted mesh material composed of poly-L-lactic acid functionalized with a cyclodextrin polymer (polyCD) and activation with ciprofloxacin with cyclodextrin. The purpose was to achieve long-term, local release of the antibiotic while preserving the biocompatibility of the mesh. Another technique is cell coating. The purpose of utilizing cell-coated mesh would be to isolate the implanted mesh from the immune system and thus prevent adsorbing proteins and inflammatory cells from contacting the implant. A study performed by Majumder et al. [38] investigated cell-coated mesh. Fibroblast cells and mesenchymal stem cells (MSCs) were coated onto three different commercial mesh: Parietex (polyester, Medtronic), TIGR (copolymer composite resorbable, Novus Scientific), and Strattice (non-crosslinked collagen, biologic mesh, LifeCell.) Results of this study were mixed with the cell-coated synthetic mesh demonstrating a positive effect on integration in the onlay position. Additional studies are needed in order to determine if cell-coated mesh will improve clinical outcomes.

Choosing the "Best" Mesh

While polypropylene, PET, and PTFE make up the majority of current hernia mesh materials, there are over 80 different types of hernia mesh available [1]. Given that the properties of the mesh can vary considerably, choosing the best mesh for a particular patient population and/or procedure can be confusing. Thus, it is not surprising that investigators have performed controlled prospective and retrospective case studies in order to formulate different algorithms and suggestions of mesh usage [39]. In addition, ventral hernia experts have tried to achieve a consensus on the best practices to manage ventral hernias. Unfortunately, the lack of high-quality data led to lack of consensus in mesh type, component separation technique, and management of complex patients [40].

Since not all hernias are alike and they can differ significantly in size and complexity, the choice of mesh should be based on risk of adhesions, risk of infections, surgeon familiarity, cost, and patient characteristics. In particular, patient characteristics such as BMI, diabetes, tobacco use, second surgeries, previous hernias, etc. need to be considered. Studies that take into account patient demographics need to be performed in order to fully characterize patient-material effects and eventually be utilized to develop algorithms that match the "best mesh" for a particular patient population. Because of the complexity of this issue and the biologic variability in people, traditional reductionist scientific tools, like prospective, randomized, controlled trials will not be adequate to produce these algorithms that will better match patient subpopulations to appropriate mesh choices. A published peer-reviewed international guideline for ventral/incisional hernia management recommends that tools from systems and data science will be required for this effort. Tools from this scientific paradigm include continuous quality improvement and nonlinear analytics [41]. From a material's point of view, the "best mesh" would be one where the engineering properties of the mesh match the engineering properties of the abdominal wall. Table 8.2 summarizes some of the engineered mesh material factors that may influence tissue response.

Future of Hernia Mesh Materials

With over 80 different surgical meshes available for hernia repair, surgeons are left with the impossible task of choosing the "best" mesh for their patients. While research in this area will continue as investigators search for the ideal mesh, it is unlikely that a "summum bonum" mesh will ever be determined due to the complex nature of human systems.

Table 8.2 Mesh-tissue response

Mesh physical characteristics	Noted tissue responses
Interstices greater than 75 µm	Allows passage of macrophages, fibroblasts, blood vessels; reduces risk of infection
Interstices less than 10 µm	Leads to rigid scar plate formation due to granuloma bridging; restricts passages of macrophages that may lead to infection
Interstices less than 1.00 mm	Leads to rigid scar plate formation
Density (heavyweight vs lightweight)	A more severe foreign body reaction (FBR) is noted with heavyweight mesh
Tensile strengths of synthetic mesh	Almost all mesh are over-engineered, causing compliance mismatch between the mesh and tissue that can result in enhanced FBR
Strains at physiological loads	Mesh with less strain than tissue can result in enhanced FBR
Coating or composite type of coating	Initial FBR is reduced, adhesions reduced, but long-term performance needs to be characterized
Filament diameter (smaller diameter filaments have more compliance, flexibility)	Less FBR with smaller diameter filaments but too small of filaments may lead to breakage
Isotropic or anisotropic behavior of mesh (based on weave)	Tissue response of different mesh designs has yet to be investigated
Pore design (hexagonal pores, square pores, etc)	Tissue response of different mesh designs has yet to be investigated

Implementing continuous quality improvement (CQI) could alleviate the uncertainty in mesh selection by using adaptive processes and outcome measures to determine mesh-patient population matches. But until such systems are in practice, surgeons will have to rely on their own clinical experiences in choosing the best mesh for their patients.

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9 Logistics and Specialised Hernia Units

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Introduction

Inguinal hernia repair is one of the most common operations done by general surgeons in practice today [1].

In the early 1990s, the surgical approach to inguinal hernias underwent a major transformation from pure tissue repairs to the widespread use of meshes tension-free mesh repairs and, since that, we have witnessed a more and more increasing interest in this issue, both from surgical society and manufacturing companies.

Today abdominal wall surgery is considered as a high specialised discipline that requires deep knowledge, great professionalism and intellectual dedication: these features are essential to obtain better outcome.

Hence, centres dedicated exclusively to this type of surgeons (the so-called hernia centre) appeared spontaneously, first in the USA and, in the last years, also in Europe.

Routinely and daily hernia surgery is not enough to be tagged like hernia centre.

A Specialised Hernia Unit is a multidisciplinary programme providing state-of-the-art care for all types of hernias, from the most common to the most complex and technically challenging, from the simple primary hernia to multi-recurrent hernia or mesh-related complication (such as infection or post-operative chronic pain), from the small ventral hernia to the swiss cheese with real loss of substance incisional hernia, from the pubic inguinal pain syndrome (the so-called sportsman hernia) to the floppy abdomen postpartum.

General surgeon, plastic and reconstructive surgeon, osteopath and physiotherapist, nutritionist, radiologist, anaesthesiologists and pain therapist: these are essential part of the unit and collaborate to gain better result in each single patient.

Surgeon should be confident in all kinds of approach [2] (open and laparoscopic, both for inguinal and ventral hernia, in anterior and posterior approach), in the use of further surgical step in abdominal wall reconstruction, like, for example, in the different possibilities of component separation or TAR (transversus abdominis release) when necessary and in the use of all surgical implants (synthetic, composite or biological) and their fixation.

A minimum number of about 300 procedures per year should be required because research [2, 3, 5] has demonstrated that hernia surgeons performing a high volume of procedures obtain better outcomes for their patients, such as in other specialist procedures.

Scientific and researching activities (like active attendance to congresses, publications in peer reviewed journals, operative positions in scientific committee and/or society, direction of basic and clinical researches) are aimed to refine surgical technique, improve mesh materials and enhance clinical outcomes.

These features all together make a centre a Specialised Hernia Unit.

The need for a credible certification process for hernia centre is well pointed out by Kockerling et al. [4], and hernia societies and/or non-profit organisations that are interested in assuring the best possible quality of hernia surgery are called upon to define clear requirements and certification processes for hernia centre. The first steps in that direction have been taken with the Certified COEHS (Centre of Excellence in Hernia Surgery) programme of the Surgical Review Corporation and the Certified Hernia Centre programme of the German Hernia Society (DHG) and the German Society of General and Visceral Surgery.

Several procedures listed before can be performed as outpatient, and inguinal hernia repair is certainly among the procedures that contribute to the worldwide development and diffusion of ambulatory surgery practice in the last 25 years.

In ambulatory surgery (called also as day surgery or outpatient service), as the name implies, the patient is sent home

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the same day of the surgical treatment, with no overnight stay [5]. Day surgery arose from the need to reduce healthcare costs while maintaining quality of treatment. Early discharge is also appreciated by patients. Among other things, these procedures require the same technically sophisticated facilities as when done on an inpatient basis, rigorous preoperative selection procedures and post-operative follow-up of some hours.

Modern day surgery is not simply a shortened hospital stay or an architectural model. Rather, it is a complex, multifaceted concept involving institutional, organisational, medical, economic and qualitative consideration.

Day surgery can be performed in:

- Freestanding on campus: department with free management and administration engaged in a hospital site, with own operating theatre, division and staff.
- Freestanding off campus: department located out of a hospital site, with free management and administration, with own operating theatre, division and staff, but with a formal agreement with a hospital in case of complication or emergency
- Division: integrated unit in a hospital, multidisciplinary or monodisciplinary. Operating room is shared with other divisions according as agreed turns.
- Beds: beds in a general surgery department, dedicated to day surgery. Operating room is shared with other division according as agreed turns [6].

Best option for a hernia centre is a freestanding department on campus.

Day surgery rather than inpatient surgery must be regarded as the standard for all elective surgery: it should be considered the principal option and no longer an alternative form of treatment [7].

In a self-contained day unit, the day surgery patient is the centre of attention and receives more personalised care [8].

Day surgery procedure must be performed by highly qualified professionals, with considerable experience in traditional inpatient surgery, to reduce the number of complications and/or unplanned readmission and to achieve greater efficiency.

A daily hospitalisation avoids problems that may arise from prolonged stay, like exposure to infection [9, 10] or variation in the usual drug therapy (e.g. diabetic inpatients are often unnecessary switched from their oral drugs to insulin or drug doses may be missed, delayed or duplicated by hospital staff) [11].

Day surgery is not associated with complication rates higher than those encountered following inpatient surgery. Readmission rates [12, 13] and contacts with the primary and community healthcare teams [14] are no greater than for the same procedures undertaken as an inpatient. There is less post-operative pain and a reduction in the risk of thromboembolism associated with early ambulation [15], and it is less stressful for patient. Patients' satisfaction rates following day surgery are high [16].

Because the risk of last minute cancellation is minimal in dedicated day surgery facilities, hospital can manage elective surgery more efficiently. This allows more accurate scheduling than for inpatient work and makes more effective use of staff and facilities alike [17].

Day surgery is cost-effective compared with inpatient surgery as hospitalisation time is reduced, night and weekend staffing is not required, the hotel element of treatment is removed and capital facilities and staff are used more intensively and effectively [18].

However, not all patients can be treated on a day surgery basis: it is not the operation that is ambulatory, it is the patient. It is of paramount importance that all patients are carefully selected, taking social, medical (comorbidity) and surgical criteria into account.

As early as 1955, the advantages of inguinal hernia repair as day surgery were already described in the literature [19], and nowadays they are confirmed in several studies, many retrospective [20–24] and some randomised [25–30].

EHS guidelines for inguinal hernia repair [31] report day surgery as safe, effective and in addition cheaper for every patient.

In a large American cohort study [32], the cost of inguinal hernia repair in a clinic setting was found to be 56% higher than those for day surgery. Also in Germany, this procedure is generating less costs [33].

In addition to these few randomised studies, there are a multitude of cohort studies concerning patients successfully operated on as day surgery, under general, regional or local anaesthetics, and with both classical operation techniques as well as open tension-free repairs and endoscopic techniques. A large study conducted in Denmark noted the hospital readmission rate of 0.8% [33, 34].

Although a tension-free repair under local anaesthetic seems to be the most suitable operation, the published series showed that other surgical and anaesthesiologic techniques can also be effectively used as day surgery. Only the extensive open preperitoneal approach (Stoppa technique) has not been described in the context of day surgery [31].

On a worldwide basis, there is a clear increase in the percentage of inguinal hernia repairs in ambulatory surgery [35, 36].

There is a considerable variation between different countries, which cannot be clarified solely by the degree of acceptability of day surgery among patients and surgeons but, to a significant extent, is also determined by healthcare financing system. In the last year (2000–2004), 35% of inguinal hernia operation carried out in the Netherlands and 33% in Spain were done on a day surgery basis; there is room for this number to be increased. In the Swedish National Registry, 75% of inguinal hernia repair are performed in day care [37]. In 2013 in Italy, 50% of inguinal hernia repair in adult were done in day surgery [38].

In literature there is no high evidence about abdominal wall hernia in ambulatory surgery rather than inguinal hernia, but some successful personal experience for umbilical, epigastric or incisional hernia repair in outpatient setting are reported [39–41].

Patient Pathway in a Hernia Centre

First Access in Hospital

Surgeon, during the first examination in the consulting room, requires more test (e.g. ecotomogrophy or CT) if necessary, makes a diagnosis and, if necessary, gives a surgical indication. In this case, he makes the first choice about the kind of recovery (ambulatory surgery or ordinary hospitalisation) according to social, medical and surgical criteria.

Social Criteria

Patient should prove the availability of a person to accompany him at home and remain with him for the first night. The patient should be contactable by telephone and reside (home or hotel) within 60 min or 1 h by car from the hospital. Patient should be able to understand the operation and its requirements, comply with advice given by the physician and have acceptable personal hygiene and a suitable lodging.

Medical Criteria

Anaesthetic risk categories ASA I-II or ASA III for stable comorbidities unaffected by the surgical procedures are suitable for ambulatory surgery. Advanced age, diabetes, asthma, obesity (up to BMI <35 kg/m^2), sleep apnoea (if post-operative opioids not programmed) and epilepsy are not exclusion criteria. Remember that selection of patient should be based on their overall physiological status.

Surgical Criteria

Procedure suitable for ambulatory surgery has the following characteristics:

- Post-operative care might be specific, but is neither invasive nor prolonged, and will not lead to unexpected admission to hospital.
- The risk of severe pre- and post-operative blood loss is low.
- The duration of the procedure is less than 90 min.
- Post-operative pain is easily controlled [42].

Almost all primary inguinal or femoral hernia repairs with normal size or small recurrences approachable with open or laparoscopic technique can be performed in outpatient setting.

Patients complaing huge, old, unreducible hernia should have the option to be able to an extended recovery (overnight).

Little epigastric or umbilical hernia suitable for a primary repair or for a small mesh repair can be performed in ambulatory surgery. Pubic inguinal pain syndrome treatments are feasible for day surgery setting.

All ventral defects requiring large mesh repair must be hospitalised for a short stay or longer.

Preoperative Screening and Selection

Advanced assessment provides a valuable opportunity to have more knowledge about whole health condition of patient, correct abnormalities and drugs therapy.

The patient during a day hospital admission is submitted to the following evaluations:

- Blood test.
- ECG.
- Chest X-rays (according to the hospital policy, usually required adult older than 40 years old or smokers or patients with lung disease history).
- Interview with the surgeon for a complete clinic history, for review the examination results and for obtaining informed consent for day surgery and for the procedure.
- Interview with the anaesthetist.
- The patient will be supplied with a written booklet with information about preparation at home, surgery and post-operative care.

At the end of day hospital, surgeon and anaesthetist decide if the patient is suitable to surgery and to the kind of recovery proposed (ambulatory surgery or ordinary hospitalisation). Otherwise the patient can be switched to a different kind of hospitalisation.

The patient will be advised by hospital secretariat by phone about the day of the surgery.

According to the hospital policy, preoperative screening can be organised and accomplished the same day of surgery.

Day of Surgery

At the hernia centre, patient is normally admitted to the hospital the same day of the surgery. The nurse and surgical team receive the patient and check his preparation (drug therapy, shaving, fast) and mark the correct side of the hernia.

Operating Theatre

According to the European Hernia Society guidelines, in clinic settings with low rates of wound infection, there is no indication for the routine use of antibiotic prophylaxis in elective open groin hernia repair in low-risk patients. In elective incisional or large ventral hernia, requiring a large mesh repair, the antibiotic prophylaxis starts in the operating theatre and goes on at least until the removal of drains.

Antithrombotic prophylaxis is given if the patient had risk factors for thrombosis.

Antiemetic medication is given if indicated.

Drains are not usually used in patients undergoing normal size groin hernia repair and small ventral hernia repair. Drains are always placed in open retromuscolar ventral hernia repair.

Nasogastric tube is normally placed during surgery requiring the opening of the abdominal cavity (large ventral hernia repair or incisional hernia repair).

At the end of the surgery, a waterproof dressing is placed and patients are supported wearing stretchable post-operative underwear (groin hernia) or strip (ventral hernia).

Post-operative Time and Discharge

After a period of observation in the recovery room, the patient is transferred to his bed in the ward.

In case of outpatient, a small meal is served. Adequate post-operative analgesia is mandatory for successful day surgery and is ensured using multimodal opioid-sparing techniques shown to improve recovery and outcomes after short admissions.

Before discharge, patient is assessed for vital signs, pain, nausea, vomiting, dizziness, bleeding, walking and dressing, using the modified postanesthesia discharge scoring system (PADSS) (Table 9.1) [43]. A minimum PADSS score of 9 was required for discharge. If the patient scores below 9, he or she is moved to a normal ward and the admission is no longer in day centre regime.

Voiding seems not to be a requirement before discharge from DS as it could delay the discharge of 5–10% of patients who have no risk factors of urinary retention after ambulatory surgery.

But hernia surgery is considered, like anorectal surgery, old age, male sex, spinal anaesthesia, risk factor for post-operative urinary retention. So, we usually prefer to wait for spontaneous voiding before discharge.

Table 9.1 Postanesthesia discharge scoring system (PADS) for determining home-readiness

	Score
Vital signs	
Vital signs must be stable and consistent with age and preoperative baseline	
Blood pressure and pulse within 20% of preoperative baseline	2
Blood pressure and pulse 20–40% of preoperative baseline	1
Blood pressure and pulse w > 40% of preoperative baseline0	0
Activity level	
Patient must be able to ambulate at pre-op level	
Steady gait, no dizziness, or meets pre-op level	2
Requires assistance	1
Unable to ambulate	0
Nausea and vomiting	
Patient should have minimal nausea and vomiting before discharge	
Minimal: successfully treated with os medication	2
Moderate: successfully treated with intramuscular medication	1
Severe: continues after repeated treatment	0
Pain	
Patient should have minimal or no pain before discharge	
The level of pain that the patient has should be acceptable to the patient	
Pain should be controllable by oral analgesics	
The location, type and intensity of pain should be consistent with anticipated post-op discomfort	
Acceptability	
Yes	2
No	1
Surgical bleeding	
Post-operative bleeding should be consistent with expected blood loss for the procedure	
Minimal: does not require dressing change	2
Moderate: up to two dressing changes required	1
Severe: more than three dressing changes required	0

Of course, patient must accept discharge in readiness and he is required to be accompanied by a responsible, physically able adult who can bring him at home and care for him overnight. Patients and their care must understand the planned procedure and post-operative care.

In case of complex surgical procedure not suitable for outpatient, fasting is continued until the following morning; in the first day the patient has usually a liquid diet and in the second a light diet.

In the first day, patient is supported to mobilisation, and a breathing physiotherapy programme starts.

Early discharge for a patient traveling long distance is extremely challenging. Often, a simple visit to the office for a wound check or drain removal may require several hours of car ride or take a plane. Likewise, discharging a patient to a local hotel for a short period can result in significant cost for the patient. For these reasons, care coordination with local physicians and visiting nursing facilities is very important [5].

Patients confirmed for discharge receive a standard discharge report also specifying the date and time of next check-up, phone number in case of emergency and a booklet with post-operative instructions.

All discharged patients receive a phone call in the morning after the surgery, to check for any problems.

Follow-Up

The patient comes back to the hospital for a clinical check some days after surgery, as described in the discharge letter.

Periodic follow-up by phone is organised for long-term results.

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10 Outcomes Assessment and Registries

Ferdinand Köckerling, Iris Kyle-Leinhase, and Filip E. Muysoms

Introduction

What is the outcome of an abdominal wall hernia repair and how can it be measured?

Outcome of abdominal wall hernia repair is mostly described by evaluating the recurrence rate related to specific operation techniques or devices. The recurrence rate of a hernia operation is an important factor, but there are certainly more outcome parameters to be considered for hernia repair outcome assessment. The interpretation of outcome after hernia surgery is complex and influenced by the large number of variables included.

As described by Muysoms [1, 2], the outcome of abdominal wall hernia repair should be assessed in three main domains: hernia recurrence, operative and postoperative complications as well as quality of life assessment and patient-reported outcome measurements (PROMs).

Moreover, as illustrated in the triple P-triangle of abdominal wall hernia repair (Fig. 10.1), the operative outcome will be influenced by many patient-related variables, characteristics of the prosthesis used and the details of the surgical procedure.

In this chapter we will focus on two aspects:

(1) The outcome parameters which describe the results of a surgery. Which parameters do we need to assess to fully describe the results of an abdominal wall surgery? By means of operative and postoperative complications, patient-reported outcome measurements (PROMs) and the recurrence rate.

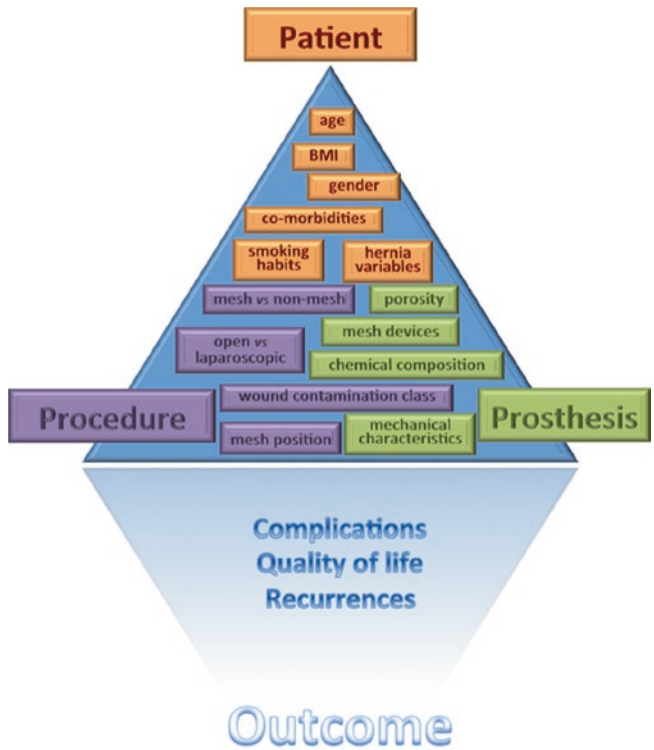

Fig. 10.1 Triple P-triangle of abdominal wall hernia repair

(2) How should we evaluate and register these outcome parameters? Consequently, reporting the outcome of a hernia operation in case control studies, through large randomized controlled trials (RCTs) or well-established hernia databases and registries.

Outcome

Complications

Each hernia operation is paired with a specific risk of either operative, postoperative or both complications, depending

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on the severity of the intervention, the patient's condition and the used technique to repair the abdominal wall defect. Hernia-specific complications as pain, postoperative seroma or hematoma need to be defined either as a related consequence or as a complication. For example, postoperative pain is quite common and up to a specific grade accepted after surgery. When postoperative pain is much higher than it can be accepted after surgery, it needs to be considered a postoperative complication.

For that reason, complications being an important outcome parameter to evaluate hernia repair should be graded using clearly defined classifications of surgical complications [3] as the general surgical complications classification by Clavien-Dindo [3] or the seroma classification by Morales-Conde [4]. This is highly relevant to compare specific results to the results of other studies across the common literature.

General Surgical Complications: Clavien-Dindo Classification

Clavien et al. defined in 1992 the negative outcome after surgery in three groups [3]:

- Complication: "Any deviation from the normal postoperative course"
- Sequela: "An after-effect of surgery that is inherent to the procedure"
- Failure to cure: "If the original purpose of the surgery has not been achieved"

By using this classification (defined in Table 10.1), complications can be categorically described according to the severity of the complications. Recurrence is clearly "a failure of cure" and thus should be reported separately and can therefore not be considered a complication.

Seroma: Morales-Conde Classification

Seroma can be considered an expected event after hernia surgery and up to specific grade accepted as short-term consequence after surgery or a procedure-related complication. To describe the consequences of seroma, Morales-Conde et al. proposed a classification of postoperative seroma [4] to distinguish clearly between postoperative incident and related complication (Table 10.2). This classification should be used describing postoperative seroma.

Surgical Site Infections (SSI)

Infection of the wound after hernia repair is a relevant complication that might induce significant morbidity and treatment costs and compromise the repair at longer term. The Centers for Disease Control and Prevention (CDC) classifies surgical site infection (SSI) categorically for severity (Table 10.3). There is a correlation to the degree of wound contamination during surgery, stratified as described by the CDC classification of wound contamination: clean/clean-contaminated/contaminated/dirty (Table 10.4).

Table 10.1 Classification and grading of surgical complications by Clavien and Dindo

Grade 0	No complications
Grade I	Any deviation from the normal postoperative course without the need for pharmacological treatment or surgical, endoscopic and radiological interventions
Grade II	Requiring pharmacological treatment with drugs other than such allowed for grade I complications. Blood transfusion and TPN are included
Grade III	Requiring surgical, endoscopic and radiological interventions
Grade III a	Intervention not under general anaesthesia
Grade III b	Intervention under general anaesthesia
Grade IV	Life-threatening complication requiring IC/ICU management
Grade IV a	Single organ dysfunction
Grade IV b	Multi-organ dysfunction
Grade V	Death of the patient

Table 10.2 Classification of postoperative seroma after ventral hernia repair by Morales-Conde et al.

Seroma type	Definition	Clinical significance
0	No clinical seroma	No clinical seroma
I	Clinical seroma lasting <1 month	Incident
II	Clinical seroma lasting >1 month	
III	Symptomatic seroma that may need medical treatment: minor seroma-related complications	Complication
IV	Seroma that needs to be treated: major seroma-related complications	

– *Clinical seroma:* Those seromas detected during physical examination of patients which do not cause any problem or just a minimum discomfort that allows normal activity
– *Minor complication:* Important discomfort which does not allow normal activity to the patient, pain, superficial infection with cellulitis, aesthetical complaints of the patient due to seroma or seroma lasting more than 6 months
– *Major complication:* Infection, recurrence, mesh rejection or need to be punctured

Table 10.3 CDC classification surgical site infection (SSI)

Superficial SSI	Date of event for infection occurs within 30 days after operative procedure (where day 1 = the procedure date) **AND** involves only skin and subcutaneous tissue of the incision **AND** patient has at least *one* of the following:
	a. Purulent drainage from the superficial incision
	b. Organisms identified from an aseptically obtained specimen from the superficial incision or subcutaneous tissue
	c. Superficial incision that is deliberately opened by a surgeon, attending physician or other designee and culture or non-culture-based testing is not performed and patient has at least one of the following signs or symptoms: pain or tenderness, localized swelling, erythema or heat
	d. Diagnosis of a superficial incisional SSI by the surgeon or attending physician or other designee
Deep SSI	The date of event for infection occurs within 30 or 90 days after the operative procedure (where day 1 = the procedure date) **AND** involves deep soft tissues of the incision (e.g. fascial and muscle layers) **AND** patient has at least *one* of the following:
	a. Purulent drainage from the deep incision
	b. A deep incision that spontaneously dehisces or is deliberately opened or aspirated by a surgeon, attending physician or other designee and organism is identified by a culture and patient has at least *one* of the following signs or symptoms: fever (>38 °C); localized pain or tenderness. A culture or non-culture-based test that has a negative finding does not meet this criterion
	c. An abscess or other evidence of infection involving the deep incision that is detected on gross anatomical or histopathologic exam or imaging test
Organ/Space SSI	Date of event for infection occurs within 30 or 90 days after operative procedure (where day 1 = the procedure date) **AND** infection involves any part of the body deeper than the fascial/muscle layers that is opened or manipulated during the operative procedure **AND** patient has at least *one* of the following:
	a. Purulent drainage from a drain that is placed into the organ/space (e.g. closed suction drainage system, open drain, T-tube drain, CT-guided drainage)
	b. Organisms are identified from an aseptically obtained fluid or tissue in the organ/space by a culture
	c. An abscess or other evidence of infection involving the organ/space that is detected on gross anatomical or histopathologic exam or imaging test evidence suggestive of infection

Table 10.4 CDC classification wound contamination class

Clean	An uninfected operative wound in which no inflammation is encountered and the respiratory, alimentary, genital or uninfected urinary tracts are not entered. In addition, clean wounds are primarily closed and, if necessary, drained with closed drainage. Operative incisional wounds that follow nonpenetrating (blunt) trauma should be included in this category if they meet the criteria
Clean-contaminated	Operative wounds in which the respiratory, alimentary, genital or urinary tracts are entered under controlled conditions and without unusual contamination. Specifically, operations involving the biliary tract, appendix, vagina and oropharynx are included in this category, provided no evidence of infection or major break in technique is encountered
Contaminated	Open, fresh, accidental wounds. In addition, operations with major breaks in sterile technique (e.g. open cardiac massage) or gross spillage from the gastrointestinal tract and incisions in which acute, nonpurulent inflammation is encountered including necrotic tissue without evidence of purulent drainage (e.g. dry gangrene) are included in this category
Dirty or infected	Includes old traumatic wounds with retained devitalized tissue and those that involve existing clinical infection or perforated viscera. This definition suggests that the organisms causing postoperative infection were present in the operative field before the operation

Patient-Reported Outcome Measurements and Quality of Life Assessment

As mentioned above, the outcome of a hernia operation cannot solely be measured by the rate of complication or by the occurrence of a hernia recurrence only. Patient-reported outcome measurements (PROMs) that evaluate the quality of a hernia surgery are considered an important factor besides the recurrence rate as outcome measurement parameter [5]. Patients can have an asymptomatic recurrent hernia, yet still be very satisfied with the outcome.

Moreover, implantation of a permanent prosthesis to stabilize the abdominal wall can induce a foreign body feeling associated with the development of chronic pain or restriction of the patients' activities, all resulting in a tremendous impact on the patients' quality of life (QoL).

To address the patient for personal outcome reporting, elementary scores such as the VAS (visual analogue scale) and the VRS (verbal rating scale) for pain can be applied. Additionally, more complex quality of life questionnaire have found their way into clinical routine after hernia surgery.

Visual Analogue Scale (VAS) for Pain

The VAS score is often routinely used in hospitals for measuring postoperative main and for management of pain medication. The patient is asked to mark the amount of experienced pain on a calibrated line of 10 cm long [6]. The lower side of the line is mentioned to be "0 = no pain" and the upper side as "10 = the worst imaginable pain". For immediate pain estimation especially in the early postoperative period, the VAS is a feasible tool, but it has to be considered less valuable to assess long-term chronic pain.

Verbal Rating Scale (VRS)

Using the VRS, the patient is only verbally asked to grade the level of experienced pain in four levels. For assessing of the development of chronic pain, the VRS seems a better tool than the VAS [6], but it cannot be implemented preoperatively.

This score, defined by Cunnigham et al. [7], evaluates pain into four main categories:

- *No pain* = no discomfort experienced.
- *Mild pain* = occasional pain or discomfort that did not limit activity, with a return to pre-hernia lifestyle.
- *Moderate pain* = pain preventing return to normal preoperative activities.
- *Severe pain* = pain that incapacitated the patient at frequent intervals or interfered with activities of daily living.

Generic Quality of Life Scores Short-Form 36 (SF-36)

A questionnaire used to evaluate the quality of life after hernia surgery is the Short-Form 36 (SF-36). Although the SF-36 is frequently used in studies on abdominal wall surgery, it should be considered too generic to use for evaluation of QoL after abdominal wall repair [8].

For quality of life assessment after hernia repair, several more hernia-specific quality of life instruments have been developed and were validated in the last years:

Carolina Comfort Scale™ (CCS), Inguinal Pain Questionnaire (IPQ), Ventral Hernia Pain Questionnaire (VHPQ), Hernia-related Quality of Life (HerQles) and the EuraHS-Quality of Life QoL score (EuraHS-QoL) of the EHS.

Carolina Comfort Scale™ (CCS™)

The CCS has been developed as a questionnaire to assess the QoL of patients that had a hernia repair using a prosthetic material [8, 9]. The use of the CCS needs approval of the Carolina Medical Centre and its use will be charged.

The CCS contains 23 questions with a 6-point scale from 0 to 5 to report sensation of the mesh, pain or movement limitation for eight different activities. Added to the numerical scale is a descriptive scale: 0 = no symptoms, 1 = mild but not bothersome symptoms, 2 = mild but bothersome symptoms, 3 = moderate and/or daily symptoms, 4 = severe symptoms and 5 = disabling symptoms. The total score ranges from 0 to 115.

The CCS was used successfully to demonstrate QoL improvement after hernia repair [10]. Unfortunately, many questions of the CCS are related to the sensation of the implanted mesh and are therefore not applicable for preoperative QoL assessment.

Inguinal Pain Questionnaire (IPQ) and Ventral Hernia Pain Questionnaire (VHPQ)

Fränneby et al. validated the Inguinal Pain Questionnaire (IPQ), evaluating pain and difficulties in performing activities after groin hernia repair [11]. The same Swedish group from the Karolinska Institute published and validated in 2011 the Ventral Hernia Pain Questionnaire (VHPQ) to evaluate QoL after ventral hernia repair [12].

Both scores are free of charge by the used after request to the authors.

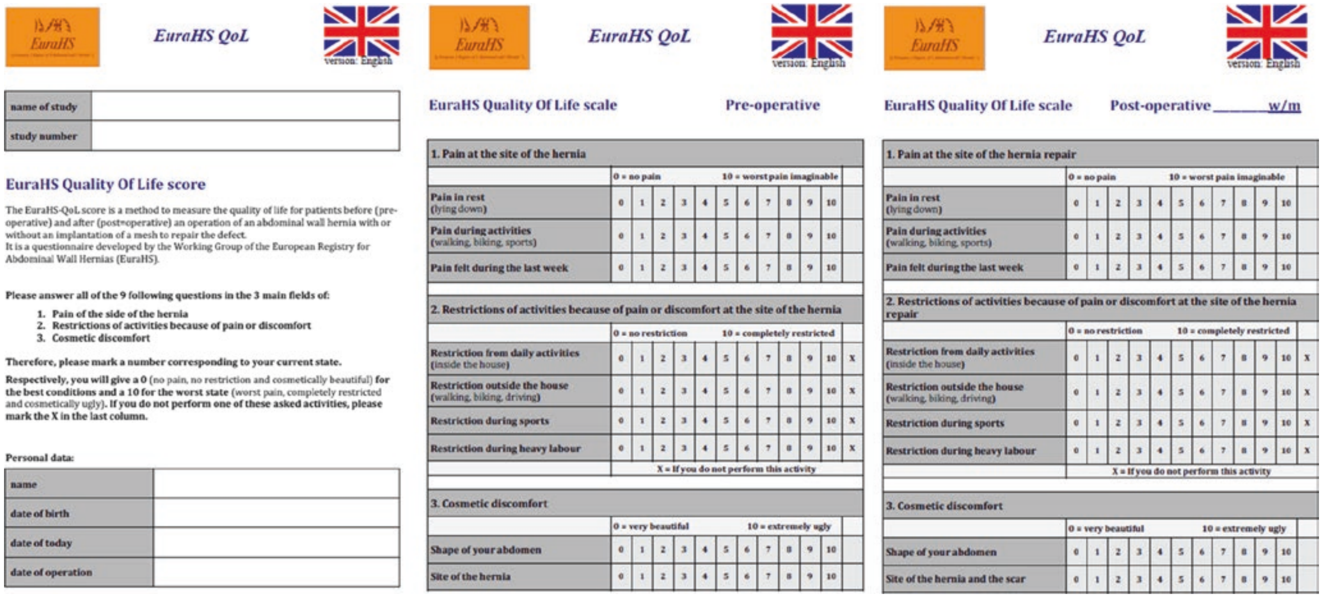
EuraHS-Quality of Life Score (EuraHS-QoL)

The EuraHS-QoL was developed by the EuraHS working group at the request of the European Hernia Society (EHS). The EuraHS-QoL score was recently validated for laparoscopic inguinal hernia repair, and a validation study for ventral hernia repair is ongoing [13].

The reason to implement the development of this QoL instrument is fourfold:

- Development of an instrument that can be used both pre- and postoperative
- Free of charge use for the surgeon and implementation in the online EuraHS register
- Development of considerably shorter questionnaire that should find a broader acceptance
- Creation of an instrument that can be used both in groin and ventral hernia patients

Questions were chosen as most relevant for QoL assessment before and after hernia repair [1]. The EuraHS-QoL


EuraHS QoL
version: English

name of study	
study number	

EuraHS Quality Of Life score

The EuraHS-QoL score is a method to measure the quality of life for patients before (pre-operative) and after (post=operative) an operation of an abdominal wall hernia with or without an implantation of a mesh to repair the defect.
It is a questionnaire developed by the Working Group of the European Registry for Abdominal Wall Hernias (EuraHS).

Please answer all of the 9 following questions in the 3 main fields of:

1. **Pain of the side of the hernia**
2. **Restrictions of activities because of pain or discomfort**
3. **Cosmetic discomfort**

Therefore, please mark a number corresponding to your current state.

Respectively, you will give a 0 (no pain, no restriction and cosmetically beautiful) **for the best conditions and a 10 for the worst state** (worst pain, completely restricted and cosmetically ugly). **If you do not perform one of these asked activities, please mark the X in the last column.**

Personal data:

name	
date of birth	
date of today	
date of operation	

EuraHS QoL
version: English

EuraHS Quality Of Life scale Pre-operative

1. Pain at the site of the hernia												
	0 = no pain					10 = worst pain imaginable						
Pain in rest (lying down)	0	1	2	3	4	5	6	7	8	9	10	
Pain during activities (walking, biking, sports)	0	1	2	3	4	5	6	7	8	9	10	
Pain felt during the last week	0	1	2	3	4	5	6	7	8	9	10	
2. Restrictions of activities because of pain or discomfort at the site of the hernia												
	0 = no restriction					10 = completely restricted						
Restriction from daily activities (inside the house)	0	1	2	3	4	5	6	7	8	9	10	X
Restriction outside the house (walking, biking, driving)	0	1	2	3	4	5	6	7	8	9	10	X
Restriction during sports	0	1	2	3	4	5	6	7	8	9	10	X
Restriction during heavy labour	0	1	2	3	4	5	6	7	8	9	10	X
	X = if you do not perform this activity											
3. Cosmetic discomfort												
	0 = very beautiful					10 = extremely ugly						
Shape of your abdomen	0	1	2	3	4	5	6	7	8	9	10	
Site of the hernia	0	1	2	3	4	5	6	7	8	9	10	

EuraHS QoL
version: English

EuraHS Quality Of Life scale Post-operative ______ w/m

1. Pain at the site of the hernia repair												
	0 = no pain					10 = worst pain imaginable						
Pain in rest (lying down)	0	1	2	3	4	5	6	7	8	9	10	
Pain during activities (walking, biking, sports)	0	1	2	3	4	5	6	7	8	9	10	
Pain felt during the last week	0	1	2	3	4	5	6	7	8	9	10	
2. Restrictions of activities because of pain or discomfort at the site of the hernia repair												
	0 = no restriction					10 = completely restricted						
Restriction from daily activities (inside the house)	0	1	2	3	4	5	6	7	8	9	10	X
Restriction outside the house (walking, biking, driving)	0	1	2	3	4	5	6	7	8	9	10	X
Restriction during sports	0	1	2	3	4	5	6	7	8	9	10	X
Restriction during heavy labour	0	1	2	3	4	5	6	7	8	9	10	X
	X = if you do not perform this activity											
3. Cosmetic discomfort												
	0 = very beautiful					10 = extremely ugly						
Shape of your abdomen	0	1	2	3	4	5	6	7	8	9	10	
Site of the hernia and the scar	0	1	2	3	4	5	6	7	8	9	10	

Fig. 10.2 EuraHS-QoL score English version. (Printed with permission from the EuraHS working group represented by Filip Muysoms MD)

score is a short hernia-specific questionnaire with nine questions that can be scored by the patient in an 11-point scale from 0 to 10. An example in the English language for preoperative assessment is shown in Fig. 10.2.

The EuraHS-QoL questions are divided in three main domains:

- Pain (range 0–30)
- Restriction of activities (range 0–40)
- Aesthetical discomfort (range 0–20)

The total score ranges from 0 to 90, with the lower scores being the most favourable outcome.

Recurrence Rate

The number of patients who develop a recurrent abdominal wall hernia is considered most important to evaluate the success of a hernia surgery. In fact, the recurrence rate is an important factor, but certainly not the only outcome parameter to judge the final outcome and success of a hernia repair surgery. Moreover, recurrence rate evaluation strongly depends and can even be limited by different aspects as:

- The lack of grading for severity
- The impact on the patient
- Distinction of recurrence versus patients satisfaction
- Lack of clear data registration to diminish the risk of bias in determining the recurrence rate

Furthermore, the number of incisional hernia recurrences increases over time [14–17], so it is strongly recommended (as reported in the EHS guidelines on the closure of abdominal wall [18]) to follow the patient for a period of at least 12–24 months. Moreover, the number of patients with follow-up and the reasons for eventual lost to follow-up should be clearly reported to diminish a bias in evaluation. Only a follow-up rate above 80% makes the recurrence rate a reliable parameter to describe the surgical outcome.

Also, clinical examination by a surgeon is considered efficient to determine the presence or absence of a hernia recurrence. Additionally the inclusion of medical imaging like ultrasound or CT scan evaluation will significantly increase the level of evidence for recurrence [19–21].

Registries

How Should We Evaluate and Register These Outcome Parameters?

Surgical outcome reporting is important in understanding the postoperative course for patients undergoing hernia repair and in learning how outcomes are affected. Registration of performed hernia operations is necessary to evaluate this outcome as well as the personal performance of the surgeon. This includes the registration of the surgical technique, the prostheses and fixation materials used, the operative time, operative and postoperative complication as well as effective long-term patient follow-up.

As a fact, we can only learn about our own abilities when we register our performance and our daily medical practice and patient care in one way or the other. Only if surgeons can realistically judge their own ability and learn about their strengths, weaknesses and benchmarks, can performance in hernia surgery be increased in the future.

Hernia surgery is currently described by:

- Case reports, case-control studies
- Randomized controlled trials (RCTs)
- Hernia-specific congresses
- Reviews and meta-analyses
- Hernia classifications and guidelines

In addition, large hernia registries using standardized data entry for risks factors, comorbidities, outcome of surgical procedures and effective long-term follow-up have increased the knowledge of hernia surgery tremendously in the last few years.

Case-Control Studies

Case-control studies or cohort studies are primary types of observational studies to evaluate the effects and outcome of new methods or material in hernia surgery. To address investigative questions in hernia surgery, large randomized controlled trials are not always indicated or time-efficient to conduct (see Chap. 5).

In the field of surgery, hernia surgery is a unique subfield. No other surgical discipline encloses so many different techniques and sub-techniques. Moreover, the development and evaluation of surgical material as meshes and fixation devices is evolving rapidly. Well-designed observational studies are needed to evaluate the efficiency of hernia techniques and surgical materials. Observational studies are important to investigate the correlation between surgical interventions and their outcomes, such as recurrence rate or complications.

Randomized Controlled Trials (RCTs)

Large randomized controlled trials (RCTs) are the gold standard in clinical research. In the last decades, hernia surgery has profited enormously from the results being published resulting from these RCTs. However, RCT methodology, which was first developed for drug trials, can be difficult to conduct for surgical investigations and improvements. RCTs are mostly performed in hernia expert centres and lack the demonstration of real-time surgical reality. RCTs are designed for specific defined questions in strict correlation with specific techniques, materials or patients outcome. Taking into consideration that these RCTs also have a strict defined set-up with more or less narrow inclusion and exclusion criteria, results produced from the RCTs do not always mirror daily clinical practice.

Hernia Registries

Large registries, as the Danish Hernia Database, collecting lots of data in a wide surgical community for various aspects in hernia surgery reflect a broad surgical community. In contrast to RCTs, data can be collected in a shorter time frame. Complications corresponding specific techniques of surgical materials that occur rarely can be detected earlier with huge patient numbers.

Nevertheless the outcome of the patients undergoing a specific procedure can be registered in both systems: RCTs and registries. Moreover, clearly defined and standardized registries are favourable to register the outcomes of RCT. Using a common hernia registry for data recording of RCT helps to unique data gathering and reporting. This gives an advantage when large RCTs are compared in meta-analyses. On the other hand, large patient registries can function as a source for innovative concepts for RCT.

In conclusion, RCTs and hernia registries can benefit from each other, more than standing in conflict (Fig. 10.3).

Development of Registries in Europe

At this moment, several hernia-specific registries coexist in Europe and in the United States as shown in Fig. 10.4.

The Swedish Groin Hernia Registry pioneered in 1992, followed by the Danish Groin Hernia Database in 1998. The first registry to include the inguinal and the ventral hernia route was the German Herniamed Registry released in 2009.

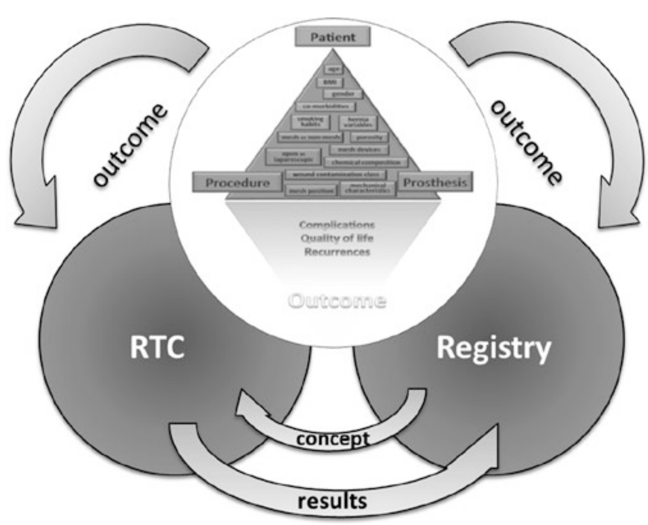


Fig. 10.3 Surgical outcome registration in randomized controlled trials (RCTs) and hernia registries

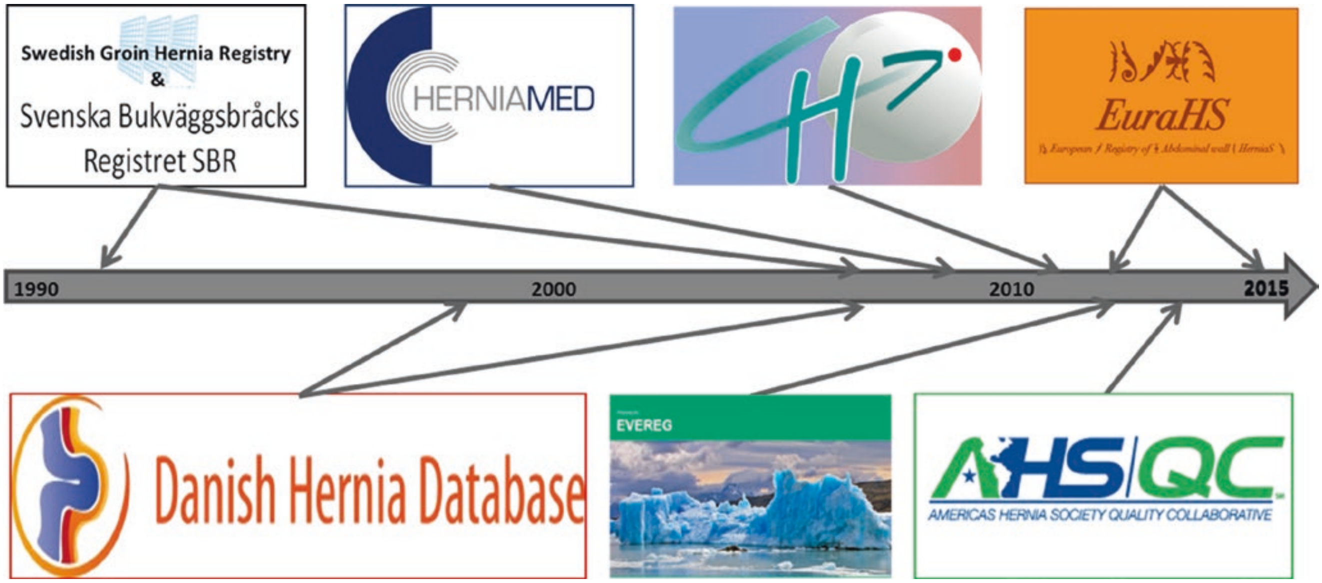


Fig. 10.4 Hernia registries since 1992

While the French Club Hernie, a database for inguinal and ventral hernia, was initiated in 2011 by a selected group of surgeons combining their investigational efforts. The year 2012 was a very productive year in terms of hernia registries with three hernia registries to be released: EuraHS, the Spanish Evereg database and the INCH trial.

EuraHS is the official database of the European Hernia Society (EHS) and is used all over Europe in multiple languages [1].

For the United States, the AHSQC, the hernia registry of the AHS, was launched in 2013.

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Part II

Groin Hernia

11 Diagnosis of a Lump in the Adult Groin

Andrew C. de Beaux and Dilip Patel

Inguinal Hernia: The Adolescent and the Adult

The younger the patient, the more likely the hernia is to be indirect. An indirect hernia is where the hernial sac follows and is closely associated with the spermatic cord. It thus starts at the deep inguinal ring, passing medially and inferiorly down the inguinal canal, where with time it will emerge from the superficial inguinal ring. As the hernia continues to enlarge and follow the spermatic cord into the scrotum, it is then named an inguinoscrotal hernia. In contrast, a direct inguinal hernia exploits a weakness in the transversalis fascia, in the region of the superficial inguinal ring. The hernial sac in this case is less adherent to the spermatic cord.

The majority of inguinal hernias are diagnosed by the patients when they see or feel a lump in their groin. The shower room seems to be a common theme to the place of diagnosis, for obvious reasons. Sometimes pain or discomfort draws the patient's attention to the groin, but this is rarely a significant element in the patient's symptoms to begin with. As the hernia enlarges, symptoms in the groin, particularly a dragging sensation, but at times quite marked pain, can be reported. This swelling, discomfort, or pain rapidly settles on lying down but returns as the patient becomes ambulant again. It is not unusual for the patient to report episodes of discomfort in the groin on exercise for months or even a few years prior to the appearance of a swelling in the groin. The natural history of hernia development is very variable, with some patients' hernia remaining small in size for years, while in others, there is rapid progression of a small lump to a large hernia. Symptoms from an inguinal hernia are also very variable, ranging from no symptoms at all apart from the swelling to pain that significantly interferes with work and recreation of the patient. Patients with a chronic cough, or who have to strain to micturate or defecate, may complain of symptoms while performing these maneuvers. Inguinal hernias in women are more likely to present with pain. It is postulated that the closed inguinal canal in the adult female means that a small indirect hernia in women causes more stretching of the tissues and hence more pain.

As the length of time that the patient has had the hernia increases, the cumulative probability of pain increases to almost 90% at 10 years, and the probability of irreducibility increases from 6.5% at 12 months to 30% at 10 years [1]. Patients who have an asymptomatic hernia may not progress to irreducibility of the hernia as quickly. A recent randomized trial of surgery vs. watchful waiting management of an asymptomatic inguinal hernia reported 72% in the watchful waiting group crossed over to surgery by 7.5 years, with increase in hernia pain being the most common reason offered [2]. Of these 80 men assigned to watchful waiting, only two had incarceration of their hernia during the follow-up period.

Inguinal hernias are more common in adult males than in adult females in a ratio of 10:1. However, it must not be forgotten that indirect inguinal hernias in women are as common as femoral hernias in women.

A number of patients will present with bilateral inguinal hernia, although one side is usually significantly larger than the other. Sometimes this can indicate a connective tissue disorder such as Ehlers-Danlos syndrome, although such diseases are rare. Patients with ascites, such as heart or liver failure, are more prone to bilateral hernias, as are patients on continuous ambulatory peritoneal dialysis (CAPD). It is not clear whether the incidence in such groups is higher or whether the fluid in the abdominal cavity results in more symptoms so that such patients present sooner.

Another area that can cause some diagnostic difficulty is recurrent inguinal hernia. Pain tends to be a more prominent feature. The mechanism for this is unclear, although recurrent

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inguinal hernias often have a tighter neck, perhaps due to fibrosis from the previous mesh or suture repair limiting dilatation of the neck or constriction of the hernial sac contents. However, such patients often give a good history, and the giveaway line is the comment that the symptoms feel similar to when the patient had the hernia previously.

An interesting element to modern hernia practice is the so-called work-related hernia or hernia following a single strenuous event. The patient is aware of sudden pain in the groin while lifting, pulling, or straining at a task. At the same time, or shortly afterward, a swelling in the region of the groin is evident. There has been a debate as to whether this strenuous event causes the hernia or simply brings a preexisting asymptomatic hernia to the attention of the patient. Current opinion is more of the latter. The strenuous event precipitates identification of the hernia, which would have become evident in a few months' to years' time anyway, had the strenuous event not taken place. Several studies have reported on this. In one study [3], 129 patients with 145 hernias presenting with an inguinal hernia pursing a negligence claim, only in nine (7%) did the patient have a "convincing history suggestive" of an associated strenuous event. However, the time from this event to diagnosis of the hernia was up to 4 years. In another study [4], 133 consecutive patients presenting with a hernia (the majority of which were inguinal) were examined. Fourteen (11%) reported a sudden development of the hernia, but on detailed questioning of these patients, there was no good evidence to point to a single strenuous event as the cause. A further similar study [5] reported 108 patients who alleged that their hernia was the result of an accident, clearly a subset of the hernia patient population. While 51% did have an alleged identifiable strenuous event, of the remaining 49%, no hernia was detectable in 23%; there was no single event in 19%; and the hernia was documented present before the alleged accident in 6%. Nevertheless, work-related hernia has been and continues to be a source of work-related litigation for compensation. The following guidelines have been suggested when considering such a claim [3]:

1. The incident of muscular strain must be reported officially to the patient's line manager.
2. There must be severe groin pain at the time of the strain.
3. A diagnosis of a hernia must be made by a doctor within 30 days and preferably within 3 days.
4. There should be no previous history of a hernia.

While there is little evidence to support the detail of these guidelines, they remain a useful, pragmatic approach to the problem. The compensation level is minimal, as causation is a problem; the strenuous event did not cause the hernia, but simply speeded up the patients being aware that they were developing a hernia anyway.

Femoral Hernia

A femoral hernia accounts for approximately 5–10% of all groin hernias in the adult [6]. In an analysis of 379 patients with groin hernia presenting electively at a university department of surgery, 16 patients had a femoral hernia. The correct diagnosis of femoral hernia was made in only three cases by general practitioners and in only six cases by surgical staff of all grades indicating the difficulty in diagnosis.

Most femoral hernias occur in women over 50 years. The incidence of femoral hernias, male to female, is around 1:4 (remember, inguinal hernias are much commoner in men, so femoral hernias in men represent just 1% of groin hernias but 27% in women). The different pelvic shape and additional preperitoneal fat in women are postulated to increase their risk compared to men. Women with femoral hernias are usually multiparous—multiple pregnancies are said to predispose to femoral herniation. Indeed, femoral hernias are as common in men as nulliparous women.

Forty percent of femoral hernias present as an emergency with incarcerated or strangulated hernia sac contents. It is a diagnosis that is often missed, with the patient vomiting for several days, often with plain films of the abdomen supporting small bowel dilatation. The patient or the nursing staff (if the patient is confined) then detects the red, painful groin swelling during bathing duties, which prompt calls for a surgeon. It is believed that femoral hernias are more likely to strangulate because of the relatively small neck to the sac, which also makes them less likely to be reduced in the emergency setting [7]. Ischemic bowel appears to be the major risk factor for death in the emergency setting [8], and thus patients, who are fit for surgery, should have femoral hernias repaired in a timely manner, and a watch-and-wait policy is not recommended. A study reported 111 patients undergoing femoral hernia repair in the Netherlands [9]. In the elective group, 10% of whom had significant comorbidity; there was no mortality and no bowel resection. Of the 33 patients treated as an emergency of which 20% had significant comorbid disease, there were 9 bowel resections and 3 deaths. The remainder of patients with a femoral hernia, who presented electively, complained of a groin lump and/or groin pain. About half of femoral hernias are irreducible at elective presentation.

The accuracy of diagnosis of femoral hernias in the community varies. In a retrospective review [6], letters of referral were traceable in 88% of elective patients with an operative diagnosis of femoral hernia. The correct diagnosis was arrived at by the referring general practitioner in less than 40% of cases, and the diagnostic rate was only improved by 20% in the hands of the surgical staff.

Differential Diagnoses of Groin Bulges

Hydrocele

The presence of a hydrocele in the adult will most commonly be associated with an inguinal hernia. In general, this does not present a diagnostic dilemma. However, there are situations in which either the hernia or the hydrocele is so large that the diagnosis is difficult to ascertain despite all the physical examination maneuvers that are employed. The use of diagnostic ultrasound will easily determine the diagnosis, as the use of transillumination in this circumstance is not always reliable.

Vascular Disease

Arterial—aneurysms of the iliac and femoral vessels: these may be complicated by distal embolization or vascular insufficiency, which will make the diagnosis more straightforward. A recent history of cardiac catheterization or transluminal angioplasty should raise awareness of a possible aneurysm.

Venous—a saphenovarix can be confused with a femoral hernia. Its anatomical site is the same, but its soft feel, fluid thrill, and disappearance when the patient lies down are characteristics. In a thin patient, the swelling may be a blue color. Varicose veins of the leg also support such a diagnosis, although varicose veins and groin hernias are associated with a common etiology of collagen disease. Venous bulging in the groin area during pregnancy is also well recognized and does not require surgery!

Inguinal venous dilation secondary to portosystemic shunting can result in a painful inguinal bulge. Again, there is a dramatic change on lying the patient flat. A Doppler ultrasound will confirm this with ease [10].

Lymphadenopathy

Chronic painless lymphadenopathy may occur in lymphoma and a spectrum of infective diseases. Acute painful lymphadenitis can be confused with a strangulated femoral hernia. A lesion in the watershed area, the lower abdomen, inguinoscrotal area, perineal region, anal canal, or the ipsilateral lower limb will often suggest this. Ultrasonic examination is very helpful to distinguish this pathology.

Tumors

Lipomas are very common tumors. The common "lipoma of the cord," which in reality is an extension of preperitoneal fat, is frequently associated with an indirect or direct inguinal hernia. A study reported 140 inguinal hernias in 129 patients [11]. A fatty swelling was deemed significant if it was possible to separate it from the fat accompanying the testicular vessels. The fatty swelling was designated as being a lipoma if there was no connection with extraperitoneal fat and was designated as being a preperitoneal protrusion if it was continuous through the deep ring with extraperitoneal fat. Protrusions of extraperitoneal fat were found in 33% of patients and occurred in association with all varieties of hernia. There was a true lipoma of the cord in only one patient. It was concluded that the mechanisms causing the hernia were also responsible for causing protrusion of extraperitoneal fat. Read has commented that occasionally extraperitoneal protrusions of fat may be the only herniation, and therefore inguinal hernia classifications need to include not only fatty hernias but sac-less, fatty protrusions [12]. Indeed, in the laparoscopic approach, it is our impression that a lipoma of the cord may be more common than suggested above. Lipomas can also occur in the subcutaneous fat of the groin and upper thigh. A lipoma is rarely tender; it is soft with lobulated or scalloped edges, is not fixed to the skin, and does not have a cough impulse. A number of rare tumors have also been described, some arising in the pelvis and growing down the inguinal canal such as giant aggressive angiomyxoma [13] and tumors of the spermatic cord [14].

Secondary Tumors

A lymph node enlarged with metastatic tumor usually lies in a more superficial layer than a femoral hernia. Such lymph nodes are more mobile in every direction than a femoral hernia and are often multiple. A metastatic deposit of a tumor arising from the abdominal cavity such as adenocarcinoma can present as a rock-hard immobile mass that can be confused as either a primary incarcerated inguinal hernia [15] or a postoperative fibrotic reaction following inguinal hernia repair.

Genital Anomalies

Ectopic testis in the male—there is no testicle in the scrotum on the same side. Torsion of an ectopic testicle can be confused with a strangulated hernia.

Cyst of the canal of Nuck—these cysts extend toward or into the labia majora. They can be transilluminable [16].

Inguinal endometriosis can also mimic a hernia, although the cyclical nature of the swelling when present is the diagnostic giveaway [17].

Obturator Hernia

An obturator hernia, especially in the female, lies in the thigh lateral to the adductor longus muscle. Vaginal examination may sometimes help with the diagnosis. This hernia is nearly always detected as an emergency, with the patient presenting with bowel obstruction with a Richter's-type hernia.

Rarities

A cystic hygroma is a rare swelling; it is loculated and very soft. Usually the fluid can be pressed from one part of it to another.

A psoas abscess is a soft swelling frequently associated with backache. It loses its tension if the patient is laid flat. It is classically lateral to the femoral artery. This will frequently be associated with elevation of the white blood cell count and a fever.

A hydrocele of the femoral canal is a rarity reported from West Africa. In reality it is the end stage of an untreated strangulated femoral epiplocele. The strangulated portion of omentum is slowly reabsorbed, the neck of the femoral sac remains occluded by viable omentum, while the distal sac becomes progressively more and more distended by a protein-rich transudate.

Clinical Examination of a Swelling in the Groin

Traditional surgical teaching is that the patients should be undressed and the entire abdomen and lower limbs examined. When the diagnosis of a hernia is suspected from the history and examination reveals an obvious hernia, then this pursuit of excellence is not necessary, and the patient is not expecting such exposure. However, if a hernia is not evident, then such exposure to allow adequate examination is necessary.

In the male, the first step is to observe where the testicles are. Knowledge of testicle position prevents all the confusions of undescended testicles, etc. If there is a significant scrotal swelling, the key question to differentiate between an inguinoscrotal hernia and a scrotal swelling is "can I get above the swelling and palpate a relatively normal cord," which excludes an inguinoscrotal hernia. A lack of a cough impulse is additional support that the scrotal swelling is not a hernia. If the swelling is confined to the scrotum, the next key question is whether a testicle is palpable or, if not, a hydrocele is present. If a testicle is palpable, the next question is "is it normal?" If the testicle is diffusely enlarged and painful, then think infection, either bacterial or viral. If eccentrically enlarged, then a tumor is likely. If the swelling is separate from the testicle, but appears to be applied to one side of the testicle, then an epididymocele is likely. If the swelling is separate from the testicle but along the cord, then a spermatocele is likely.

The groin should be examined with the patient standing erect and again with the patient lying flat. Hernias are sometimes only apparent when the patients are standing or when they strain or cough. The majority of moderate and large hernias, especially in the nonobese, are evident on inspection of the groin in a standing patient with asymmetry evident between the two sides of the groin (Fig. 11.1). This swelling is then gently palpated, the patient is asked to cough, and a cough impulse will confirm the presence of a hernia. Sometimes the swelling will visibly increase in size, again consistent with a hernia. In small groin hernias or in the obese, visual inspection may not show a hernia so obviously. In this case, palpate the groin in both the anatomical positions of an inguinal or femoral hernia and also over the area where the patient feels pain.

If a cough impulse is not obvious, lie the patient down. Again palpate the groin before and during a cough. As the hernia is likely to have reduced by lying down, the cough impulse is often more prominent when lying down, and indeed the cough thrill of hernial sac contents passing under the examination fingers may be palpated.

As already discussed, the need to differentiate direct from indirect inguinal hernias and, to a lesser degree, inguinal from femoral hernias is largely a hangover from a far from perfect art from the past. The operative approach to groin

Fig. 11.1 Asymmetrical left groin swelling suggestive of a hernia on that side

hernias allows whichever groin hernia is encountered at surgery to be corrected. This is especially true of the laparoscopic approach to groin hernia repair. The key is to be able to make a diagnosis of a hernia and modify the surgical strategy depending on the hernia type found during surgery.

Previous surgery may add to the difficulty of hernia diagnosis. Femoral hernias may present as "recurrences" after repair of an inguinal hernia at open surgery [18]. In these circumstances, they are often indistinguishable from inguinal hernias. The diagnostic difficulty is increased by the fact that as a femoral hernia emerges through the cribriform fascia at the fossa ovalis, the fundus comes forward and then turns upward to lie over and anterior to the inguinal ligament. If the external ring and the cord can be palpated, the diagnosis is more easily made. The difficulty is in the female. If the hernia can be reduced, careful palpation of the hernial aperture should enable the examiner to orientate it relative to the inguinal ligament. If the hernia emerges above the inguinal ligament when the patient coughs, the hernia is inguinal: if below the ligament, it is femoral.

Reducing the hernia and then using one finger to hold it while the patient coughs is a useful test, which will enable the inguinal canal or the femoral ring to be identified, almost with certainty. This test becomes less reliable the fatter the patient becomes, as accurate location of landmarks becomes more difficult. Invagination of the scrotal skin into the inguinal canal, a time-hallowed test, is uncomfortable for the patient and does not provide useful information, except perhaps in small indirect inguinal hernias.

Remember, once you have thought about a lump or swelling in terms of any changes in the skin overlying the lump; the position, size, shape, and consistency of the lump; any fixation to the skin or deep tissues; disappearance of the lump when contracting the muscles in the area; fluctuation or pulsation of the lump; and in the scrotum, transillumination, the diagnosis of the swelling is usually evident. Further investigations may be necessary, not to confirm the type of lump or swelling but to investigate the cause of the lump, especially if malignancy is expected, but this is out with the remit of this chapter.

Inguinoscrotal Pain

Inguinoscrotal pain may arise in the groin and radiate to the ipsilateral hemiscrotum, thigh, flank, or hypogastrium. Such pain may be neuralgic in type and accentuated by physical exertion. If the cause is a hernia or preperitoneal fat forcing its way out through the deep inguinal ring, it is postulated that these structures are stretched and pain fibers are stimulated. This is thought to cause a local reflex increase of tone in the internal oblique and transversus muscles coupled with neuralgic pain from stretching of the ilioinguinal nerve. The pain due to increase in tone is intermittent, whereas the neuralgic pain leading to hyperalgesia can be constant. This pain can resolve following hernia repair but sometimes can persist following surgery. It is imperative that this fact be made known to the patient preoperatively.

Table 11.1 Differential diagnosis of inguinoscrotal pain

Hernia: direct or indirect inguinal hernia, femoral hernia, lipoma of the cord
Scrotal conditions: epididymo-orchitis, prostatitis, urinary tract infection, torsion of the testis
Urological conditions: tumor or stone disease, urethral extravasation, vasitis
Gynecological conditions: pelvic inflammatory disease, uterine or ovarian tumor
Musculoskeletal disorders: adductor tendinitis, adductor avulsion, gracilis syndrome, pubic instability, osteitis pubis, rectus abdominis tendinopathy, iliopsoas injury
Spinal abnormalities
Hip abnormalities
Enthesopathy

Numerous other conditions can give rise to acute or chronic pain in the inguinoscrotal and neighboring anatomical regions (Table 11.1). These include gynecological and urological pathology and a variety of musculoskeletal syndromes. An important entity increasingly being characterized is the syndrome of Gilmore's groin or the sportsman's hernia. Thus, patients presenting with pain, as opposed to a painless, reducible swelling in the groin, require a careful history and examination for urological, gynecological, and musculoskeletal disorders.

In many patients presenting with chronic groin pain, a urological disorder is the initial working diagnosis. Chronic prostatitis or seminal vesiculitis is commonly suspected, and many patients may have been treated with multiple courses of antibiotics.

When pain is the main presentation, it is useful to ask patients to shade in pain areas on an anatomical diagram, to identify areas in which the pain occurs and is developing (Fig. 11.2). Sometimes patients will point to an area of spot tenderness with one finger, but a more diffuse area of pain is more typical.

Clinical Examination of Patients with Groin Pain

Examination will have begun as you observe the patient walking into your office. However, it is useful to ask the patient to walk and observe their gait. Exposure from the abdomen to the toes is necessary while preserving their modesty as best as possible. Palpate the spine. Test for movement of the lumbar spine in forward, backward, and

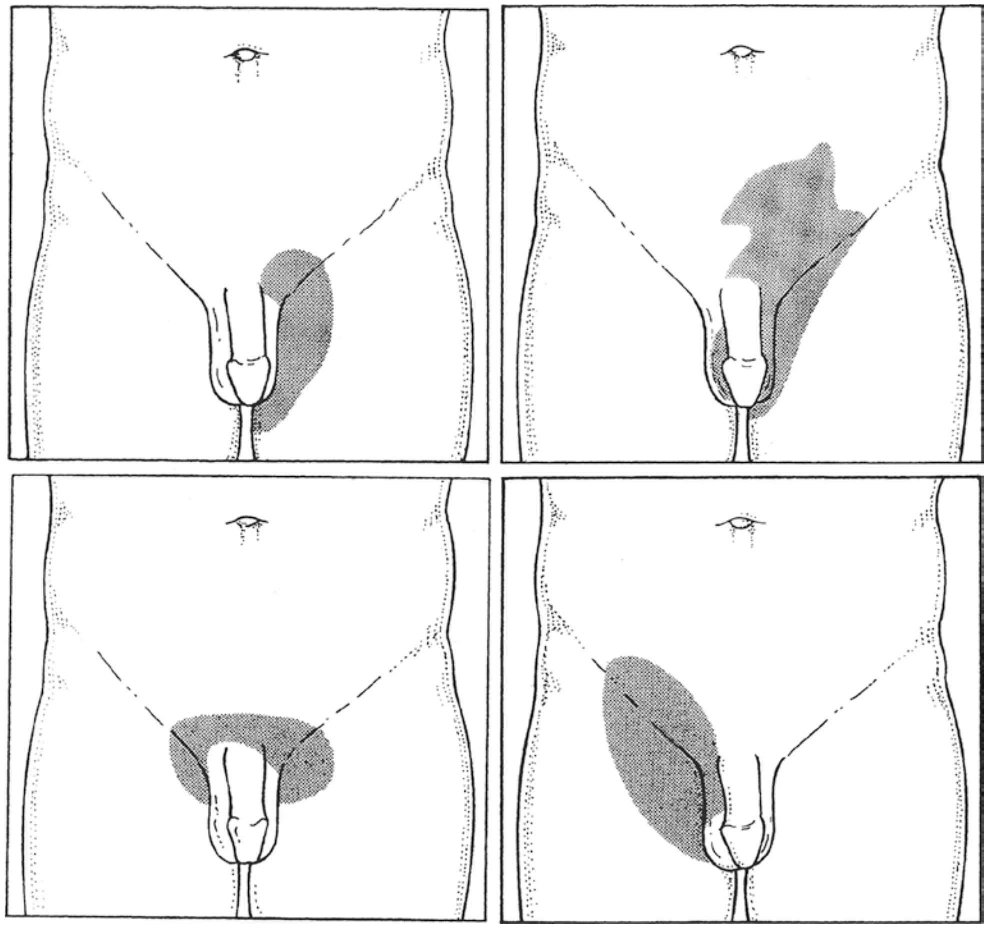

Fig. 11.2 Pain diagrams, each accompanied by the instruction "Please shade the areas where you felt pain prior to your operation"

lateral flexion and rotation. Ask the patient to hop on one and then the other foot. Pain elicited over the pubic symphysis while hopping points to instability or osteitis pubis. Perform bilateral femoral nerve stretch tests. Examine the patient standing as described above for a possible hernia in the groin. Then lay the patient flat and perform full active and passive movements of the hip, comparing one side with the other. Sportsmen, especially those with well-developed quadriceps muscles (hockey players), load their hip joint in an abnormal way, and early arthritis can be picked up by subtle reduction in the range of movement on the affected side. Perform bilateral sciatic nerve stretch tests. Palpate carefully the whole of the groin and upper thigh area, although the area of palpation will at times be focused if the patient reports pain in one spot. Enthesopathy—tennis elbow of the groin (inflammation of the insertion, enthesis, of a ligament or tendon) [19]—typically produces point tenderness at the affected site, in particular at the adductor longus insertion, inguinal ligament insertion, rectus abdominis insertion, or along the inguinal ligament at sites where the transversalis and internal oblique muscles insert. Such symptoms may respond to local injection of long-acting local anesthetic and steroid. If no point tenderness is evident, then examine the pectineus muscle, adductor muscles (magnus, brevis, and longus), and gracilis muscle by palpation, passive abduction, and adduction against resistance and hip flexion. The rectus abdominis muscle should be examined by active contraction with both legs elevated and by palpation of its origins. Examine the bony pelvis by palpation of the pubic arches, the crests and tubercles, and the pubic symphysis by compression and direct pressure. Depending on the patient's symptoms, a full neurological examination of the lower limb and affected groin, with particular reference to ilioinguinal or genitofemoral nerve neuralgias, may be appropriate.

In sportsmen's hernia, the clinical findings following a period of rest may be minimal. However, following a period of training or sporting activity, the whole inguinoscrotal region may be tender. While examination is important to rule out other pathology, it is my feeling that the sequence of events in the history is more important in reaching a diagnosis than the examination findings, as there is no single finding or test that easily supports the diagnosis. Palpation of the external ring by invagination of the scrotal skin is an uncomfortable maneuver, but it is typically much more painful on the affected side, which is made worse by coughing, and a more prominent cough impulse may be detected. If the diagnosis is still in doubt, ask the patient to adopt a half sit-up and cough while the margins of the superficial ring and the posterior inguinal wall palpated. An enlarged tender ring and posterior pain as compared to the other side are evidence of inguinal canal disruption [20].

Clinical examination of the scrotum may be necessary if the diagnosis is still not clear or there are symptoms in the scrotum. A small hernia protruding at the deep ring may stimulate the genital branch of the genitofemoral nerve to give scrotal pain in the male or labial pain in the female as its feature. If the patient presents acutely complaining of pain in the groin associated with a lump, the differential examination should look for hernias, torsion of the testicle or testicular appendage, spasm of the cremaster, and trauma to the testicle or cord.

Other rare causes of inguinoscrotal pain include abdominal aneurysms, degenerative disease of the lower thoracic and lumbar spines, and degenerative disease of the hip joint. The genital pelvic viscera, prostate, seminal vesicles, and proximal vasa have an autonomic supply from T12 to L2 and from S2 to S4. Referred pain from these organs may radiate via the genital branch of the genitofemoral nerve L1 and posterior scrotal nerves S2 and S3 to the groin and external genitalia.

Investigations in Occult Hernia and Groin Pain

In the majority of cases, a good history and examination is all that is required to establish the likely diagnosis and initiate management. However, there are occasions where help from a radiologist or a laparoscopy may help with the management. The tests will be discussed in turn and then use such investigations to answer the three questions laid out in the introduction of this chapter summarized.

Herniography

Herniography is still popular with some hernia surgeons, although I have not requested this investigation in 10 years! In those patients referred to me who have had a herniogram demonstrating a symptomatic hernia, I would have been happy to offer hernia surgery on the basis of the history and clinical examination alone. Nevertheless, herniography is used by many surgeons and is a sensitive tool, capable of demonstrating hernias in the groin, especially when clinical examination is negative [21]. One study reported lateral protrusion of the urinary bladder ("bladder ears") into the deep inguinal ring in 9% of 406 patients undergoing intravenous urography and cystograms [22].

Direct herniography was first performed in experimental animals [23] and subsequently performed in children [24]. Herniography with fluoroscopy and peritoneography, performed by puncture of the abdominal wall and injection of nonionic contrast medium, is now the preferred method of investigation [25]. Indications are principal symptoms indicative of a hernia but no palpable lump, obscure groin pain (other diagnoses having been excluded by appropriate investigation), and evaluation of patients who remain symptomatic following primary hernia repair.

Technique is important. The patients must be placed on a tilt table with fluoroscopy, enabling tangential views of the pelvic floor and groin. The bladder should be empty at the time of the examination to avoid inadvertent puncture. A needle puncture is performed using a 22-G spinal needle or occasionally a 21-G Chiba needle at the border of the lateral rectus muscle below the level of the umbilicus on the opposite side to the patient's symptoms. This site of puncture is chosen to minimize the risk of injury to the inferior epigastric vessels. Typically three pops are felt as the needle traverses the anterior rectus sheath, posterior rectus sheath, and transversalis fascia to enter the peritoneal cavity. Correct needle placement within the peritoneal cavity is confirmed by injection of a small volume of nonionic contrast under fluoroscopic guidance, which should freely run away from the needle tip. Approximately 60–80 mL of contrast is then injected with the head of the table elevated 30° to encourage the contrast to pool in the various fossae and hernial orifices. After the contrast has been injected, the patient is turned prone with the head elevated 20°, and PA and oblique views are taken. The patient is then instructed to exercise for 15–20 min, and repeat radiographs are taken with additional views obtained with the patient straining and coughing or during any other maneuver, which precipitates the symptoms.

A thorough examination of the entire surgical anatomy of the pelvic and inguinal floor should be performed for exact verification of all potential hernia orifices. Figure 11.3 demonstrates a normal herniogram.

Fig. 11.3 Normal herniogram

The different types of hernia can be diagnosed from their shape, relation to the pelvic peritoneal folds, and the resulting pelvic fossae. Five pelvic peritoneal folds in the pelvis and groin (lateral umbilical, medial umbilical, and median umbilical) divide the pelvic cavity into five fossae: the supravesical, the left and right medial umbilical, and left and right lateral umbilical fossae. An indirect hernia protrudes lateral to the lateral fold through the lateral (inguinal) fossa. A direct inguinal hernia protrudes lateral to the median fold through the medial (inguinal) fossa, whereas a femoral hernia protrudes through the median umbilical fossa in a lateral direction through the femoral canal. Figure 11.4 demonstrates herniograms depicting bilateral indirect hernias in a patient suspected clinically of having a unilateral left-sided hernia.

Herniography can be used in the postoperative evaluation of patients with persistent symptoms in whom clinically detectable hernias are not evident on physical examination. One study [26] performed herniograms in 46 patients with 54 symptomatic sites. Ten recurrent hernias were found, although only two were symptomatic. In addition, 14 hernias were found in the contralateral, asymptomatic groin, and the herniogram was negative in one patient with a clinical hernia. Although herniography can demonstrate a hernia, 22 of the hernias detected in this study had no clinical significance, and the reason for performing the study in the patient with a clinically evident hernia is unclear.

Inguinal and femoral hernias are most easily detected by herniography. Anterior wall defects such as ventral, Spigelian, and obturator hernias are less well demonstrated [27] and are more eloquently demonstrated by CT or MRI.

Fig. 11.4 Herniogram demonstrating bilateral indirect inguinal hernias (*arrows*) in a patient suspected clinically of having a unilateral left-sided hernia

Complications of herniography occur in around 6% of patients. Fortunately the majority of these are minor, including hematoma of the anterior abdominal wall, adverse reaction to the contrast, and extraperitoneal extravasation of contrast medium. More serious, infrequent complications include bowel perforation, mesenteric hematoma formation, and pelvic peritonitis.

In short, herniography can detect occult hernias and aid in the diagnosis of obscure groin pain, and series of patients said to benefit from the investigation continue to be reported [28]. It is performed under local anesthesia on an outpatient basis with minimal complications [29]. Visceral perforation is a rare hazard that does not usually require significant intervention [30]. However, herniography use is no longer in widespread use.

Ultrasonography

Ultrasound examination of the abdominal wall and inguinal region is being used increasingly in the diagnosis of occult hernia and groin pain. This has the advantage of avoiding the use of ionizing radiation, but the quality and accuracy of the study depend on the skill and experience of the sonographer and the body habitus of the patient. The technique is performed using a medium- to high-frequency linear array probe (7–13.5 MHz) depending on the patient's body habitus. The patient is initially examined in the supine position before and during the Valsalva maneuver and with coughing with the transducer placed parallel to the inguinal ligament with the inferior epigastric vessels used as a landmark in an attempt to distinguish between indirect and direct inguinal hernias. Using the same transducer orientation, the femoral canal is then examined to assess for a femoral hernia. Both sides are examined and the procedure should be repeated with the patient in the erect position if the supine examination is negative despite a strong clinical suspicion of an occult hernia.

Although the procedure is operator dependent, in experienced hands, ultrasonography has a reported sensitivity and specificity approaching 100% in determining the nature of groin hernia [31]. When used for the assessment of equivocal groin signs and groin pain, the accuracy of ultrasound is not so good [32]. False interpretation is said to be more likely to occur in cases of femoral hernia, although a recent study reported an accuracy of 37% in detecting clinically occult femoral hernias [33]. The typical findings and interpretation of a femoral hernia are shown in Fig. 11.5.

The antenatal diagnosis of abdominal wall defects is now a successful part of obstetric/pediatric practice. Patients born with significant abdominal wall herniation can be detected prenatally and thus delivered in a unit with the appropriate pediatric surgical expertise.

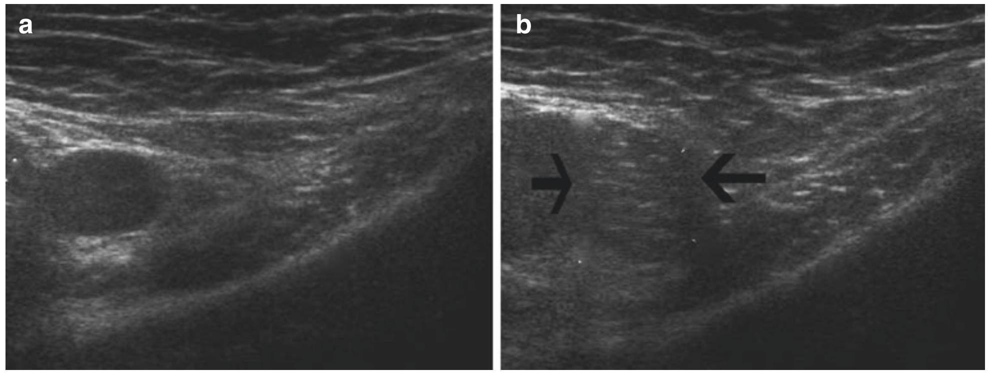

Fig. 11.5 Ultrasound scan demonstrating normal femoral canal at rest (**a**) with a femoral hernia (outlined by *arrows*) evident during straining (**b**)

The use of ultrasound to diagnose hernias in small children is less successful. One study reported ultrasound assessment of the contralateral groin accurately diagnoses a patent processus vaginalis in only 15 of 23 infants, with four false-positive and four false-negative cases [34]. Thus ultrasound alone should be used with caution to plan management of the contralateral groin in infants. An interesting study reported that inguinal hernias could be accurately diagnosed using the parent's digital photographs when the physical examination is not diagnostic [35].

In boys, where there is doubt about the diagnosis, ultrasound is a noninvasive and highly accurate diagnostic tool [36]. Using 4 mm as the upper limit of the normal diameter of the internal ring, occult inguinal hernias can be diagnosed with 98% accuracy.

A small study in 19 patients with clinically diagnosed groin hernias assessed the ability of color Doppler sonography to distinguish between different types of groin hernia in adults [37]. The inferior epigastric artery was used as a landmark to differentiate different types of hernia sac but was only visualized in 55% of cases making this examination an unreliable method for differentiating hernia types. However, a more recent study has reported a much higher accuracy of 96% in differentiating hernia types [38]. The use of a protocol-driven approach for ultrasound evaluation of the groin is suggested to ensure an accurate and comprehensive evaluation of the groin region [39].

Computed Tomography

Cross-sectional imaging by CT scanning can accurately evaluate disorders of the abdominal wall, including hernias. In the elective setting, CT scanning of a lump in the groin is indicated when the lump is not considered on clinical grounds to be a hernia. CT scanning will delineate tumors of the anterior abdominal wall, lymph node masses, and tumors of the abdominal cavity enlarging though hernial orifices. Inflammatory conditions and abscesses within the abdomen and pelvic can also be detected. Sometimes such tumors and other conditions can be the causes of groin pain (Fig. 11.6). Several studies describe the use of CT scanning to differentiate clinically evident hernias of the groin into inguinal or femoral [40, 41] (Fig. 11.7) and between direct and indirect hernias (Fig. 11.8) [42]. The multiplanar high-resolution reconstructions obtained from multidetector CT scans clearly depict the inferior epigastric vessels to allow differentiation

Fig. 11.6 Coronal CT scan demonstrating a right-sided varicocele (*arrow*) as the cause of the patient's right-sided groin discomfort which is secondary to a large retroperitoneal mass pathologically confirmed to represent a neurogenic tumor (*arrowhead*)

Fig. 11.7 Coronal CT scan demonstrating a strangulated right-sided femoral hernia (*arrow*) containing small bowel lying within the femoral canal presenting as acute small bowel obstruction

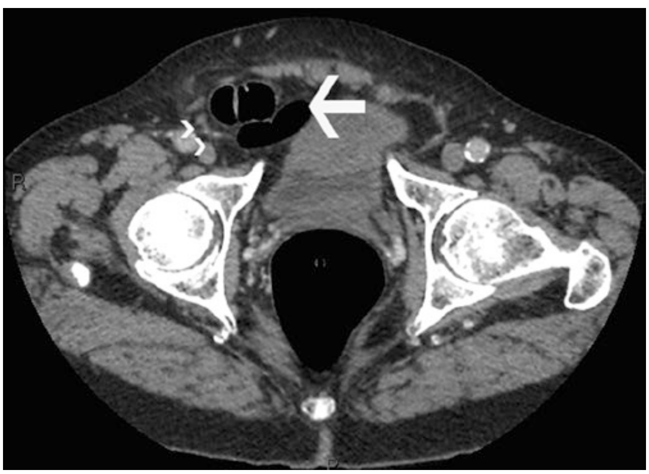

Fig. 11.8 Axial CT scan demonstrating a right-sided direct inguinal hernia (*arrow*), with the neck lying medial to the inferior epigastric vessels (*arrowheads*)

of indirect from direct hernias. The femoral canal can also be directly visualized (using the inguinal ligament, femoral vein, and adductor longus as landmarks), thus allowing the diagnosis of femoral hernias.

To laparoscopic groin surgeons, and I expect to most open groin hernia surgeons also, this is seen as a waste of resource and unnecessary radiation risk to the patient with the usual type of groin hernia.

The real role of CT scanning is in the assessment of a patient with difficult to diagnosis multiply recurrent herniation or with obstruction of the bowel. Femoral and obturator hernias, with a Richter's-type hernia, can be difficult to detect clinically until infarction and perforation of the bowel have occurred. CT scan eloquently demonstrates these otherwise occult hernias to be the cause of the underlying bowel obstruction (Fig. 11.9). It is also useful to rule out other sources of lower abdominal or groin pathology as the source of pain. However, the detection of a clinically occult hernia on CT in a patient with groin pain needs careful consideration that the hernia is truly the cause of the pain [43].

Magnetic Resonance Imaging

MRI of the abdomen and pelvis is also increasing in use for the assessment of groin pain and groin swellings not thought to be a hernia (Fig. 11.10). MRI provides superb soft tissue resolution with multiplanar anatomical depiction and avoids the use of ionizing radiation. It is a useful "screening" tool to detect foci of inflammation that may explain the patient's symptoms, especially in athletes. Osteitic changes particularly in the pubis are detected as areas and low signal intensity on T1-weighted images of high and homogenous signal intensity on T2-weighted scans [44] (Fig. 11.11). Abnormalities in myotendinous structures are also well documented by this technique as is involvement of the sacroiliac joints [45]. Groin hernias can be detected on MRI, which

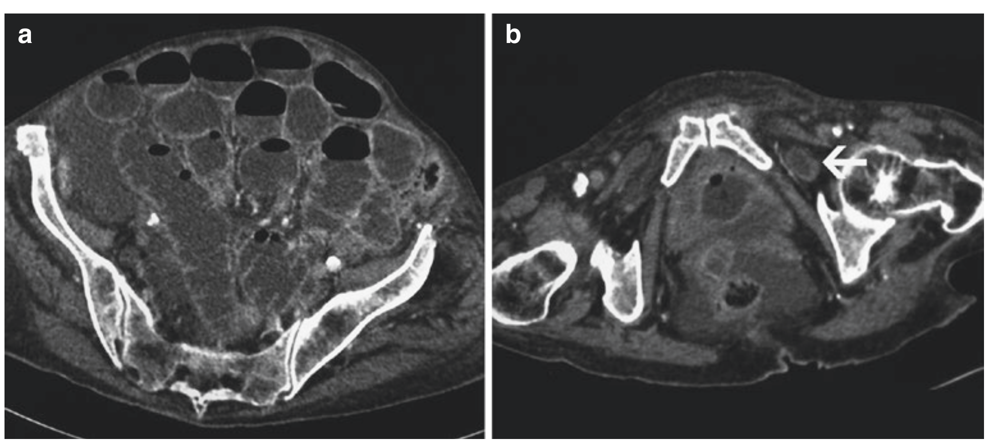

Fig. 11.9 Axial CT scans demonstrating small bowel obstruction (**a**) secondary to a clinically occult left-sided obturator hernia (**b**)

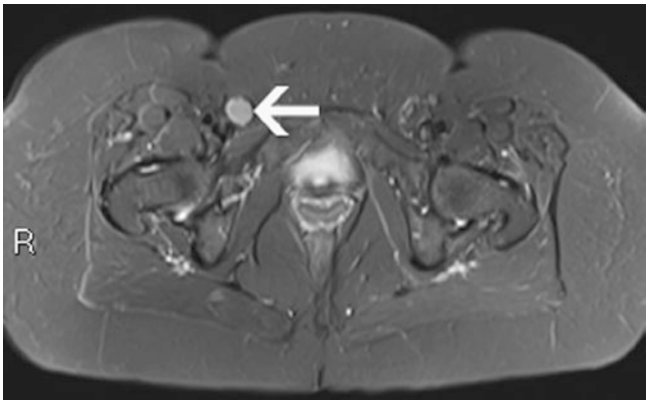

Fig. 11.10 Axial STIR MRI scan demonstrating a right inguinal node in a female patient presenting with a painful right groin mass. Excision biopsy confirmed metastatic squamous cell carcinoma

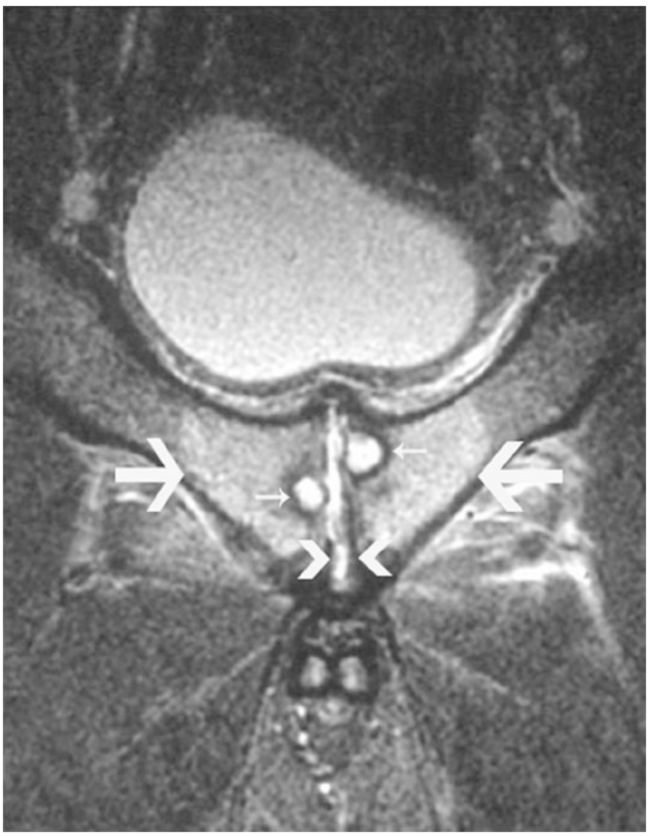

Fig. 11.11 Coronal T2 scan demonstrating osteitis pubis with bone marrow edema in the symphysis pubis (*large arrows*) with associated cystic bone changes (*small arrows*) and high signal change within the fibrocartilaginous disc (*arrowheads*)

allows direct visualization of the hernial sac within the inguinal or femoral canal (Fig. 11.12). More rapid sequence times also allow the scan to be performed with a Valsalva technique [46].

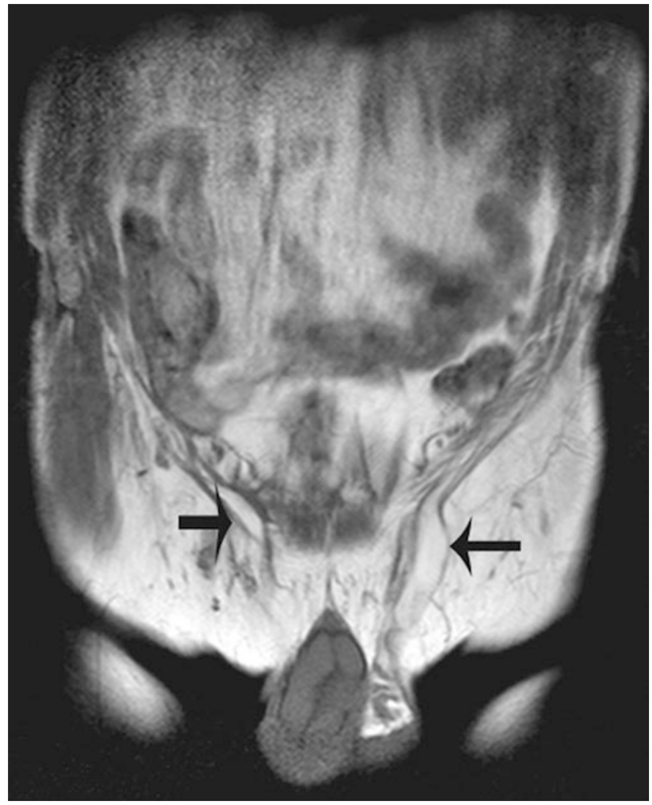

Fig. 11.12 Coronal T1 MRI scan demonstrating bilateral fat containing indirect inguinal hernias

Laparoscopy

This investigation has merit as treatment can sometimes be undertaken at the same time. There have always been cases, where the history is suggestive of a hernia (including the so-called sportsman's hernia), but the clinical findings are equivocal, yet the patient has symptoms that interfere with work or social activities. In such patients, I discuss investigation options vs. exploring their groin with a laparoscope. While traditional intraperitoneal laparoscopy is within the ability of most general and hernia surgeons, lipomas of the cord, obturator hernias, and small femoral hernias when there is little in the way of hernial sac can be missed by this approach. If a hernia is found by conventional laparoscopy, then the options would be to do a TAPP or convert to a traditional open operation or perhaps convert to a TEP depending on the surgeon's experience. I still feel uncomfortable exploring the groin by open surgery, when the diagnosis is not clear, because of the small risk of severe chronic groin pain (in the region of 2–3%), while severe chronic pain following laparoscopic surgery is a more rare event but can still occur (see Chap. 23 on Pain).

Clinical Dilemmas

1. Symptom but no swelling: is there a hernia?

The investigative options here are to consider an ultrasound scan first, perhaps a herniogram, but my preference unless significant anesthetic risk or contraindication is to proceed with laparoscopy and perform a TAPP repair.

2. Swelling, but is it a hernia?

The investigative options here are to consider an ultrasound scan first, followed by an MRI or CT scan if the ultrasound is equivocal, or further evaluation of deeper aspects of the swelling is necessary.

3. Hernia, but is it causing the symptoms?

The investigative options here are to consider an MRI scan first. If this is normal or fails to identify an alternate obvious cause for the symptoms, then proceed with laparoscopy (or open exploration) of the groin.

Conclusions

An effort should be made to distinguish inguinal from femoral hernias before surgery to help plan the surgical approach. However, with laparoscopic surgery, this is less important as all the hernial orifices in the groin can be easily exposed during the operation.

Careful identification of the pubic tubercle, the anterior superior iliac spine, and, between them, the inguinal ligament is the prerequisite. Inguinal hernias emerge from the fascia transversalis above this line and femoral hernias below it.

Femoral hernias never pass from the abdomen into the scrotum or labia majora as indirect inguinal hernias do.

The diagnosis of inguinoscrotal pain can be a challenging clinical problem. A diagnosis can often be achieved by taking a detailed history and examination, supported with appropriate radiological investigation [47, 48].

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Anterior Open Repair of Inguinal Hernia in Adults

12

David L. Sanders, Kelly-Anne Ide, and Joachim Conze

Introduction

With a lifetime occurrence of 27–43% in men and 3–6% in women [1], inguinal hernia repair is now performed on more than 20 million people annually [2], making it one of the most commonly performed operations worldwide.

Even when initially asymptomatic, 70% of patients require surgery within 5 years [2]. Surgical treatment, although successful in the vast majority of patients, requires reoperation for recurrence in 2.2–4.4% [3]. Repair of recurrent groin hernia accounts for 15% of all groin hernia repairs [4]. Chronic pain, defined as moderate pain persisting for more than 3 months [5], affects 10–12% of patients [6, 7], with 0.5–6% experiencing severe chronic pain affecting normal daily activities [6]. This has a significant impact on global health and healthcare costs. This chapter aims to provide an overview of preoperative considerations and the operative steps to help achieve successful outcomes.

Open inguinal hernia repair was first performed in the late sixteenth century, and the literature provides numerous descriptions of operative techniques (Table 12.1). Marcy laid the foundations for the modern approach to inguinal hernia repair by observing the anatomy and physiology of the deep inguinal ring and inferring the importance of the obliquity of the canal [8]. His teachings were heard by Bassini in 1881, who grasped the significance of the anatomic arrangement and, in particular, the role of the fascia transversalis and transversus abdominis tendon [9]. The role of the transversalis fascia in groin hernia formation, by a process of degeneration and alteration in both structure and function, has been recognised and discussed by many surgeons [10, 11]. It was Bassini, however, that emphasised the importance of dividing the fascia transversalis and reconstructing the posterior wall of the inguinal canal. He described a 'triple-layer' repair using non-absorbable sutures, in which the fascia transversalis and transversus abdominis muscles are sutured to the upturned, deep edge of the inguinal ligament and include the lower arching fibres of the internal oblique muscle where it forms the conjoint tendon. These observations are often lost in modern literature, and in fact many of the failed 'Bassini's operations' occurred when only the fleshy conjoint tendon is sutured to the inguinal ligament. This is not the only essential component of the Bassini operation that has been lost throughout history. It is still performed by many surgeons, but the division of the cremaster muscle and posterior canal wall is not always included, possibly because Bassini did not describe this step in his original papers. His colleague Attilio Catterina, who later became professor of surgery at Genoa, recognised the importance of Bassini's advances and that Bassini had failed to get the technical points across to his surgical audience. Catterina later depicted the operation in an illustrated book published in the 1930s which, despite publication in many languages, was not widely read amongst European surgeons and was not published in North America. As such, this may account for the inaccurate dissemination of Bassini's technique and the observed poor results. Wantz again tried to propagate the Bassini technique through his atlas, illustrated by surgeon artist O. Gaigher, and numerous lectures across Europe. Nevertheless the Bassini operation was abandoned in America, and alternatives including McVay-Cooper's ligament repair, Marcy's simple ring closure or Nyhus preperitoneal approach were adopted.

The third person in seminal herniology is Halsted, whose major contribution is twofold. His original input, which he later abandoned, advised drawing the external oblique down behind the cord to reinforce the repair. He did, however, insist upon scrupulous atraumatic technique and the importance of adequate follow-up—an ideal also upheld by Bassini. In a more general sense, Bassini and Halsted are epoch individuals because they introduced quality control

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Table 12.1 Techniques for inguinal hernia repair

Single-layered closure
Halsted (1889) [104]
Madden (1971) [105]
Multilayered closure
Bassini-Halsted principle
Bassini (1887) [25]
Ferguson (1899) [106]
Andrews (1895) [107]
Halsted II (1903) [108]
Fallis (1938) [109]
Zimmerman (1938, 1952) [110]
Reinboff (1940) [111]
Tanner (1942) [112]
Shouldice repair
Glassow (1943) [113]
Griffith (1958) [114]
Lichtenstein (1964, 1966) [115]
Palumbo (1967) [116]
Cooper's ligament repair
Lotheissen–McVay principle
Narath (cited by Lotheissen, 1898) [117]
Lotheissen (1898) [117]
McVay (1942, 1958) [118]
Preperitoneal approach
Cheatle (1920) [119]
Henry (1936) [120]
Musgrove and McReady (1940) [121]
Mikkelson and Beme (1954) [122]
Stoppa (1972) [123]
Condon (1960) [124]
Nyhus (1959) [125]
Read (1976) [126]
Rignault (1986) [127]
Paillier (1992) [128]
Primary repair with prosthetic materials
Koontz (1956) [129]
Usher (1960) [130]
Lichtenstein (1972) [115]
Trabucco (1989) [131]
Valenti (1992) [132]
Corcione (1992) [133]
Plug repair
Lichtenstein (1970) [115]
Bendavid (1989) [134]
Gilbert (1992) [135]
Robbins and Rutkow (1993) [65]
Gilbert (1998) [136]
Laparoscopic repair
Ger (1990) [137]
Corbitt (1991) [138]
Ferzli (1992) [113]

and audit to surgeons. Florence Nightingale's exhortation that 'to understand God's will we must study statistics' was translated into surgical science by Bassini and Halsted.

In the last 50 years, the role of collagen in hernia formation has become increasingly apparent, after first being researched in 1967 by McVay and Read who proposed that an unrecognised connective tissue disorder may be involved [12]. They studied a large series of veterans, whom they noted to have a preponderance of bilateral and direct defects. Their biochemical analysis revealed a marked loss of collagen, with poorly proliferating fibroblasts and decreased collagen synthesis. Similar changes were noted in the skin and pericardium, indicating a systemic disease of collagen metabolism [13].

Klinge et al. also investigated collagen metabolism in hernia patients three decades later, finding a significant increase of type 3 collagen and terming this systemic condition 'herniosis' [14–16].

The true tension-free hernioplasty using mesh and not suture closure of the hernial defect was introduced in 1984 by Irving Lichtenstein and colleagues [17]. His technique resulted in a paradigm shift and new gold standard in hernia surgery. Lichtenstein reported his personal experience of 6321 cases in 1987 with a 91% follow-up over a period of 2–14 years and a recurrence rate of 0.7% [18]. At this time apart from the innovation of polypropylene mesh, Lichtenstein had abandoned high ligation and excision of indirect sacs but continued to use single-layer approximation of the transversus abdominis and the inguinal ligament with a relaxing incision. After a period of evolution, the perfected tension-free hernioplasty was reported by Lichtenstein, Shulman, Amid and Montelier in 1989 [19].

Repair of the posterior abdominal layer with a suture line was abandoned, except for a simple imbrication suture for large sacs that aided flattening of the posterior wall before placement of the mesh. The recurrence rate in over 1000 cases was 0% at a 1–5-year follow-up, with no mesh infections, and the authors stated that the technique was simple, rapid, relatively pain-free allowing prompt resumption of unrestricted physical activity. This report prompted a campaign of popularisation of the tension-free hernioplasty [20].

Like the Shouldice Hospital, the Lichtenstein Institute surgeons have written multiple publications in the surgical literature, repeating their experiences with a gradually enlarging number of patients [21–23]. The authors emphasise that the hernial defect edges are not approximated and the sole strength of the repair is based on placing a synthetic implant over the posterior inguinal wall with a tension-free patch. Many thousands of patients have now undergone repair with this operation at the Lichtenstein Institute; the operation is being performed under local anaesthesia and patients discharged within a few hours of operation with minimal discomfort, for which mild analgesics are prescribed. Unrestricted activity is encouraged and patients discharged from the unit are able to resume normal activity in 2–10 days. A postal survey performed by Shulman of 70 surgeons utilising this technique who did not have a special interest in inguinal hernia surgery indicated similar results in 22,300 repairs [24].

In the UK, the Lichtenstein technique was first reported by Kingsnorth and colleagues and subsequently by a private hernia clinic, The British Hernia Centre [25, 26].

Kark and colleagues, reporting on 1098 tension-free hernia repairs, found only one recurrence after primary repair and an overall sepsis rate of 0.9% [26]. This report emphasised the cost savings associated with the operation and the rapid return to activity: 50% of office workers returning to work in 1 week or less and 60% of manual workers in 2 weeks or less. Nevertheless, the operation can present technical difficulties to the novice, as illustrated by a report from Brussels in which 139 primary inguinal hernias were repaired by tension-free hernioplasty and a 4.6% recurrence rate was reported during a mean follow-up of 12.7 months. The probable technical fault was failure to overlap the pubic tubercle and the entire posterior inguinal wall by a wide margin of mesh [27]. These authors reported a 50% saving of resources by utilisation of the tension-free hernioplasty.

The first randomised trial reporting a comparison between the tension-free hernioplasty and the Shouldice operation was reported by Kux and colleagues, verifying the low recurrence rate (one recurrence in the Lichtenstein group over a 30-month period) and a reduced requirement for postoperative pain relief. Patients under the age of 60 years were excluded from this study [28].

The EU Hernia Trialists Collaboration examined all randomised and quasi-randomised trials comparing open mesh with open non-mesh methods for repair of groin hernia [29]. Fifteen eligible trials, which included 4005 participants, were identified. Return to usual activities was quicker in the mesh group for seven of the ten trials (p value not significant). There were fewer reported recurrences in the mesh groups (1.4% compared with 4.4%). Therefore, using the powerful statistical methods followed by the Cochrane Collaboration, the currently available literature indicates that mesh repair is associated with three times fewer recurrences than non-mesh, in the repair of inguinal hernia. All these studies comparing different surgical procedures are limited in their conclusion due to the missing classification of the hernia included.

Amid published his results of 5,000 Lichtenstein procedures with a recurrence rate of 0.1% after a follow-up of 5–10 years, however the data of multicentre studies shows a different recurrence rate of up to 10% [3, 30, 31].

Classification of Inguinal Hernia

The classification of groin hernias in day-to-day practice is not something that is routinely performed. The terms direct, indirect, femoral, inguinal, recurrent or primary are familiar to all surgeons; however, formal classification is needed to ensure that we are comparing like for like in research, quality audits/databases and when we are tailoring the surgical treatment offered to different hernia types. There are multiple classification systems available, and it is currently uncertain which of these is most suited to the desired purpose. The World Guidelines for Groin Hernia Management [32] advocates the use of the European Hernia Society's classification system based on expert opinion and the evidence available, and this system is now the standard in Europe, but as yet none of the enlisted classification systems has attained worldwide acceptance and propagation. The attributes of successful classification are organising the important variables into a simple and easy to use system.

The EHS Classification [33]

This system was introduced in 2006 as an attempt at a practical and user-friendly classification and is based on the Aachen classification by Schumpelick. The parameters recorded are anatomical location, primary or recurrent, and size of hernia orifice (see Table 12.2). According to the Aachen classification, 1.5 cm was chosen as it is simple to measure, being the average diameter of a surgeon's index fingertip or the length of the branches of laparoscopic scissors.

Table 12.2 The EHS classification of groin hernias [33]

	Primary/recurrent				
EHS groin classification system	0 (no hernia identified)	1 (<1.5 cm)	2 (1.5–3 cm)	3 (>3 cm)	X (not assessed)
Lateral/indirect (L)					
Medial/direct (M)					
Femoral (F)					

Gilbert Classification [34]

Introduced in 1988, the Gilbert system describes five classes of hernias based on the anatomic and function defects identified at operation. Types 1–3 are indirect and types 4–5 are direct.

Type 1 – The hernia has a tight internal ring that would hold the contents within the abdominal cavity once the sac is surgically reduced.

Type 2 – The hernia has an enlarged internal ring, up to 4 cm.

Type 3 – The hernia has an internal ring greater than 4 cm with the sac frequently having a sliding or scrotal component.

Type 4 – The hernia involves the entire posterior wall of the inguinal canal.

Type 5 – A direct diverticular defect in the suprapubic position.

Rutkow and Robbins added to this system in 1993 to describe a sixth type, which has both direct and indirect components, and a seventh type for femoral hernias [35].

Nyhus Classification [36]

In 1991 Nyhus introduced a further classification system, which he envisioned would enable preoperative planning and individualisation of surgery.

Type 1 – An indirect inguinal hernia with a normal internal ring—both in size and structure. The sac extends variably from just distal to the internal ring to the middle of the inguinal canal. Usually occurring in infants, children or young adults, the boundaries are well defined, and Hesselbach's triangle is normal.

Type 2 – An indirect inguinal hernia with an enlarged and distorted internal ring that does not impinge on the posterior wall of the inguinal canal. Hesselbach's triangle is normal, and the hernia sac may occupy the entire length of the canal but does not enter the scrotum.

Type 3a – A direct inguinal hernia.

Type 3b – An indirect inguinal hernia with a large internal ring that has encroached on the posterior wall of the inguinal canal. The sac may enter the scrotum or have a sliding element.

Type 3c – A femoral hernia.

Type 4 – A recurrent hernia, subdivided into direct (4a), indirect (4b), femoral (4c) or mixed (4d).

Zollinger Classification [37]

This system was designed to build on all the systems described above following a survey of 50 North American and 25 European expert hernia surgeons by Zollinger. He described seven types of inguinal hernias:

Type 1 – Small indirect hernias with an intact internal ring.

Type 2 – Large indirect hernias with loss of internal ring function.

Type 3 – Small direct hernias with intact internal ring and functioning posterior canal wall.

Type 4 – Large direct hernias where the integrity of the entire posterior wall is lost.

Type 5 – A combined direct and indirect hernia with either loss of internal ring competence (5a), loss of posterior wall integrity (5b) or both (5c).

Type 6 – Femoral hernias.

Type O ('other') – This category incorporates the mixed femoral-inguinal hernias, pre-vascular hernias and any special circumstances including massive inguinal hernias.

In order to attain international acceptance, a classification system must be simple to perform, but only by attaining this will it be possible to objectively assess the surgical results of all the different procedures. This will ultimately allow for a truly individualised treatment plan for each patient with a groin hernia.

Preoperative Considerations

Who Needs an Operation?

In the last edition of this book, it was stated that the main reasons and motivation for elective inguinal hernia repair are the risk of incarceration (irreducibility) and strangulation of the contents of the hernia sac. Indeed, the Danish and Swedish hernia registers provide evidence that emergency operation for a strangulated hernia is associated with a higher mortality rate than elective surgery (>5% versus <0.5%) [2, 3, 38]. This has been corroborated by two systematic reviews, which also found an increased morbidity from 8 to 32% for emergency hernia surgery [39, 40]. There is, however, no accurate data available on the annual rate of incarceration, which is estimated to be 0.3–3%. The rate of incarceration for indirect inguinal hernias is thought to be greater than for direct inguinal hernias. Other risk factors appear to be age [39, 40] and the length of history. Gallegos and colleagues retrospectively studied the cumulative probability of strangulation in relation to the length of history over a 3-year period. Of 476 hernias (439 inguinal, 37 femoral), there were 34 strangulations (22 inguinal versus 12 femoral). After 3 months the cumulative probability of strangulation for inguinal hernias was 2.8%, rising to 4.5% after 2 years. For femoral hernias the cumulative probability of strangulation was 22% at 3 months and 45% at 21 months [41]. They concluded that the rate at which the cumulative probability of strangulation increased was greatest in the first 3 months for both femoral and inguinal hernias. Similar results were reported by Rai and colleagues that proved a short duration of hernia to be a risk factor predicting complications in an adult with a groin hernia [42].

We would like to revise the statement from the last edition; the main reason for elective hernia repair is to improve the patient's quality of life. What do we know about the natural course of untreated inguinal hernia? Two moderate-quality randomised controlled trials have been published, comparing operation with 'watchful waiting'. A trial in 2006 coordinated by Fitzgibbons randomised 720 men (over 18 years of age) to either primary surgery or watchful waiting. Crossover from watchful waiting to surgery was 23% at 2 years and 50% after a further 7 years. The most common reason for conversion was pain. Three patients underwent emergency surgery, with 0% mortality [43, 44].

In a trial by O'Dwyer, 160 men over 55 years of age were randomised to operation or watchful waiting. Twenty-nine percent of men on watchful waiting converted to surgery by 1 year [45] and 54% at 5 years [46], the most common reason again being pain. They noted three serious hernia-related adverse events in the watchful waiting group after 1 year. One of these had a strangulated hernia. The remaining two were crossover patients, one of whom suffered a postoperative myocardial infarction and the other suffered a postoperative cerebrovascular event. They both had coexisting cardiovascular disease at enrolment that had deteriorated throughout the observation period. Had they been operated on at presentation, such an event may have been avoided.

Although both trials differ slightly, watchful waiting does appear to be an acceptable option for elderly men with asymptomatic or minimally symptomatic inguinal hernias with incarceration proving rare. However, the significant crossover to surgery in the watchful waiting groups in both studies highlights that most patients will require surgery at some point. Clearly there needs to be a balanced discussion of the risks of benefits of conservative management versus surgery, so that an informed decision can be made.

To estimate the risk of incarceration vs. the option for 'watchful waiting', Gai reported a study investigating the morphology of the hernia sac by ultrasound. He differentiated three different sono-morphological hernia types: if the hernial orifice and hernia sac appear like a bulge, it is a type A hernia; if the hernial orifice and hernia sac appear like a tube, it is a type B hernia; and if it appears like a sand clock, it is a type C hernia. According to his results, the highest risk for incarceration is a type C hernia. Gai used this tool to decide on 'watchful waiting' vs. elective surgery in asymptomatic hernias [47].

The approach is slightly different, however, in female patients. Whilst groin hernia repairs are eight to ten times more common in men [48, 49], femoral hernias occur four times more commonly in women [50]. Women are more likely to require emergency surgery than men (17% versus 5%), and women with femoral hernias undergoing emergency surgery require in bowel resection in 17% and have a 3.8% 30-day mortality [51, 52]. Given the higher frequency of concomitant femoral hernias in women and the increased risks this poses, the World Guidelines for Groin Hernia Management strongly opposes a watchful wait approach in women and advises timely hernia repair [32]. They make similar recommendations for male femoral hernias as the risk of strangulation is unacceptably high [53–56].

'One Fits All' or a Tailored Repair?

Selecting the optimal technique for groin hernia repair is challenging, and influencing factors are both operator and patient specific. The ideal technique should be low risk and relatively easy to learn; have an acceptable recovery time with reproducible, satisfactory results; and be cost-effective. The method used may also depend on surgeon preference and abilities, the resources available, the anaesthesia type and patient's wishes. There are, however, certain circumstances where the patient benefits from a specific technique, as discussed later in this section [32].

Existing literature and guidelines support the use of mesh in all hernia repairs, yet long-term follow-up of the Shouldice repair revealed a comparative recurrence rate to mesh repair when performed in expert centres [57].

Recurrent Hernia

There is high-quality evidence that for a recurrent hernia, the repair should be undertaken through the opposite method to the primary repair to obtain the best results, i.e. if the primary repair was open, then the second repair should be laparoscopic and vice versa [58, 59].

The High-Risk Anaesthetic

It is widely accepted that a high-risk, co-morbid patient may benefit from an open repair under local anaesthetic to reduce their risk of intra- and postoperative complications. Local anaesthetic can also prove beneficial in other patient groups as it has a lower risk of urinary retention [60, 61] and allows for earlier mobilisation and discharge [61] in addition to the socio-economic benefits [62]. Interestingly these benefits are not seen with regional anaesthetic, such as spinal anaesthesia, where increased medical complications (myocardial infarction, pneumonia, deep vein thrombosis) are seen along with slower recovery and discharge [63]. There is some concern about the increased recurrence rate observed in local anaesthetic repairs [64, 65]; however, this is known to be lower in surgeons who are well versed in performing local anaesthetic repairs, indicating it is likely to be an experience-related complication.

Preoperative Pain

In those patients with high levels of pain preoperatively, a laparoscopic repair may be beneficial as the cutaneous nerves are not disrupted [66, 67].

Bilateral Hernia

A laparoscopic approach should also be considered in bilateral hernias where it has been shown to have lower recurrence rates and lower postoperative complication rates [3, 59, 68–74]. It has also been shown to reduce operative time and postoperative recovery time [75] improving the cost-effectiveness.

Groin Hernia in Women

Laparoscopic repair is advised in females as it allows for inspection of all the hernia orifices, allowing femoral hernias to be excluded. Reoperation rates for recurrence are higher in women, and in 40% of cases, the 'recurrence' is found to be a femoral hernia [51, 68–70, 76, 77] which may indicate a missed hernia at the original operation. The reoperation rate is lower if the primary repair is performed laparoscopically [68–72].

The decision concerning which technique to use should not be driven by the surgeon's favourite, standard procedure but should take into account the patient's systemic condition and type of hernia. Therefore, a surgeon who operates on inguinal hernias should have several techniques in his surgical arsenal or the insight to refer to a surgeon who can provide the optimal treatment if they are unable to in a specific case, hence 'tailoring' the surgical procedure to each patient, taking into account the patient's personal risk profile and individual hernia anatomy [14–16].

Consent for Open Inguinal Hernia Repair

The process of consent is thoroughly covered in other resources, and full guidance is provided by the General Medical Council [78] and therefore will not be covered in this chapter. Readers should, however, be aware that consent does not simply refer to the consent form being signed but a process of information giving that begins at the initial consultation.

The documentation used depends on the local protocols but usually details the procedure, the intended benefits and potential risks, and the anaesthetic modality as well as the alternative management options.

The Royal College of Surgeons of England provided a list of common or serious risks that they advise a patient should be aware of before undergoing an inguinal hernia repair, which was later adapted by Hoosein et al. (see Table 12.3) [79, 80]. These risks are discussed with varying consistency [79, 81], and with the increasing legal challenges faced by medical professionals, thorough informed consent is vital to ensure a patient is fully prepared for his or her surgery.

Table 12.3 Risks of open inguinal hernia repair [79, 80]

Wound complications	Bruising
	Haematoma
	Infection
Scrotal complications	Ischaemic orchitis and testicular atrophy
	Damage to vas deferens or testicular vessels
	Hydrocele
Special complications	Genital oedema
	Nerve injury and chronic pain
	Compression of femoral vessels
	Retention of urine or bladder injury
General complications	Visceral injury
	Chest infection
	Deep vein thrombosis and pulmonary embolism
	Cardiovascular accident
Operative complications	Recurrence
	Missed hernia during surgery
	Mortality

Suture or Mesh Repair

Mesh repair is widely accepted as the gold standard. In specialist centres, however, good outcomes are reported for suture repairs, such as the Shouldice Hospital which achieves a recurrence of <2% for Shouldice repairs [82]. It is clear that results differ between specialist and general centres, but the available evidence implies that a mesh repair obtains superior results to a suture repair. Unacceptably high recurrence rates have been reported for other suture repairs, and therefore they are not recommended [32].

A Cochrane review analysed RCTs comparing Shouldice to Lichtenstein repairs and found an increased recurrence rate in Shouldice repairs (OR 3.65, 95% CI 1.79–7.47); however, there was no difference in postoperative stay, chronic pain, seroma/haematoma formation or wound infection. They did, however, conclude that the Shouldice technique was the superior suture repair, despite higher incidence of wound infection (OR 1.34, 95% CI 0.7–2.54) as it has lower recurrence rates (OR 0.62, 95% CI 0.45–0.85), lower rates of chronic pain (OR 0.3, 95% CI 0.4–1.22) and fewer haematomas (OR 0.85, 95% CI 0.63–1.13) [83].

Other studies from the Danish Hernia Database made similar conclusions, finding recurrence rates of 3% for Lichtenstein repairs and 8% for suture repairs. They also found no difference in chronic pain [3, 84, 85].

Operative Steps

Principles of Open Inguinal Hernia Repair

Different repair techniques in open anterior hernia repair can all be divided into two steps: separation and dissection of the hernia sac from adjacent structures, including the cord, followed by repositioning of the contents of the sac into the preperitoneal space or peritoneal cavity. Once this has been achieved, the second step is reconstruction of the inguinal floor by suture or augmentation with prosthetic mesh.

Patient Positioning and Theatre Set-up

For anterior open repair of an inguinal hernia, the patient is positioned supine, and the pubic area is shaved to allow dressing placement. The surgeon stands on the side that is being operated on, and the assistant and scrub nurse stand on the contralateral side. Skin preparation (we recommend 2% chlorhexidine and 70% isopropyl alcohol solution) is applied, and appropriate sterile drapes are positioned.

Antibiotic Use

The practice of antibiotic prophylaxis is variable amongst institutions and countries. The World Guidelines for Groin Hernia Management combined evidence from a Cochrane review [86] and two more recent RCTs [87, 88] and concluded that antibiotic prophylaxis should only be used in high-risk patients and high-risk environments (defined as wound infection incidence of more than 5%). In these patients antibiotics were shown to significantly reduce the wound infection rate (8.7% in the placebo group versus 4.2% in the treatment group). For the majority of patients (low risk), the benefit was less significant (2.3% vs. 1.6%). Antibiotic use made no significant difference to deep tissue infection rates.

Operative Steps

Incision and Access

The skin incision is performed one finger above and lateral to the pubic tubercle, usually transverse along the skin crease lines with a length of approximately 5 cm. This access provides a slightly better cosmetic outcome and facilitates sufficient overview (Fig. 12.1). It is important to keep the knife at right angles to the patient's skin during the incision in order to avoid undercutting the flap in one or the other direction. After skin incision a stepwise sharp dissection of the subcutaneous fatty tissue is performed. Usually the Vasa epigastrica superficialis are encountered and need appropriate ligation. The aponeurotic layer of the m. oblique externus emerges and facilitates medially the exposure of the superficial inguinal ring and the rolled edge of the inguinal ligament. This superficial inguinal ring and the inguinal ligament are the first landmarks of every open anterior repair (Fig. 12.2). Alternatively, an oblique incision that runs parallel to the inguinal ligament can be chosen. It provides excellent exposure but at the expense of a slightly inferior cosmetic result.

Nerve Identification

The identification of the inguinal nerves and their handling has been a topic of vigorous debate in hernia surgery. In 2008 an International Consensus Conference was held in Rome with a working group of 9 hernia experts and 200 participants [89]. The working group recommended the identification of all three inguinal nerves and resection and documentation of any 'nerves at risk'. The recommendations were based largely on two published studies reporting the results of the role of the identification of all three inguinal nerves (2305 cases all together) with long-term follow-up period (ranging from 1–5 years), which concluded that identification and preservation of all three inguinal nerves reduced chronic incapacitating groin pain to less than 1% [90, 91]. Furthermore the working group estimated that all three nerves could be identified in 70–90% of inguinal hernia repairs.

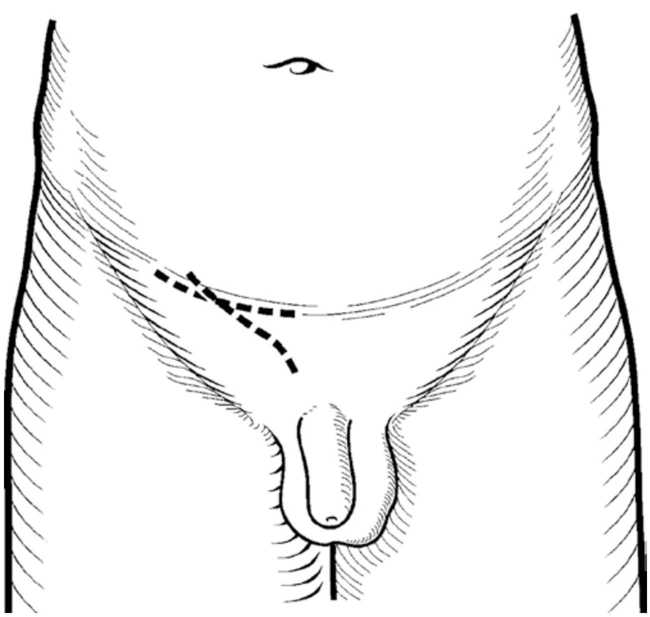


Fig. 12.1 An incision is made 1 cm above and parallel to the inguinal ligament; the incision should expose the superficial inguinal ring

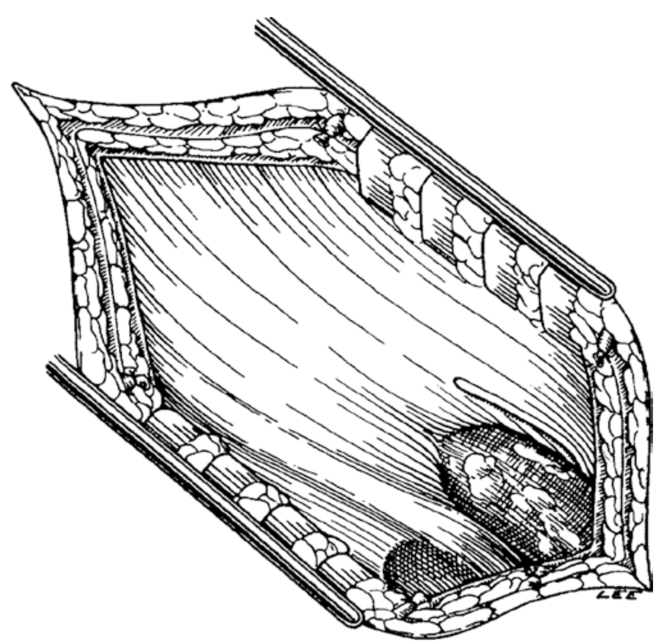
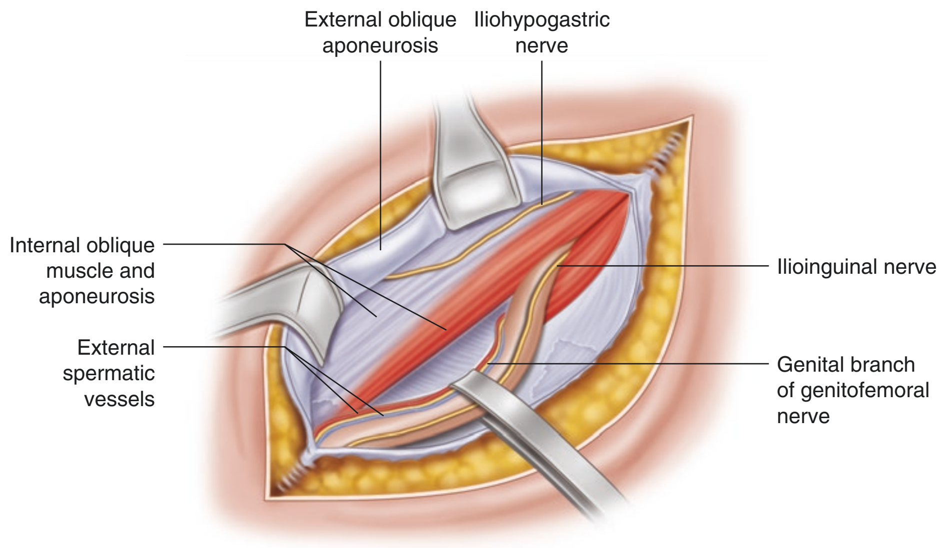


Fig. 12.2 The external oblique aponeurosis is exposed

Fig. 12.3 The inguinal nerves



The detection of all three nerves can be aided by becoming familiar with their usual anatomic course (Fig. 12.3). The iliohypogastric nerve usually enters the inguinal canal lateral to the incision and travels medially in a horizontal course until it pierces the external oblique muscle on average 3.8 cm (2.5–5.5 cm) caudally to the external ring. The ilioinguinal nerve is absent in approximately 22%. When present it pierces the internal oblique laterally to the internal ring, courses parallel and ventrally to the spermatic cord and exits through the external ring. The genital branch of the genitofemoral nerve has a more variable course, usually entering the canal laterocaudally through the internal ring. In most cases it then joins the cremasteric artery and vein on the dorsocaudal aspect of the cord to form a neurovascular bundle. It exits through the external ring in varying positions [92].

The Dissection of the Canal

Opening the external oblique aponeurosis too close to the inguinal ligament is a common mistake for novices and makes the reconstruction difficult. The optimum site is to open the external oblique about 2–3 cm cranial to the inguinal ligament; this 'high' incision allows maximal tissue for final closure and reconstitution of the inguinal canal (Fig. 12.4). A small knick is made in the external oblique aponeurosis, and the two edges elevated with haemostats. The underlying tissue is gently pushed down using a closed scissors or haemostat 'out of harm's way' to avoid inadvertent damage to the ilioinguinal nerve which can sit just behind the aponeurosis. The rest of the aponeurosis is then opened to expose the underlying deep ring and caudally to open the superficial inguinal ring using scissors. The apo-

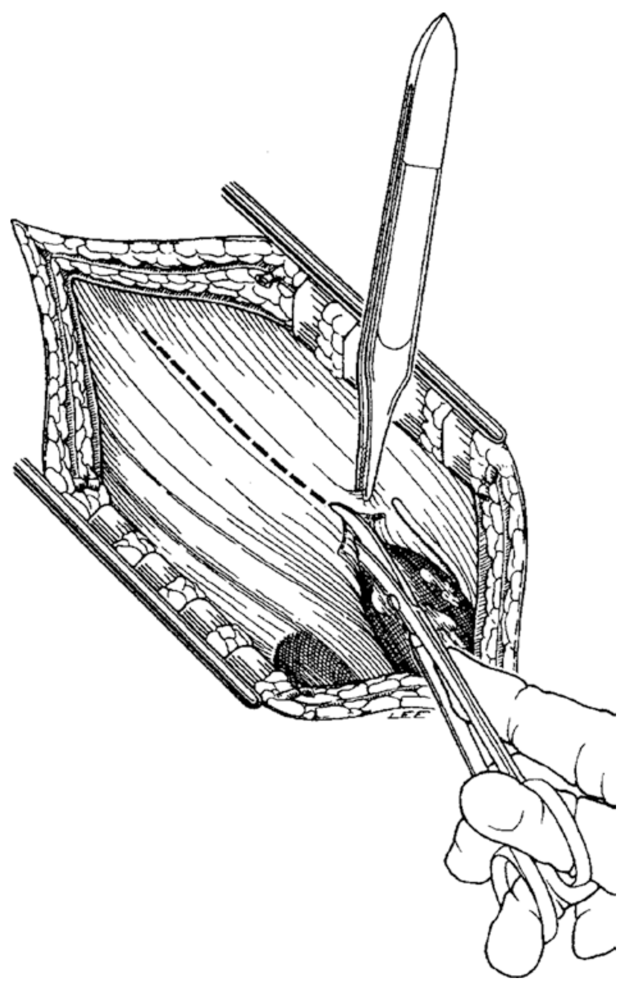


Fig. 12.4 Opening the inguinal canal

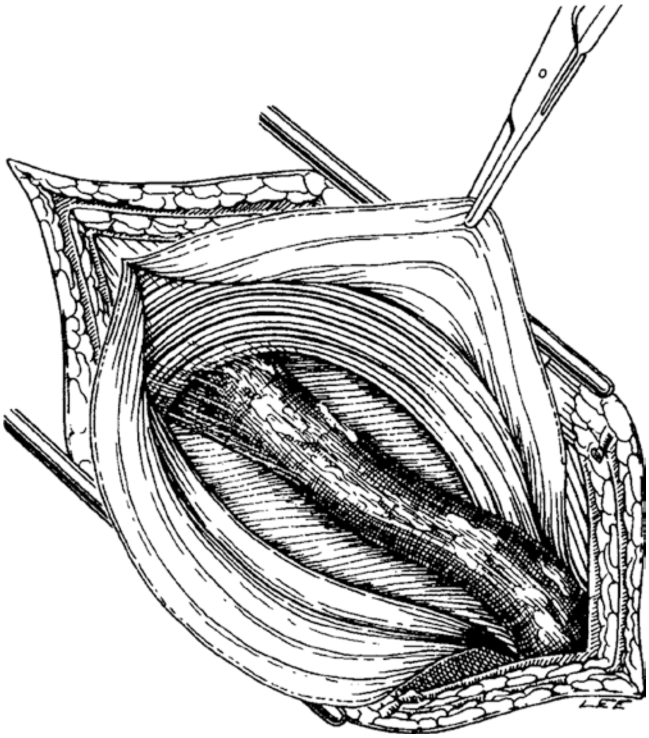


Fig. 12.5 Dissection of the canal

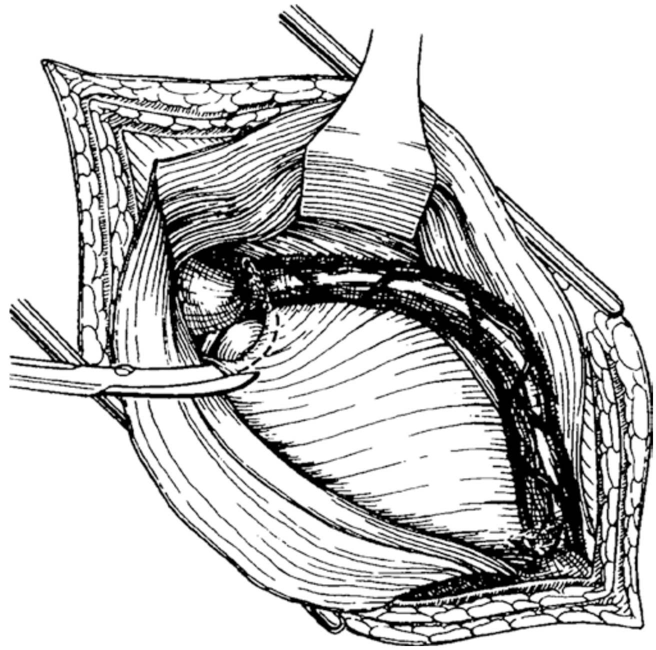


Fig. 12.6 The deep ring is freed from the cord by sharp dissection

neurosis is gently freed from underlying structures by careful dissection up to its fusion into the lateral anterior rectus sheath. This plane is made up of areolar tissue and is dissected using sharp dissection with scissors (the surgeon should be cautious not to damage the iliohypogastric nerve during this dissection). Similarly, the lower lateral leaf of the external oblique is mobilised and freed of the underlying cord coverings down to the upturned deep edge of the inguinal ligament, which is exposed (Fig. 12.5). Thus, the whole of the cord is exposed. The use of diathermy inside the inguinal canal should be used sparingly and with precision, and we recommend sharp dissection using scissors.

Mobilisation of the Spermatic Cord and Identification of the Fascia Transversalis

After the contents of the cord have been adequately visualised, they are lifted up, by placing a finger behind the cord and onto the pubic tubercle, from lateral to medial. The cord has already been mobilised in the dissection of the canal and should lift off the fascia transversalis with relative ease. The continuation of the fascia transversalis onto the cord at the deep ring is identified. The condensation of the fascia transversalis around the emerging cord is the deep ring, and it must be dissected accurately. The correct identification and dissection of the deep ring are crucial to the subsequent repair operation (Fig. 12.6).

The internal spermatic fascia must be dissected off the cord to the deep ring, taking care not to damage the cord structures. Only when the cord is fully dissected like this can the deep ring be assessed.

The medial superior margin of the cord needs careful inspection now to identify any indirect sac. However small—even a tiny crescent of peritoneum entering the cord between the vas and medial margin of the deep ring—such a sac must be dissected cleanly and removed; otherwise it will enlarge postoperatively and appear later as a fully developed indirect hernia. A peritoneal crescent is the herald of an early recurrence if it is not treated adequately (Fig. 12.6).

It is important to check all the hernial sites at operation. A femoral or a direct inguinal hernia may easily be overlooked if exposure is inadequate. If a hernia is missed, it will either appear postoperatively or later as 'a recurrence'. Whether the recurrent hernia is through a repaired portion of the inguinal region or not is immaterial to the patient; it is 'a recurrence' from the patient's perspective and most importantly necessitates another operation. Careful inspection of all hernial areas must be carried out at each operation.

The Management of the Hernia Sac

The degree of difficulty in locating the hernia sac depends on several factors such as the soft tissues in the canal, the location of the hernia orifice and the size of the hernia sac. Also the possibility of a combined hernia should always be considered.

Indirect

An indirect hernia sac lies medial to the cord and on the anterosuperior aspect of the cord structures. In the case of scrotal herniation, with a fixed hernia sac in the scrotum, a transection of the empty hernia sac at the midpoint of the canal leaving the distal part in situ is recommended to minimise the risk of postoperative ischemic orchitis. The anterior wall of the distal sac can be incised to prevent postoperative hydrocele formation. Further management depends on the presence and nature of the contents of the indirect hernial sac.

No Contents

If the sac is empty and does not extend beyond the pubic tubercle, it is lifted and freed from the adjacent structures by careful dissection. It is traced back to its junction with the parietal peritoneum (a small amount of preperitoneal fat can usually be seen at this point indicating that adequate dissection has been performed) transfixed with an absorbable suture, which is tied around it securely, and the redundant sac excised (Fig. 12.7). If an indirect hernia sac extends beyond the pubic tubercle, the sac is transected and the distal sac left in situ (Fig. 12.8).

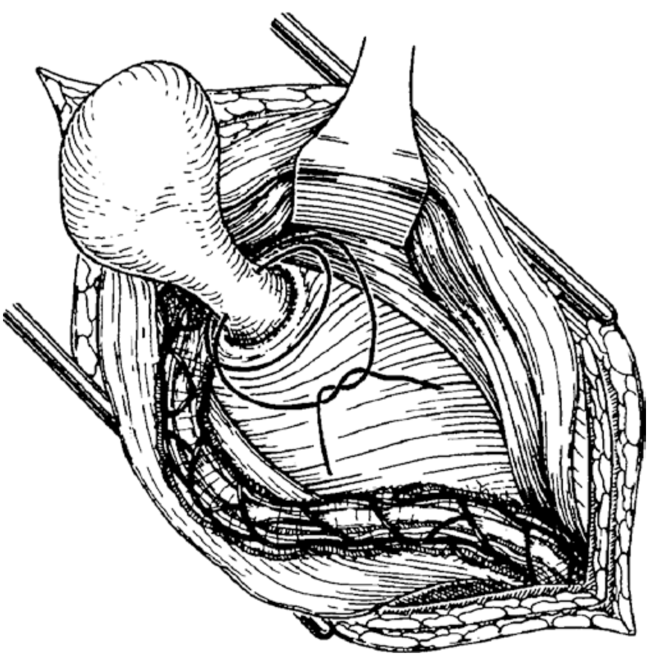


Fig. 12.7 A simple sac is ligated flush to the parietal peritoneum

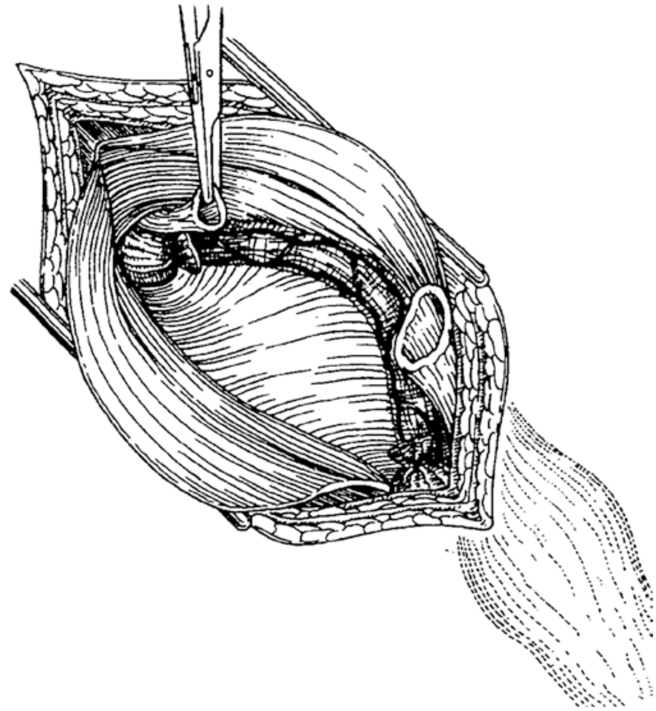


Fig. 12.8 If the indirect sac extends beyond the inguinal canal, it should not be dissected beyond the pubic tubercle; instead the (empty) proximal sac is identified, dissected free from the cord and transected. The distal sac is left in situ

Small Bowel and/or Omentum, with or Without Adhesions

Unless the hernia is strangulated and the small bowel nonviable, any adhesions are divided, and the small bowel is returned to the abdominal cavity. Strangulated omentum or small bowel can be resected at this stage. The diagnostic decision as to what should be done about very adherent and frequently partially ischemic omentum is difficult. If there is any doubt about omentum, it is best excised, because to return omentum of doubtful viability to the peritoneal cavity invites the formation of adhesions.

Sliding Hernia

Such a hernia may contain the cecum and appendix (on the right side) in its wall, the sigmoid colon (on the left side) or the bladder (in the medial wall on either side). The following guidelines apply in these circumstances:

1. No attempt should be made to separate cecum or sigmoid colon from the sac wall. This may compromise their blood supply and lead to further unnecessary problems.
2. The appendix must not be removed unless it is acutely inflamed, as this could introduce sepsis.
3. Appendices epiploicae must never be removed from the sigmoid colon; they may harbour small colonic diverticula, excision of which will precipitate sepsis.
4. On the medial side of a sac, there should be no attempt to dissect the bladder clear. If the bladder is inadvertently opened, a two-layer closure with absorbable polymer and urethral catheter are required for 7 days at a minimum.

A sliding hernia is dealt with by excising as much peritoneal hernial sac as possible and then closing it using an 'inside out' purse-string suture. When it is closed, it is pushed back behind the fascia transversalis (Fig. 12.9).

Direct

The direct sac may be either a broad-based bulge behind and through the fascia transversalis or, less commonly, it may have a narrow neck. In the first type, interference with the peritoneum is not needed; the sac should be pushed behind the fascia transversalis, which will subsequently be repaired (Fig. 12.10). In the case of a narrow necked hernia, which is usually at the medial end of the canal, extraperitoneal fat is removed, the sac carefully cleared, redundant peritoneum excised and the defect closed with absorbable transfixion suture. Care must be taken to avoid the bladder, which is often in the wall of such a sac (Fig. 12.11).

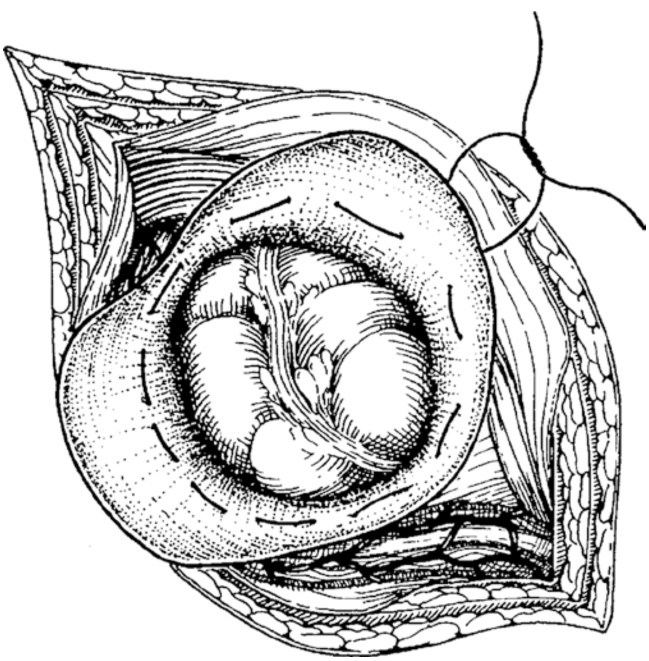


Fig. 12.9 Closing the sac of a sliding hernia

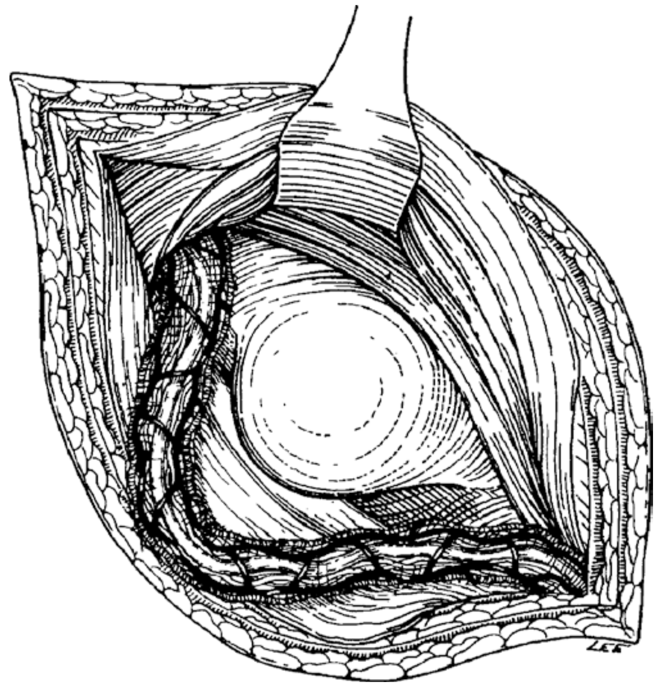


Fig. 12.10 The dome-shaped direct bulge; there is no need to open this sac

Combined Direct and Indirect

Lastly, a combined direct and indirect 'pantaloon' sac straddling the deep epigastric vessels may be found. In such cases the sac should be delivered to the lateral side of the deep epigastric vessels and dealt with as described for an indirect hernia (Hoguet's manoeuvre) [93, 94] (Fig. 12.12).

The indirect sac is completely freed from the vas, spermatic vessels and the adjacent fascia transversalis at the deep ring. It is best then to mobilise the fascia transversalis medially so that the whole of the sac can be drawn laterally. Whether or not the direct sac should be opened at this stage is a question of judgement. The hazard of wounding the bladder must be acknowledged. Any opening into a direct sac must be commenced laterally; care must be taken to identify the bladder margin medially, and any peritoneal incision must stop short of this. Alternatively the direct sac can be opened; a finger inserted into the peritoneal cavity through the indirect sac will identify the dimensions of the direct sac and facilitate dissection and mobilisation.

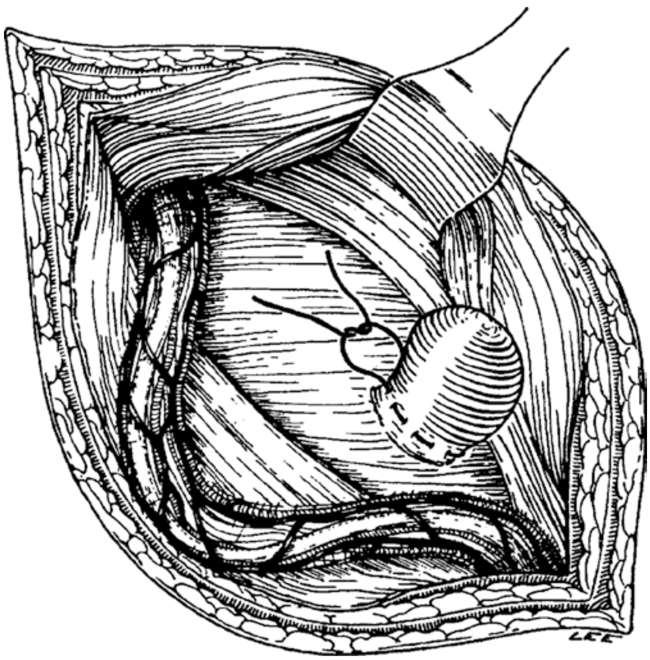


Fig. 12.11 The narrow-necked medial direct hernia. The (empty) sac is isolated, closed and excised

Once the indirect and direct sacs are mobilised, redundant peritoneum is excised and the peritoneal defect closed.

The Reconstruction

After the preparation an assessment of the hernial orifice is possible. This is also the moment to look for the femoral orifice to rule out a concomitant femoral hernia.

The repair of the defect can be achieved by an impressive variety of different procedures. The main differentiation is a repair by suture or by augmentation with non-absorbable mesh prosthesis, in an anterior or posterior position:

- Anterior flat mesh repair
  - Lichtenstein
- Open suture repair
  - Shouldice
  - Marcy/Zimmermann (for historical interest only)
  - McVay technique (for historical interest only)

The Open Anterior Mesh Repair (Lichtenstein Tension-Free Hernioplasty)

The incision, exposure, dissection of the canal and cord and the method of dealing with indirect hernial sacs are identical for that described above.

The upper leaf of the external oblique aponeurosis needs to be lifted up and dissected from the underlying internal

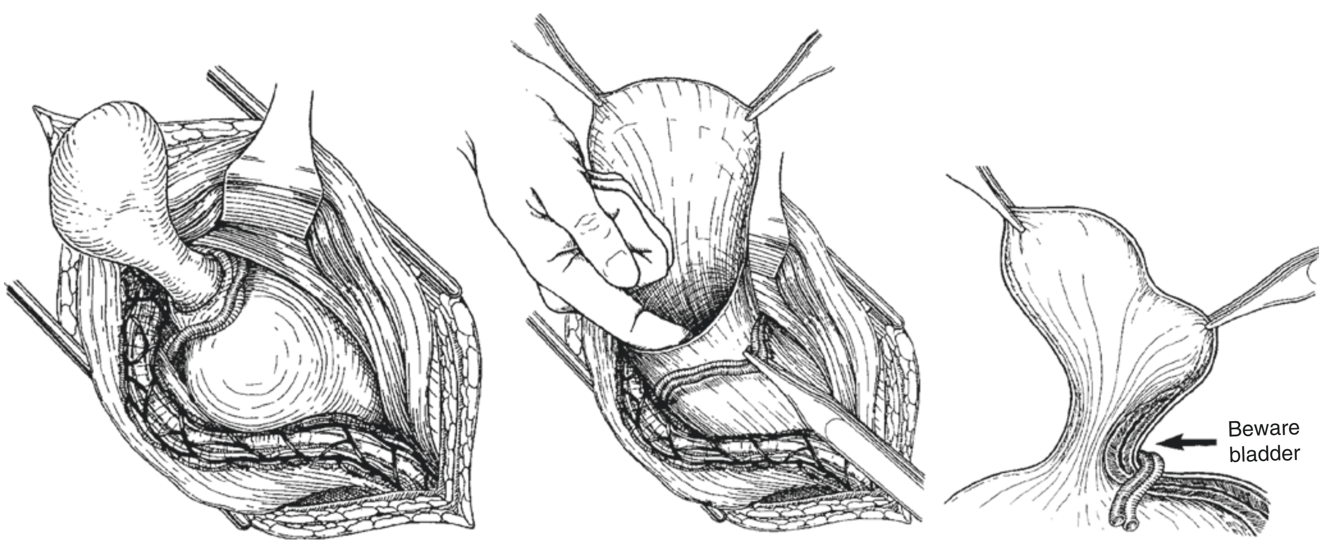


Fig. 12.12 Hoguet manoeuvre. The combined direct/indirect sac (pantaloon hernia) is delivered lateral to the deep epigastric vessels. Any redundant peritoneum is excised and the sac closed

oblique muscle and aponeurosis high enough to accommodate a 6–8-cm-wide patch. Between these two layers, the anatomical cleavage is avascular and the dissection can be performed as described above. A sufficient overlap is required of Hesselbach's triangle, the pubic tubercle and laterally beyond the internal ring. Medially this dissection should be taken beyond the pubic tubercle to the midline (Fig. 12.13).

In the case of large direct sacs, in order to flatten the posterior inguinal wall to facilitate placement of the mesh, a running, inverting, absorbable suture is applied to the transversalis fascia.

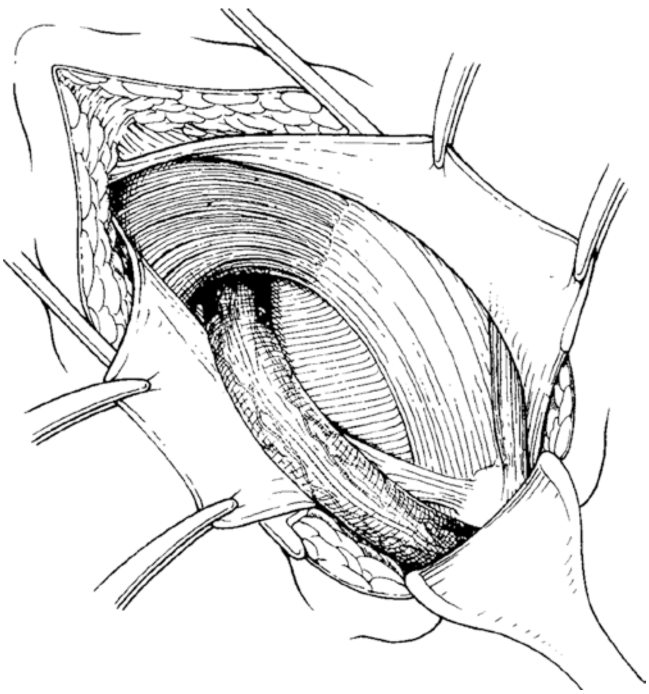


Fig. 12.13 Wide dissection of the posterior wall of the canal

A non-absorbable mesh prosthesis precut to 12 cm × 8 cm is now tailored to the individual patient's requirements. This will involve trimming 1–2 cm of the patch's width and the upper medial corner so that it will tuck itself between the external oblique and internal oblique muscles without wrinkles.

The cord is now retracted downwards and the mesh aligned into the inguinal canal such that its inferior border lies parallel with the inguinal ligament and its medial border overlaps the pubic tubercle by 1–2 cm. Using a non-absorbable monofilament running suture beginning at the upper, medial, rounded border of the mesh, the suture is placed into the tough aponeurotic tissue of the midline and secured with a knot. This suture then continues around the edge of the mesh taking bites of firm connective tissue under direct vision but avoiding the periosteum of the bone.

As the suture continues, it picks up the lower edge of the shelving margin of the inguinal ligament. Having secured the mesh medially and also secured it to 1–2 cm of inguinal ligament, this suturing is temporarily halted (Fig. 12.14). A slit is now made at the lateral end of the mesh creating two tails, a wider one (two-thirds above) and a narrow one (one-third below) (Fig. 12.15). The lower, narrower tail together with the needle and its running suture are now passed behind the cord, which is then retracted upwards (Fig. 12.16). The wider upper tail and the narrow lower tail are overlapped and grasped in a haemostat to retract the mesh and prevent unnecessary wrinkles.

The running suture between the lower edge of the mesh and the shelving margin of the inguinal ligament is now completed to a point just lateral to the internal ring (Fig. 12.17). The upper leaf of the external oblique aponeurosis is now retracted strongly upwards, and the upper edge

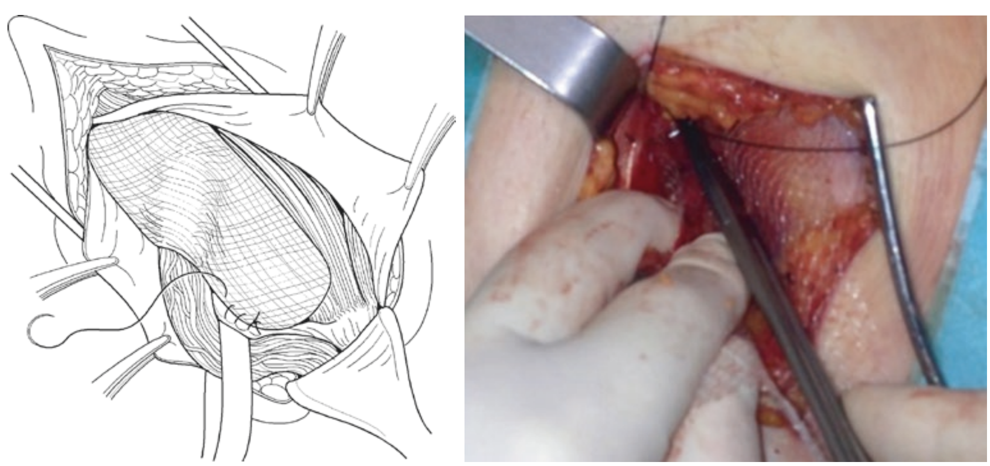


Fig. 12.14 Securing the mesh to the inguinal ligament, ensuring good medial coverage; use a non-absorbable or slowly reabsorbable suture

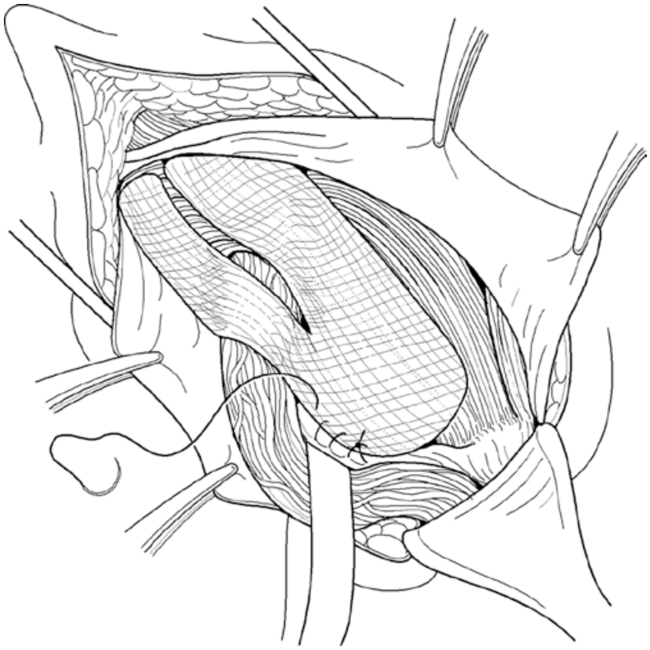


Fig. 12.15 A slit is cut in the mesh (one-third below, two-thirds above), up to the medial margin of the deep ring

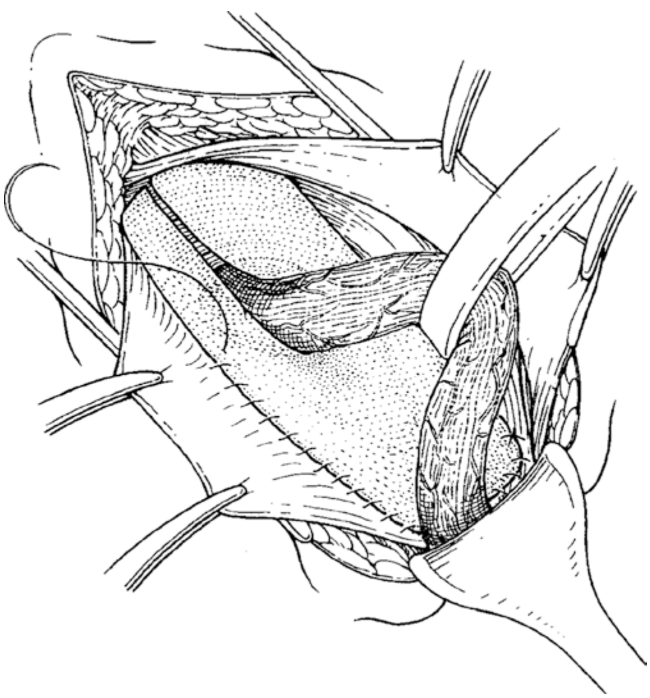


Fig. 12.16 The lower 'tail' of the mesh is flipped behind the cord, followed by the continuous suture with needle, and the cord is retracted upwards

of the mesh is sutured to the underlying internal oblique aponeurosis or muscle with a series of interrupted sutures approximately 2–3 cm apart. Care is taken to avoid underly-

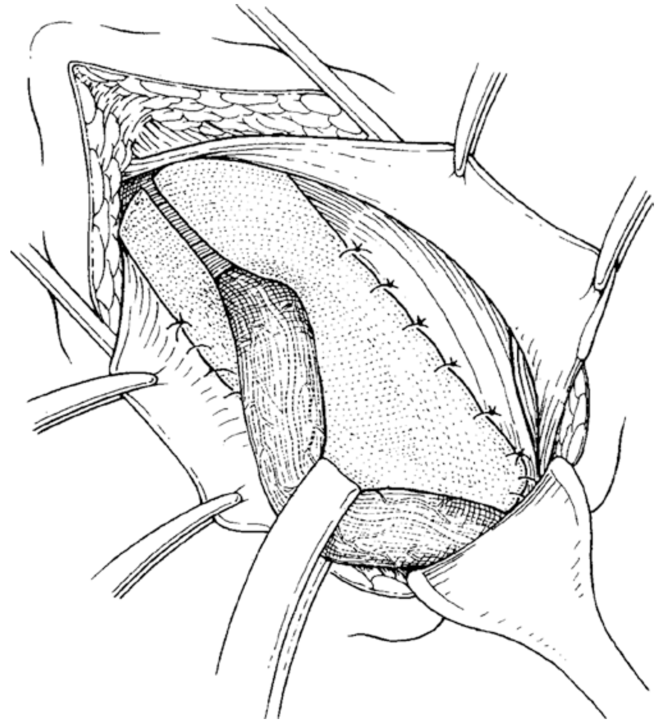


Fig. 12.17 The continuous suture line along the inguinal ligament is now continued to the lateral border of the deep ring

ing blood vessels and sensory nerves, especially the iliohypogastric nerve which has an intramuscular portion (Fig. 12.18). In order to prevent inadvertent damage to the iliohypogastric nerve, the sutures are tied loosely with 'air knots' over a haemostat thus preventing nerve compression. The mesh should not be completely flattened but should be seen to have some degree of anterior convexity in order to remain tension-free. The last fixation suture is placed laterally at approximately the same level as the internal ring.

According to Lichtenstein the lower edges of each of the two tails are now fixed to the inguinal ligament at a point just lateral to the completion knot of the lower running suture (some surgeons do not complete this step). A point is chosen in the lower edge of the upper tail approximately 1 cm beyond the lateral margin of the internal ring to avoid unnecessary buckling of the mesh (Fig. 12.19). Having created a new internal ring with crossover and overlap of the two tails, excess patch on the lateral side is now trimmed in order to leave approximately 3–4 cm of mesh beyond the internal ring. This lateral tail is now tucked underneath the external oblique aponeurosis and may be prevented from movement, curling up or wrinkling by placing sutures between it and the underlying muscle. The size of the new internal ring is now tested with a haemostat, which should pass easily between the cord and the mesh. If this gap is too wide it may be closed loosely with a non-absorbable suture (Fig. 12.20).

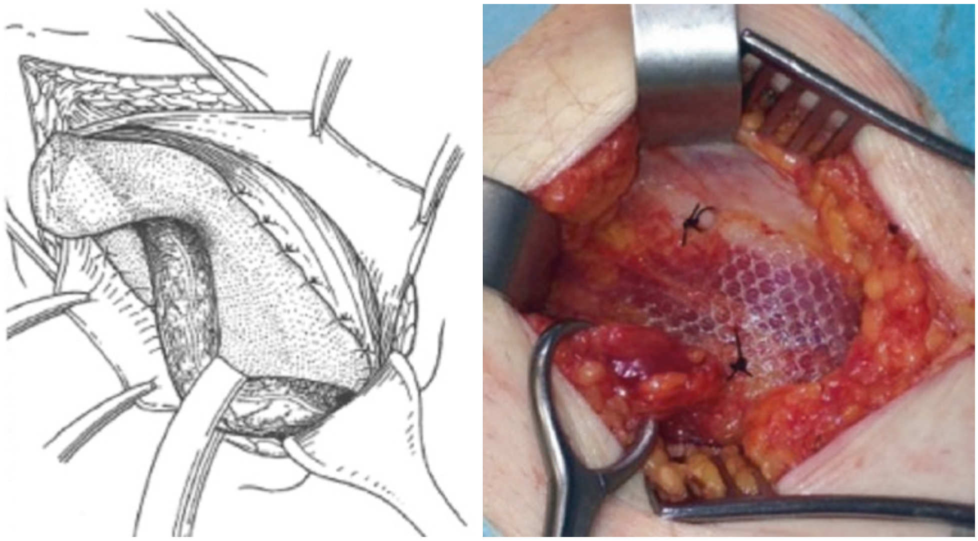


Fig. 12.18 Lateral fixation of the mesh with 'air knots'

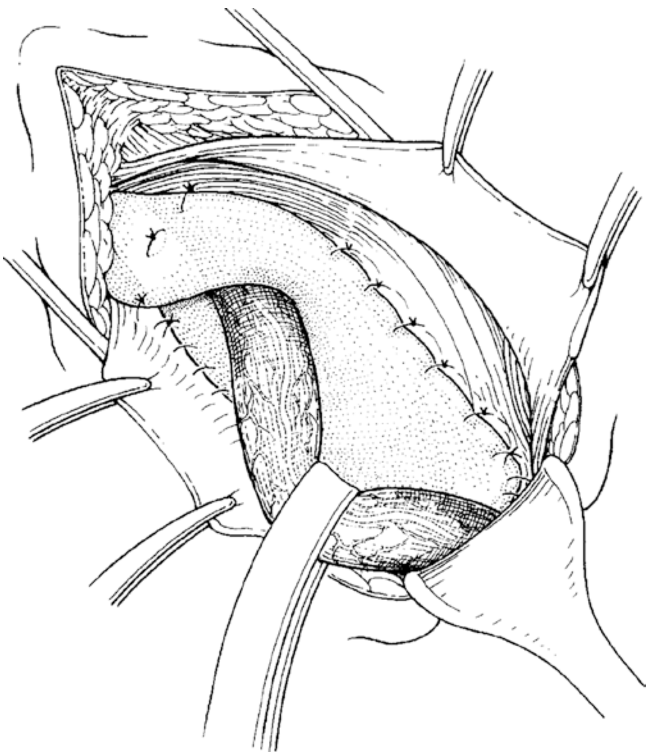


Fig. 12.19 The 'tails' are overlapped and crossed and a single suture placed to create a new deep ring

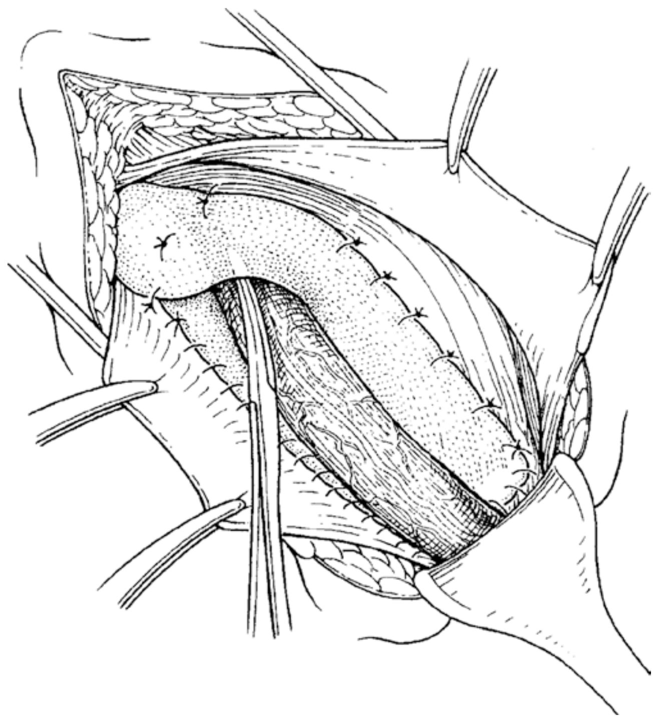


Fig. 12.20 An artery clip is run down between the mesh and the cord to ensure adequate aperture

Having completed the repair of the posterior inguinal wall with non-absorbable mesh prosthesis, the cord is placed back into the canal. The wound closure is preformed; see below.

The original Lichtenstein technique as described above has seen many modifications over the years. The main focus is today directed on the mesh and the fixation technique. The advances in mesh technology provide a great variety of different meshes (see Chap. 7).

Mesh Fixation

Lichtenstein used a non-absorbable polypropylene suture for mesh fixation. In a recent survey of the Swedish Hernia Registry, different sutures were investigated. The data of over 80.000 Lichtenstein repairs were analysed in respect of the suture material, non-absorbable, long-term or short-term absorbable suture. There was no difference in the recurrence rate between the first two groups but a significant increase in the short-term absorbable suture group [95].

Today there is a great variety of suture- and tack-free mesh fixation options available. In experimental studies the strength of glue or fibrin sealant in comparison to sutures has been demonstrated [96]. Fibrin sealant for mesh fixation was first introduced by Chevrel and Rath in 1997 for the treatment of open onlay meshes in incisional hernia repair and is now also used for inguinal open Lichtenstein repair. Negro and colleagues have performed an observational multicentre study including 520 patients over a 12-month period. They found significantly less intense pain, numbness and discomfort in the fibrin sealant group [97].

A new mesh modification that addresses the problem of fixation and mesh structure has gained popularity amongst hernia surgeons. Absorbable microhooks on the fascia-facing side of the mesh induce a 'self-gripping' or Velcro-like property, negating any additional type of fixation [98]. Recent publications have shown some advantages in total length of operation time and less acute pain, though long-term results need to be awaited (see Chap. 7).

Suture Repairs

In Table 12.1 the most common suture techniques are enlisted. A description of each technique would certainly go beyond the scope of this chapter. Therefore, only the most common current and historical techniques are described.

Shouldice Repair

In 1945 it was Earl E. Shouldice who described this novel method of inguinal hernia repair. It is an open, transinguinal suture technique to repair defects in the posterior wall of the inguinal canal. In the same year, he founded the Shouldice Hospital, but it took until 1952 and the support of his assistants E.A. Ryan and N. Obney that after several modifications of the initial technique led to the development of today's classical 'Shouldice repair' also known as the 'Canadian repair' [99].

Dissection of Fascia Transversalis

The most essential part of the Shouldice operation is the repair of the fascia transversalis. This structure should already have been identified at its condensation around the cord forming the deep inguinal ring. The condensed medial margin of the deep inguinal ring is freed from the emerging cord by sharp dissection. When this is completed, the medial margin of the ring is grasped in a dissecting forceps or a haemostat and lifted up off the underlying extraperitoneal fat. Dissecting scissors are now passed through the ring between the fascia and the underlying fat. By this manoeuvre the fascia is separated from the underlying structures, particularly the deep epigastric vessels. If there is no direct herniation and no gross distortion of the deep ring, only the margin of the deep ring, the 'sling' of the deep ring, needs dividing; if there is a direct hernia and attenuation of the fascia transversalis, the fascia transversalis is now divided along the length of the canal, beginning at the deep inguinal ring and continuing down to the pubic tubercle. The upper medial flap is lifted up away from the underlying fat. Attention is now turned to the lower flap. If it is penetrated by cremasteric vessels arising from the deep epigastric vessels, these should now be divided and ligated close to their origin. If care is not taken with the cremasteric vessels, they may be torn off the deep epigastric vessels, and troublesome haemorrhage will follow. If a direct hernia is present, it will bulge forward at this time and must be pushed back in order to free the lower lateral flap of the fascia transversalis. This flap must be freed down to its continuation as the anterior femoral sheath deep to the inguinal ligament. The lower, condensed fascia transversalis as it merges to the anterior femoral sheath is the iliopubic band. Any grossly attenuated fascia transversalis about a direct sac is excised. With the fascia transversalis opened and developed, the femoral canal should be checked again (Fig. 12.21).

Repair of Fascia Transversalis

If the previous dissection has been carried out carefully, and if haemostasis is now complete, the repair with the reconstruction of the inguinal floor commences. First, the fascia

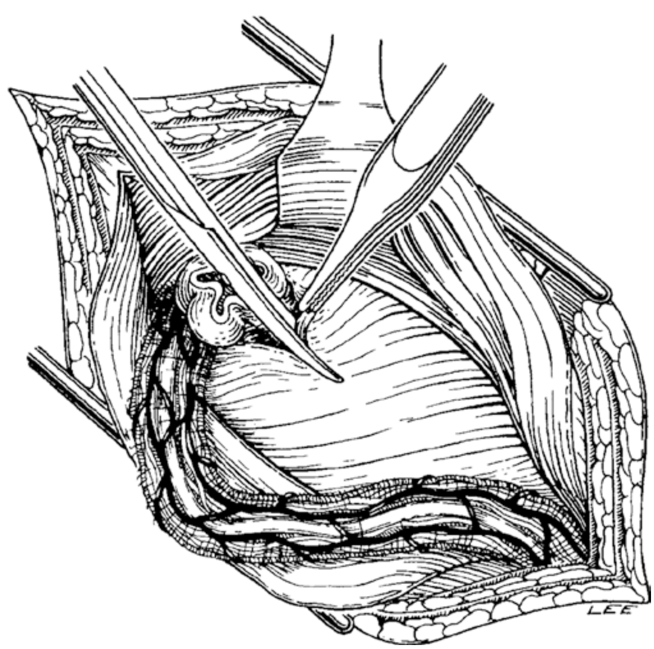


Fig. 12.21 Dissection of the fascia transversalis

transversalis is reapproximated, and the deep ring is carefully reconstituted using a 'double breasting' technique. The posterior wall of the canal must be reconstituted so that all of the peritoneum and the stump of a hernial sac are retained behind it. To do this, the lower lateral flap of the fascia transversalis is sutured to the deep surface of the upper medial flap. The repair is begun towards the medial end of the canal. Where the medial margin of the deep ring only has been divided and the more medial aspect of the posterior wall of the canal shown to be sound, no direct herniation, only the divided fascia transversalis at the medial margin of the deep ring, the 'sling', will need careful two-layered reconstruction with a non-absorbable suture (Fig. 12.22). If there is a direct hernia, the whole of the posterior wall of the canal will have been divided and will need repair, the first suture being placed in fascia transversalis where that structure becomes condensed into the aponeurosis and periosteum on the pubic tubercle. The lower lateral flap of the fascia transversalis is then sutured to the undersurface of the upper flap at the point where the upper flap is just deep to the tendon of the transversus abdominis (conjoint tendon). At this point there is a thickening or condensation of the fascia transversalis (the 'white line' or 'arch'), which holds sutures easily (Fig. 12.23).

Care must be taken with the closure of the fascia transversalis as it approaches the lateral rectus sheath, which must be adequately repaired to the fascia transversalis and the pubic tubercle. The anatomy here is variable and the falx inguinalis should be included in the repair. The fascia is sutured laterally until the stump of an indirect hernia lies behind it and it has been snugly fitted around the spermatic cord (Fig. 12.24). The direction of suturing is then reversed. The free margin of the upper medial flap is brought down over the lower lateral flap and sutured to the fascia transversalis at its condensation (the iliopubic tract), just above the upturned deep edge of the inguinal ligament in the floor of the canal. Suturing is continued back to the pubic tubercle, where the suture is tied. By this manoeuvre the fascia transversalis is 'double breasted' on itself, and the 'direct area' of the canal is reinforced and the internal ring carefully reconstituted and tightened. It is important not to split the fascial fibres. Sutures should be placed about 2–4 mm apart and bites of different depth taken with each so that an irregular 'broken saw tooth' effect is produced. The repair of the fascia transversalis is the crucial part of the operation. The fascia must be dissected and handled with care if its structure is to be maintained.

A 'trick of the trade' sometimes facilitates this suturing of the fascia transversalis: after the upper medial and lower lateral leaflets of fascia transversalis have been developed to clearly show the 'white line' of the transversus tendon through the fascia above and the iliopubic tract below, a loose swab (sponge) is pushed into the dissection to keep the extraperitoneal fat out of the way when the first sutures are introduced (Fig. 12.25). When these sutures are loosely in place, the swab is removed and the suture tension adjusted to give tissue closure.

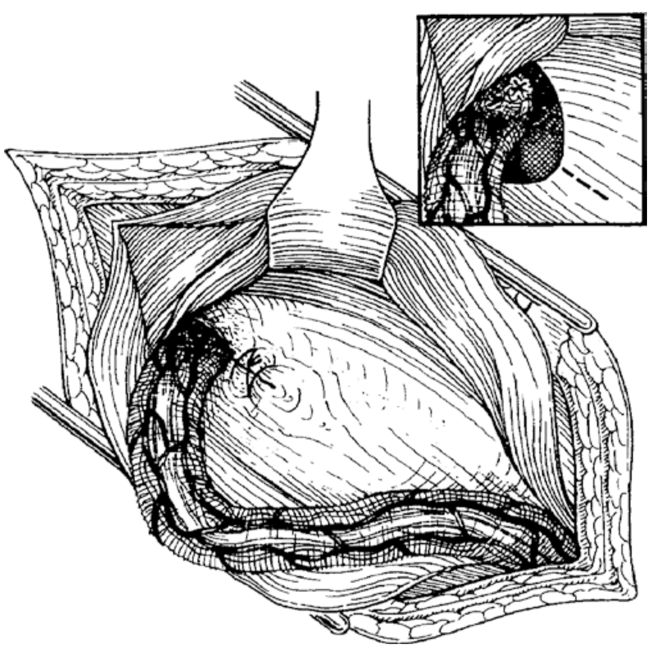


Fig. 12.22 After the neck of the sac has been divided at the deep inguinal ring, the fascia transversalis of the deep ring is identified and assessed. If the ring is normal sized, the stump of the sac is reduced and no more need be done. If the ring is marginally dilated (stretched), it should be carefully distracted and possibly divided slightly (inset) and then sutured tightly around the medial side of the cord with polypropylene to reconstitute a competent deep inguinal ring

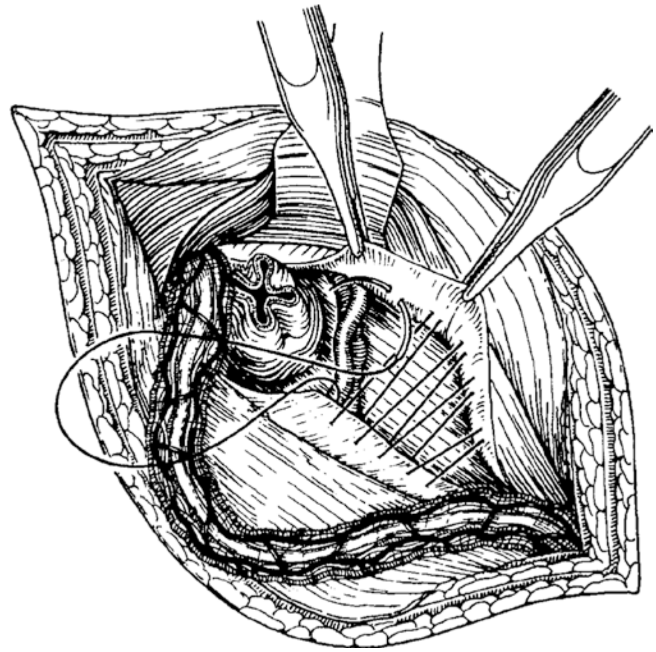


Fig. 12.23 Suturing the lower lateral flap of fascia transversalis to the under surface of the upper medial flap along the 'white line' or 'arch'

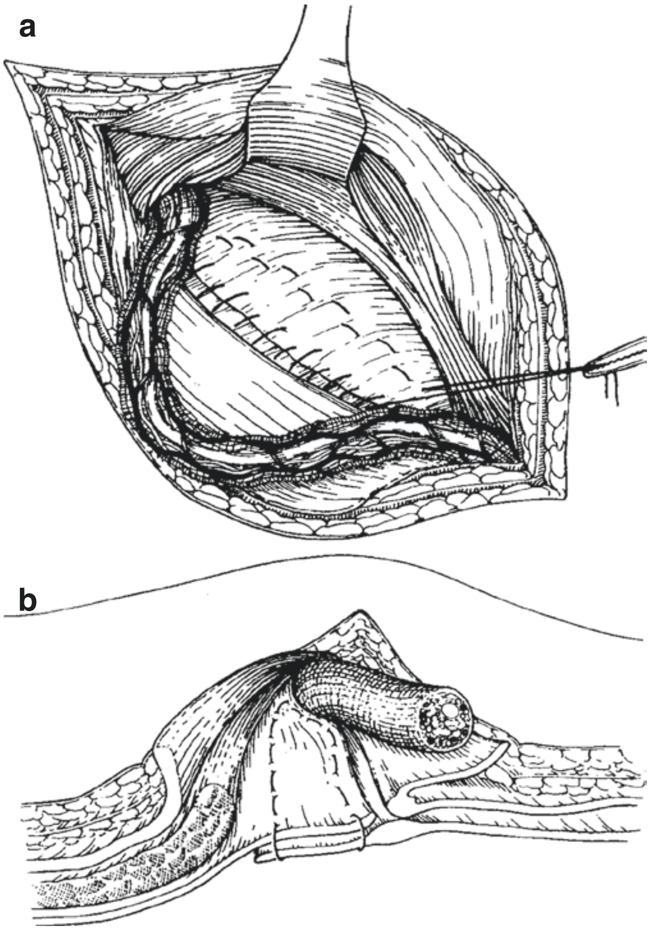


Fig. 12.24 Completing the overlap of the fascia transversalis repair. The margin of the upper medial flap is sutured to the anterior surface of the lower lateral flap (**a**). A neat closure up to the cord makes a new deep ring (**b**)

Reinforcement with the Conjoint Tendon

The conjoint tendon is now used to reinforce the repair of the fascia transversalis medially. A suture is started laterally through the upturned deep edge of the inguinal ligament medial to the margin of the reconstituted deep inguinal ring and continued to the deep tendinous surface of the conjoint tendon, which is directly to the medial side of the deep ring. Sometimes, particularly if the cord is bulky, it is easier to proceed in reverse by passing the needle first through the undersurface of the conjoint tendon and then under the cord and through the upturned edge of the inguinal ligament. At the point where this suture is inserted, the deep surface of the conjoint tendon is just beginning to become aponeurotic (the tendon of the transversus muscle), and it should hold sutures easily. The suture is continued in a medial direction, picking up the upturned edge of the inguinal ligament and the undersurface—the aponeurotic part—of the conjoint tendon down to the pubic tubercle (Fig. 12.26). The direction is then reversed, suturing the aponeurotic part of the conjoint tendon, the internal oblique tendon now, loosely to the external oblique aponeurosis about 0.5 cm above the inguinal ligament. The 'broken saw tooth' technique previously mentioned is again used, and as it is done, the suture is gently pulled snug, not tight, so that the conjoint tendon and rectus sheath are rolled down onto the deep surface of the external oblique aponeurosis. Suturing is continued laterally until the conjoint tendon ceases to be aponeurotic

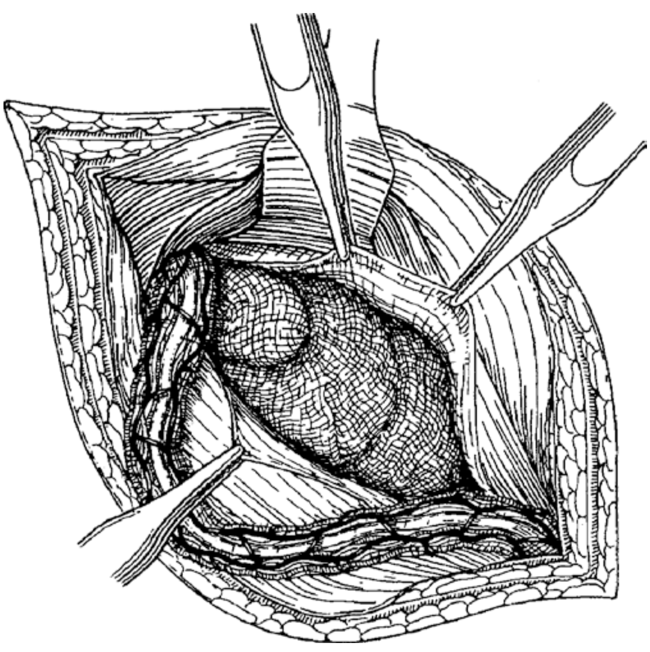


Fig. 12.25 If the subjacent extraperitoneal fat and peritoneum is bulging, a 'trick of the trade' is to pack it down with a gauze swab. This must be removed before the sutures are snugged tight

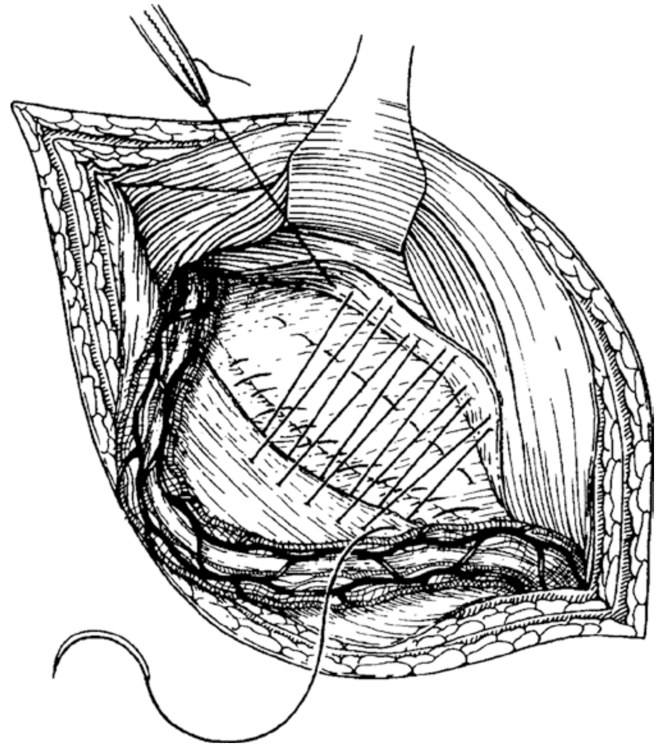


Fig. 12.26 The aponeurotic, white part of the internal oblique tendon and the conjoint tendon is used to reinforce the repair

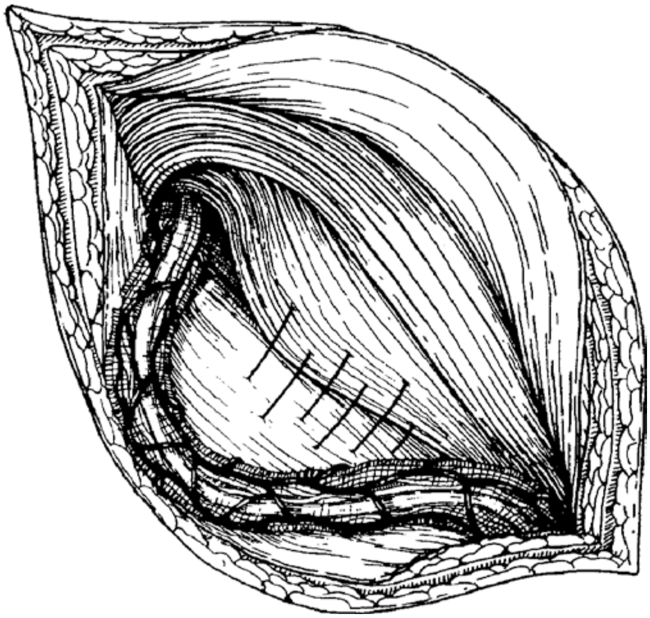


Fig. 12.27 The anterior aponeurotic surface of the internal oblique aponeurosis is loosely sutured to the aponeurosis of the external oblique medially

at the medial edge of the emergent spermatic cord. The suture is then tied. The reconstruction of the posterior wall and the floor of the inguinal canal are now complete. The cord is now placed back in the canal (Fig. 12.27).

Marcy/Zimmermann Suture Repair

The first description of a narrowing of the deeper inguinal hernia ring by suture was by Marcy in 1887 [8] and later by Zimmermann [100]. Indications for his simple repair are small, indirect inguinal hernias (EHS classification L1) with a stable fascia transversalis. In these cases a further incision of the posterior wall is neglected, and a reduction of the hernial orifice by suture is performed.

A prerequisite for this repair is a sufficient preparation of the internal inguinal ring, with identification of the fascia transversalis, complete dissection of the spermatic cord from the internal inguinal ring and removal of preperitoneal fatty tissue. The suture repair starts medial to lateral. The narrowing of the internal hernia ring should accomplish a remaining orifice of 5–8 mm, admitting just the tip of a finger, to guarantee a sufficient blood supply for the testis. To standardise the size of the ring, the use of an 11.5 Hegar dilator has proved to be helpful. The closing sutures are placed medial to the spermatic cord. To achieve a secure placement of the sutures, the fascia transversalis, the aponeurosis of the m. transversus and the caudal fibres of the iliopubic tract are included into the suture.

After sufficient narrowing of the internal hernia ring, the posterior wall of the inguinal canal is augmented by a single continuous suture fixation of the internal oblique and transverse muscles to the inguinal ligament.

McVay Repair

The initial indication for the McVay/Cooper's ligament repair was for patients with a large direct hernia and an absent caudal margin of the fascia transversalis. It is also useful in the management of concomitant femoral and inguinal hernias. Today the McVay repair has lost most of its initial relevance. The advantages of the different mesh techniques have reduced the indication and propagation of this technique.

The McVay repair is therefore described only in summary. The incision, exposure and dissection of the canal and cord are identical to the above-mentioned. The transversalis fascia is incised, preserving the inferior epigastric vessels, and the preperitoneal space opened. The dissection is then taken deeper to expose and free the iliopectineal (Cooper's) ligament. Great care must be taken here to preserve the anastomosis between the obturator and epigastric arteries ('the corona mortis'). The hernia sac can be dissected bluntly away from the superior pubic ligament. The main principle of this procedure is a triple-layer repair, attaching the fascia transversalis, the m. transversus abdominis and the m. oblique internus to Cooper's ligament. To reduce possible tension on the suture line, a relaxing incision is made as medial as possible in the internal oblique aponeurosis—anterior rectus sheath—deep to the external oblique aponeurosis before the two aponeuroses fuse (Fig. 12.28). The repair is now initiated by bringing the transverse abdominis arch down to the inguinal ligament. This is best achieved with a layer of interrupted sutures, beginning at

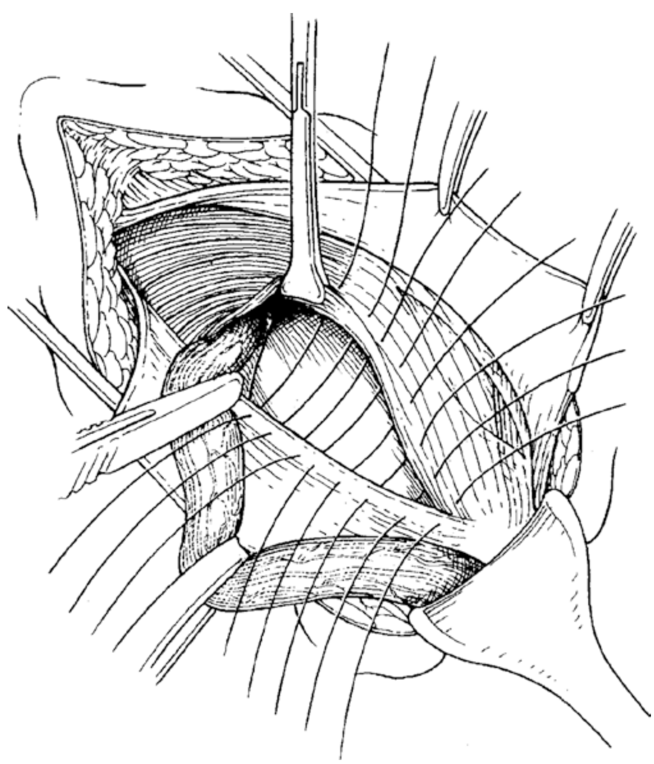


Fig. 12.28 McVay/Cooper's ligament operation, clearing the anterior femoral sheath

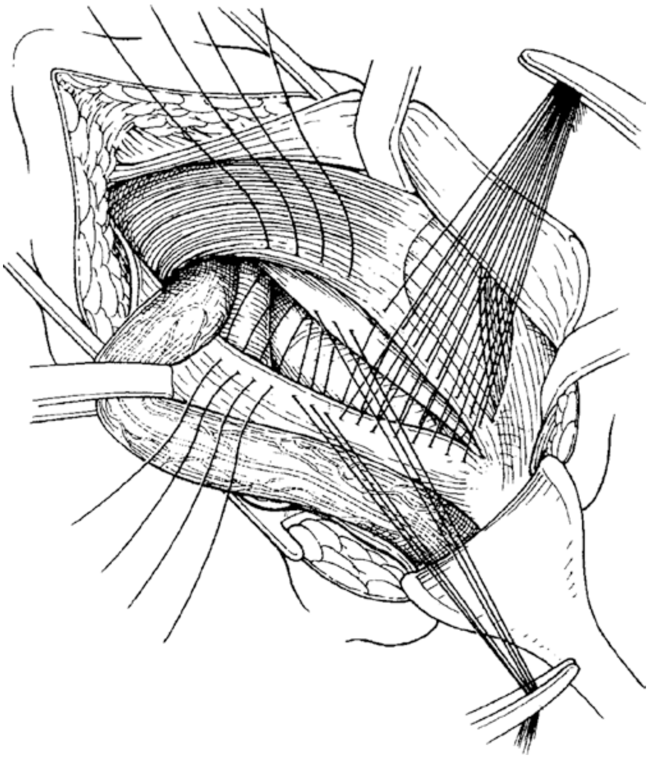


Fig. 12.29 Sutures are placed between the transversalis abdominis arch and Cooper's ligament as far as the femoral vein

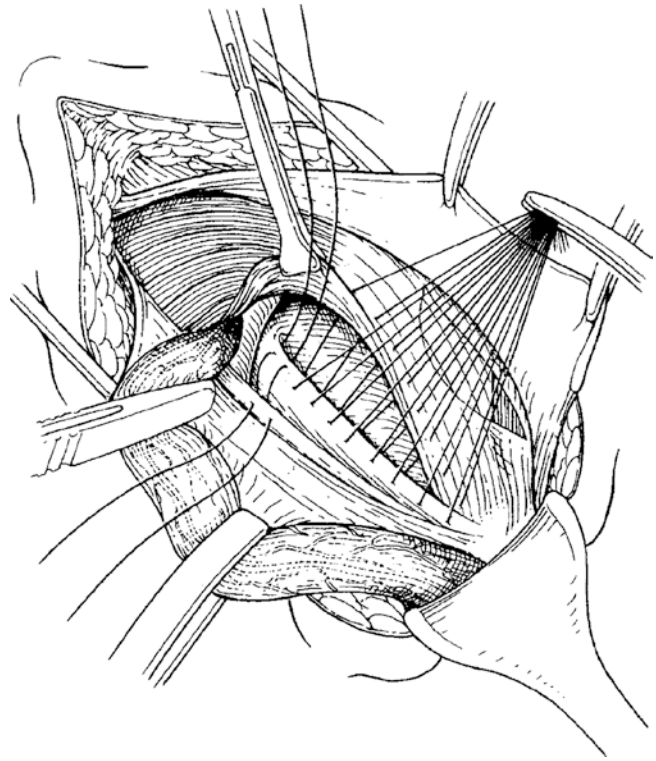


Fig. 12.30 The femoral canal is closed with two or three transition sutures between Cooper's ligament and the anterior femoral fascia

the pubic tubercle and continued laterally to the medial edge of the femoral vein. Each is placed carefully under direct vision and held before serial knotting (Fig. 12.29) and placed between the transversus arch the 'white line' and the iliopectineal (Cooper's) ligament. The femoral vein is retracted and protected by a retractor. The femoral canal is then narrowed by placement of two or three transition sutures of non-absorbable sutures between Cooper's ligament and the anterior femoral fascia (sheath). The lateral suture is placed just lateral to the last suture in Cooper's ligament; the medial two or three are medial to this and go between the Cooper's ligament sutures (Fig. 12.30). The repair is now continued laterally between the transversus abdominis arch and the anterior femoral fascia with the line of sutures just displacing the internal ring laterally but not placing any sutures lateral to the cord. These sutures are of monofilament, non-absorbable material. The sutures are now tied beginning medially and a new internal ring created such that a haemostat can be inserted between the last tied suture and the cord.

Closure

External Oblique Aponeurosis

Now that the cord has been replaced, the external oblique aponeurosis can be closed over it. This can be performed as a single continuous suture or a 'double breasting' technique. Remembering that aponeurotic wounds are slow to regain strength, non-absorbable sutures are used for this layer. A new superficial inguinal ring is constructed at the medial end of the canal. Care should be taken during the suturing to spare the ilioinguinal nerve from the suture line. The repair is now complete, and if all the layers have been sutured exactly as described, the loads on the suture lines should be well distributed; there should be no undue tension and no splitting of fibre bundles. Indeed, the structures should have just 'rolled together' (Fig. 12.31).

Subcutaneous Tissue and Skin Closure

The subcutaneous tissue is carefully closed with interrupted absorbable sutures. No 'dead spaces' should be left, and the fat should be closed so that the skin is closely approximated. If there is much tissue trauma or dead space, a closed drain is useful in this layer but seldom necessary (Fig. 12.32). The skin is closed with a subcuticular absorbable suture (Fig. 12.33).

Postoperative Management

Pain is an unavoidable feature of any postoperative course, and the optimal treatment for this remains controversial. It is clear, however, that early postoperative pain can be

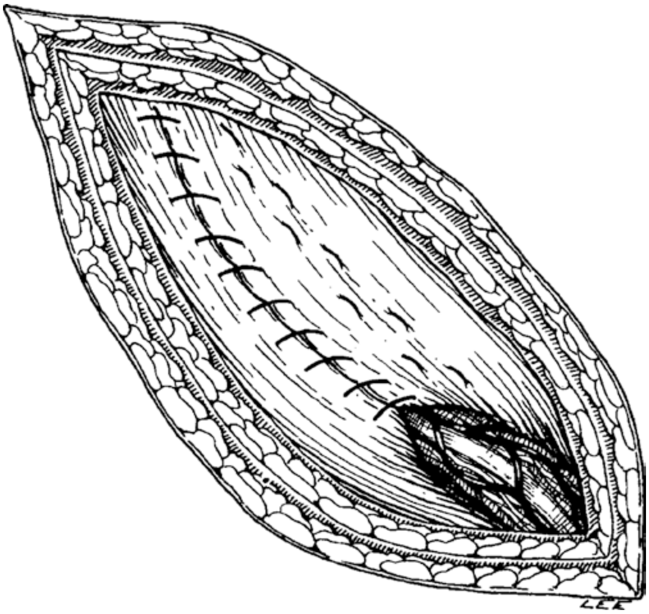


Fig. 12.31 The external oblique aponeurosis is closed anterior to the cord. Thus, the inguinal canal is reconstituted with the superficial ring recreated

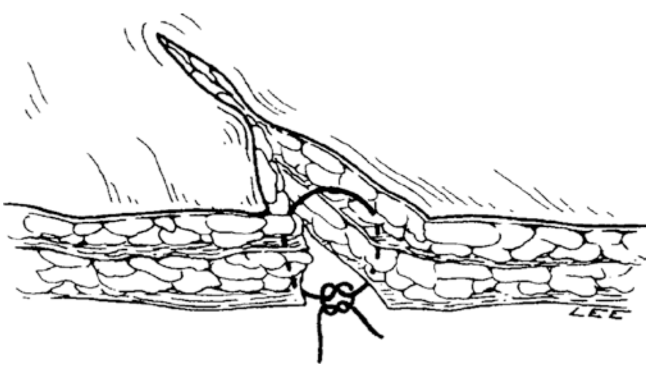


Fig. 12.32 Closure of the subcutaneous tissue using an absorbable suture

reduced by the infiltration of local anaesthetic in either the subcutaneous or subfascial plane or regional nerve blocks. It reduces the need for supplemental analgesia and as such is recommended for all open groin hernia repairs. The use of paracetamol and a NSAID or selective COX-2 inhibitor is recommended for the delayed pain and upon discharge.

The advice given to patients regarding returning to employment and physical activity is highly variable and is often not evidence based. There is currently no evidence of an increased risk of recurrence or complications in patients who return to normal activities early. An RCT of 2365 patients demonstrated that a short recovery period can be safely recommended without increasing recurrence risk. The most common reasons given for delayed return to activity are pain and wound-related problems [101]. Other studies have recorded convalescence periods in patients with non-

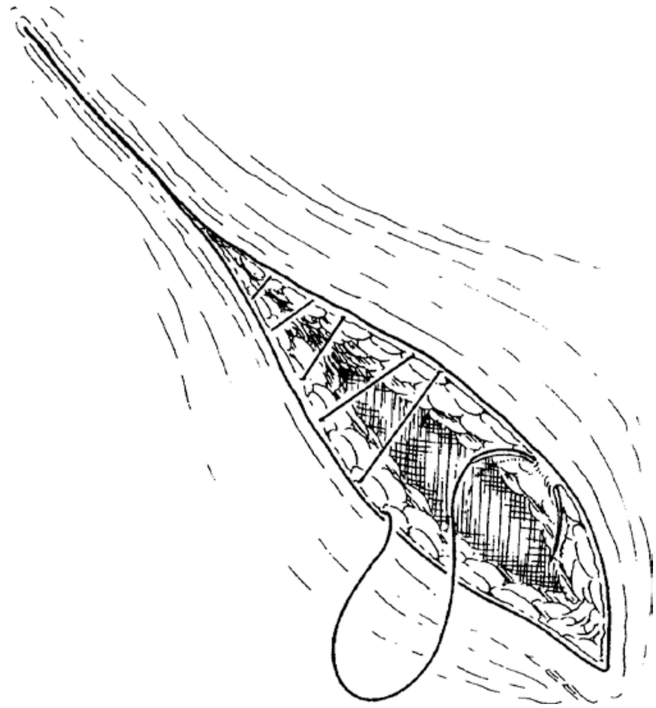


Fig. 12.33 The skin is closed with a subcuticular continuous absorbable suture

restrictive postoperative recommendations and reported a 1-week absence from domestic activities [31, 102–108], 1–2 weeks away from work [102–105, 109–118] and 1–3 weeks before return to physical activities [102, 104, 106, 110, 113, 117].

The available evidence appears to suggest that all activities can be safely resumed within 3–5 days in most cases, without increasing their risk of complications.

Conclusions

Despite the countless procedures performed since the sixteenth century, complications still occur, which impact on patient's quality of life and infer increased cost to the healthcare system. It is also apparent, however, that there is no single optimal technique for inguinal hernia repair. Every patient is different, and the ability to offer multiple techniques is now a key part of a hernia surgeon's armoury. From hernia-related factors (size, site, primary or recurrent) to patient-related factors (gender, co-morbidities, importance of cosmesis) to surgeon experience and preference, identifying the best technique for the patient in front of you is a challenge faced by all surgeons. A widely used classification system may aid in this decision as it will allow long-term follow-up and research into outcomes for different repair techniques in different populations. Until this is achieved, we rely on experience and shared knowledge to build our skill set and enable us to provide the optimal service to our patients.

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Preperitoneal Open Repair of Groin Hernias Using Prosthetic Reinforcement

13

Martin Kurzer

Introduction

Open preperitoneal mesh repairs of groin hernias place non-absorbable mesh through an abdominal incision in a plane outside the peritoneal cavity, between the peritoneum and the anterior abdominal wall. They are in effect open versions of a totally extraperitoneal (TEP) laparoscopic repair.

What I would call the 'classical' preperitoneal repairs were developed just prior to the laparoscopic era as a way of dealing with difficult recurrent groin hernias with extensive scarring and tissue loss. When this chapter was first written, 5 years ago, I therefore questioned whether, in the current era of laparoscopic surgery, open preperitoneal repair would become obsolete. However there has recently been a resurgence in interest in placing mesh in the preperitoneal plane. However these more 'modern' preperitoneal techniques are being advocated for primary inguinal hernia repair, devised in the expectation of reducing the incidence of long-term post-operative discomfort that is possibly related to the presence of mesh in the inguinal canal.

This chapter reviews the history and development of the classical approach and describes the newer small incision techniques with their reported results. Detailed descriptions of the various methods are available in the original papers and textbooks, all well worth reading. However I would strongly encourage visiting and watching the procedure being carried out by an expert as the best way to learn.

History

The preperitoneal approach to the groin is historically associated with the names of Annandale, Cheatle and Henry who all recognised the excellent access afforded to the posterior aspect of the abdominal wall in the region of the inguinal canal [1, 2]. It was seen as an ideal method of dealing with incarcerated or strangulated groin hernias. The interested reader might like to refer to Raymond Read's comprehensive review [3].

It was Nyhus and Read in the USA in the late 1950s who first became interested in and reported its use for recurrent and complex groin hernias [4–6]. In the case of multirecurrent hernias, often with extensive scarring and tissue loss, and before the introduction of modern meshes, effecting a good long-term repair with a conventional approach was almost impossible. Recurrence rates could be well over 50%, and many multirecurrent hernias with extensive scarring and tissue loss were deemed 'inoperable'. In addition the likelihood of testicular atrophy was high [7]. Read used a transinguinal approach, but Nyhus was dissatisfied with the results obtained for recurrent hernias when operating through the previous incision to entering a scarred inguinal canal, and he devised a preperitoneal approach through a transverse incision sited above the level of the inguinal canal. This allowed the operation to be carried out in a virtually virgin field with excellent views, completely avoiding scar tissue from previous surgery. Nyhus reported that the dissection was straightforward and the defect or defects were easily seen and assessed. However despite the advantage of easy access and good visualisation, the failure rate was still high—as much as 30%—if the margins of the defect were simply sutured. He therefore added what he termed a 'prosthetic mesh buttress' attached to the superior pubic ramus (Cooper's ligament) in order to reinforce his sutured repair. The incidence of re-recurrence dropped dramatically ["There were no re-recurrences after we adopted the routine placement of the prosthetic mesh buttress to bolster the anatomic repair"], and this technique rapidly became his routine for virtually all cases. It is puzzling that although the access and views that the preperitoneal approach afforded of the posterior aspect of the inguinal canal and femoral region (the myopectineal orifice) were excellent, it never gained wide acceptance amongst other surgeons. Nyhus published a 38-year review of his work in 1993 [8], describing the

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technique again, and could not understand why general surgeons refused to adopt it. Nyhus wrote, 'My associates and I were perplexed about the failure of this method to flourish'.

The Myopectineal Orifice

In the early 1960s, surgeons in France, Stoppa in Amiens [9] and Rives in Reims [10], also began using a preperitoneal method for complex, recurrent groin hernias, and from the outset, they used mesh in every case. Stoppa developed his procedure based on the work of Henri Fruchaud, a French anatomist and surgeon [11] who described a weak area of the groin known which he called the myopectineal orifice (MPO). The borders of the MPO are the internal oblique muscle superiorly, the iliopsoas laterally, the rectus muscle medially and the superior pubic ramus inferiorly (Figs. 13.1 and 13.2). This bony muscular framework is divided into two by the inguinal ligament, traversed by the spermatic cord above and the femoral vessels below. Failure of the transversalis fascia in this area to retain the peritoneum then becomes the fundamental cause of all hernias of the groin, and protrusion of a peritoneal sac through the myopectineal orifice defines a hernia [12]. In a preperitoneal prosthetic mesh repair (open or laparoscopic), the mesh prosthesis substitutes for the defective or weakened transversalis fascia, and the peritoneum is held like a balloon in a string bag so that closure of the defect is not necessary. Thus Stoppa's genius was in proposing the radical step that no attempt should be made to close the actual defect, thus avoiding any tension. Rignault put it well—'The idea of interposing a large surface of prosthetic mesh between the peritoneum and the deficient inguinal wall instead of 'mending' the defect represents a radical departure from previous methods of hernia repair. The mesh must be much larger than the defect, since it is not sutured in place and only intra-abdominal pressure maintains it in place over the hernia defect [13]. This concept has subsequently been vindicated and is of course now a standard practice in laparoscopic repair where the use of a prosthesis with a wide overlap of the area is mandatory.

Classical Preperitoneal Methods

Stoppa called the procedure 'La Grande Prothese Reinforce de Sac Visceral', and this was translated verbatim, by George Wantz, as giant prosthetic reinforcement of the visceral sac [14]. Hence the operation is also known, somewhat cryptically, as GPRVS.

At that time Rives was using a trans-inguinal approach, as was Raymond Read, and thus in doing so, they still had to operate through the scar tissue from previous surgery. In addition, in the Rives technique, the mesh had to be cut and shaped in a complex fashion [10]. Other groups have also described trans-inguinal techniques for preperitoneal mesh placement with one claimed advantage being the ability to carry out the procedure under local anaesthesia [15, 16].

Wantz in the USA was impressed with the Stoppa's technique and modified it for unilateral hernias [14]. He was dissatisfied with what he termed preperitoneal 'patch hernioplasty' (developed by Raymond Read—a prosthesis that was just sutured to the edges of the defect [17]), and he

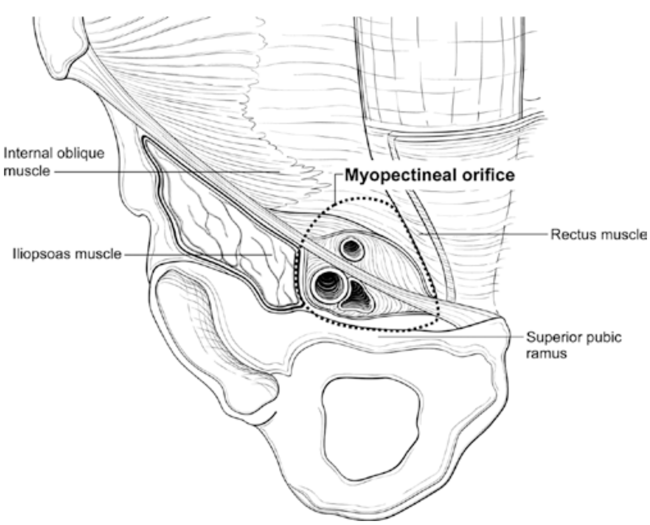

Fig. 13.1 Fruchaud's myopectineal orifice (MPO). *Right side*, anterior view

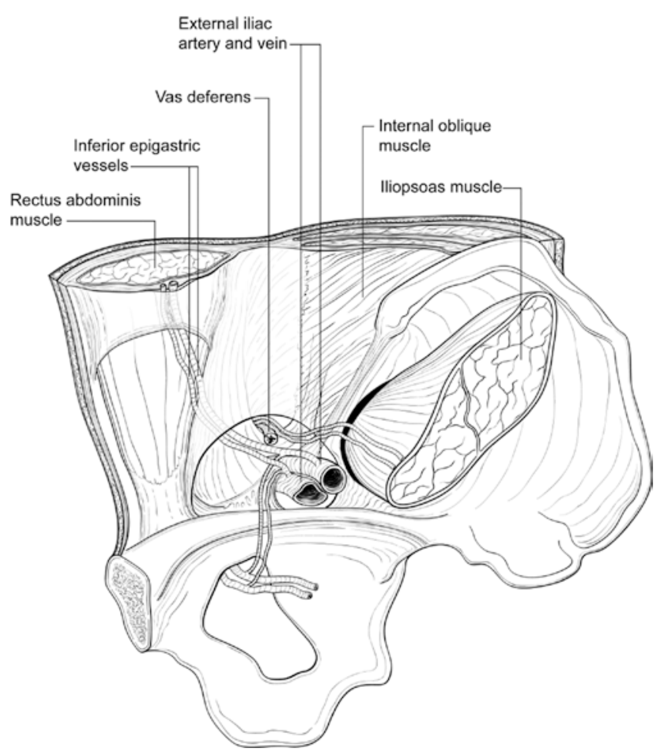

Fig. 13.2 Fruchaud's MPO. *Right side*, posterior view

saw the sense of using a large piece of mesh with a wide overlap, as is now a standard practice with a laparoscopic repair. His unilateral version of the operation used the Nyhus transverse lower quadrant incision combined with Stoppa's technique of inserting a large piece of mesh, covering the whole of the myopectineal orifice on that side, without attempting to close the defect.

Both the unilateral (Wantz) and bilateral (Stoppa) techniques were particularly well suited to complex and multirecurrent defects. Like the Nyhus procedure, they were never widely adopted, possibly because of general surgeons' unfamiliarity with, and reluctance to venture into, the preperitoneal space. Of course the modern era of laparoscopic surgery started at about this time, and it is interesting to observe that surgeons today have no concerns about entering this space with a laparoscope.

Operative Technique: Stoppa and Wantz

Both procedures require a wide deep dissection and a relaxed abdominal wall.

Stoppa used a lower midline incision routinely, but a Pfannenstiel incision [18, 19] gives excellent access, less post-operative discomfort and a better cosmetic result (Fig. 13.3) [12, 20] (Figs. 13.4, 13.5, and 13.6).

The Stoppa prosthesis was chevron shaped (Fig. 13.7), and a complex arrangement of eight long clamps was used to insert the mesh (Figs. 13.7, 13.8, 13.9, and 13.10) which was held by one single midline suture (Fig. 13.11).

The unilateral Wantz operation has been comprehensively and clearly described elsewhere in detail by Wantz [17, 22]. Wantz positioned and secured the prosthesis as shown [23], again using clamps to position the lower edge of the prosthesis deep in the pelvis (Figs. 13.12, 13.13, 13.14, 13.15, 13.16, 13.17, 13.18, 13.19, 13.20, 13.21, and 13.22).

'Small Incision' Preperitoneal Methods

Kugel and Ugahary [20, 24] described methods that allow access to the preperitoneal space through small incisions. Believing that placing mesh behind the myopectineal orifice was desirable, the original aim of these techniques was to combine the relatively short learning curve and economic advantages of the open approach with the rapid recovery of 'minimal access' surgery.

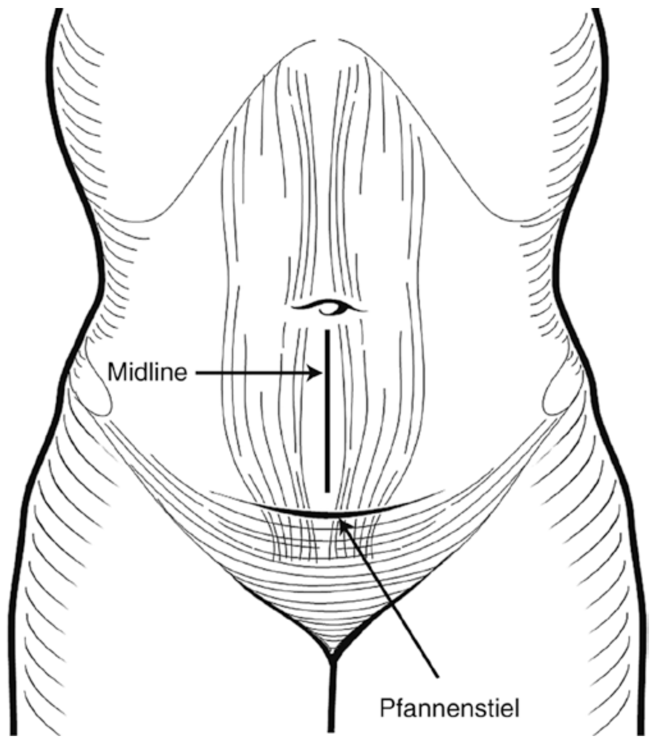

Fig. 13.3 Access to the preperitoneal space through a vertical or Pfannenstiel incision

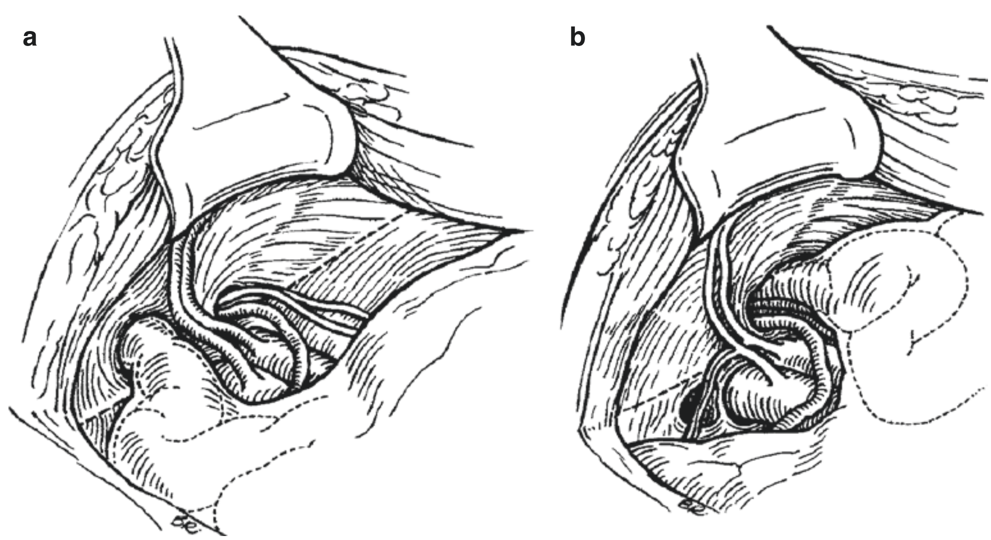

Fig. 13.4 (**a**, **b**) Preperitoneal view of the right groin (MPO), from the left side of the patient, showing a right indirect inguinal hernia (lateral to the inferior epigastric vessels) prior to its reduction, and note the femoral canal medial to the femoral vein (from Stoppa [21], with permission)

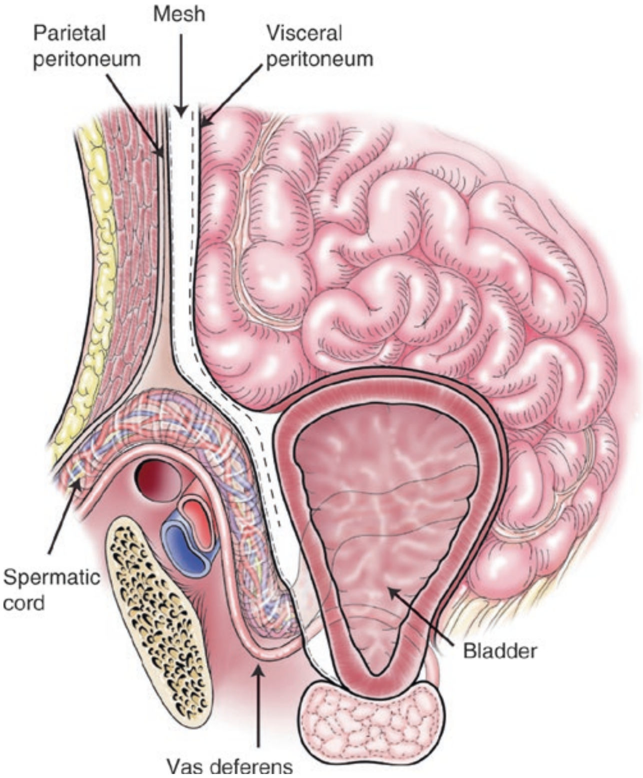

Fig. 13.5 Parasagittal section to demonstrate the mesh in the extraperitoneal or preperitoneal space, lying between the parietal peritoneum and spermatic cord on one side and the visceral peritoneum and bladder on the other

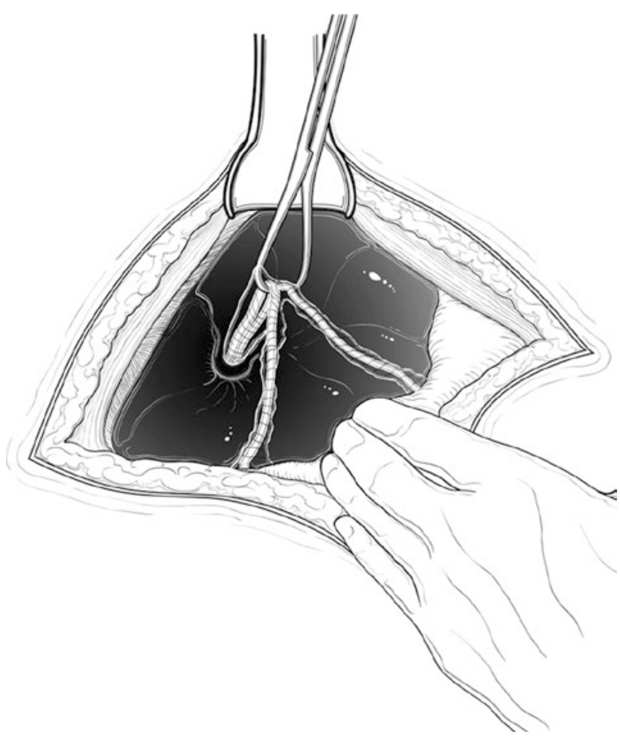

Fig. 13.6 The triangular appearance of the completed dissection on the right side, showing the vas deferens passing medially, testicular vessels passing laterally, and peritoneum. When released, the elements of the cord will fall against the parietal pelvic wall (parietalization)

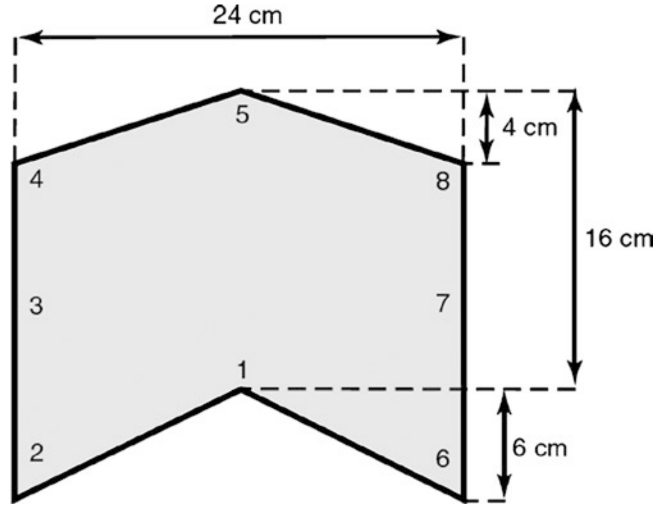

Fig. 13.7 The cardinal points of positioning of the clamps on the single bilateral prosthesis to aid in its insertion

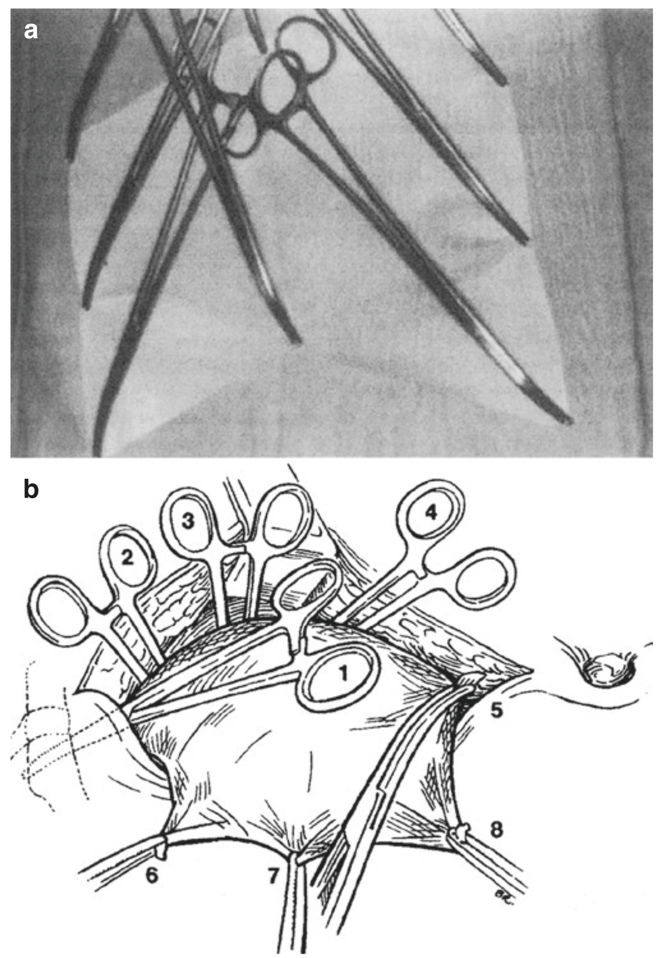

Fig. 13.8 (**a**) The chevron-shaped prosthesis is seized by eight long-curved clamps. (**b**) Operator view of the insertion of the bilateral mesh prosthesis, which is being pushed with clamps nos. 1–5. The numbers show the order in which the clamps have been used. Clamps nos. 6–8 will be used for the placement of the left part of the prosthesis. This is a complex maneuver, requiring the surgeon to have a good 3D appreciation of the space as well as a good assistant (from Stoppa [21], with permission)

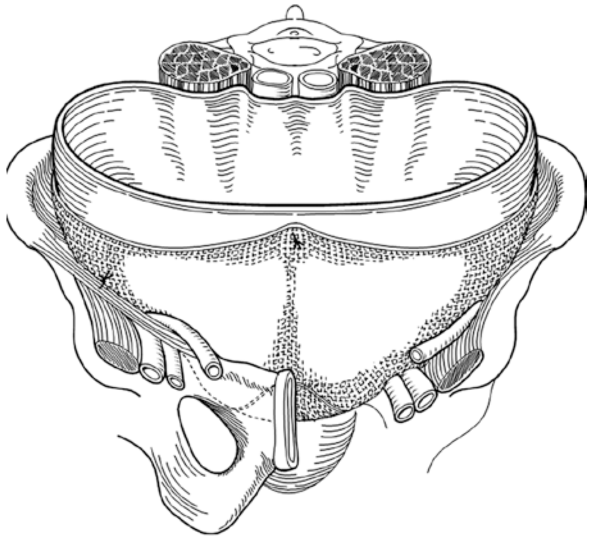

Fig. 13.9 Stoppa's recommended placement of the single suture to fixate the giant prosthesis

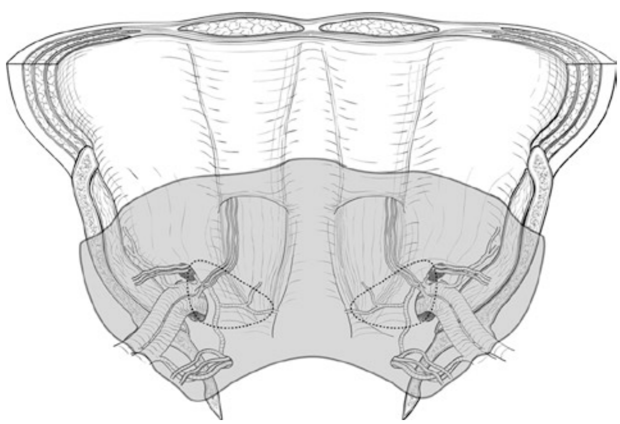

Fig. 13.10 The bilateral prosthesis in position, replacing the endopelvic transversalis fascia and extending far beyond the borders of both MPOs

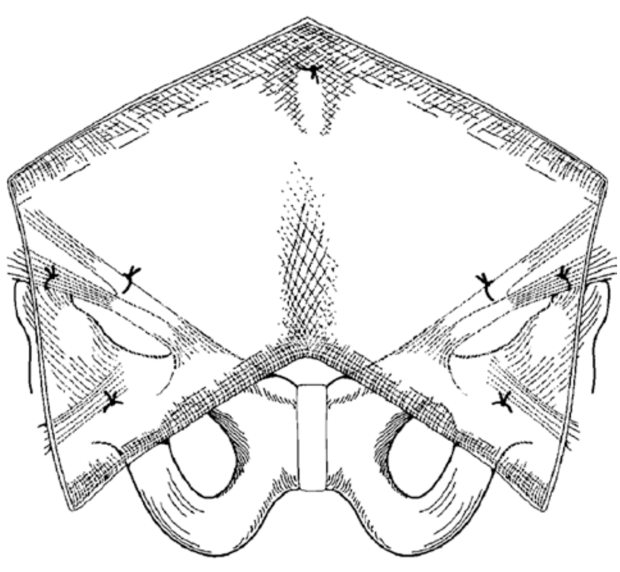

Fig. 13.11 Suture placement for fixation of the bilateral mesh

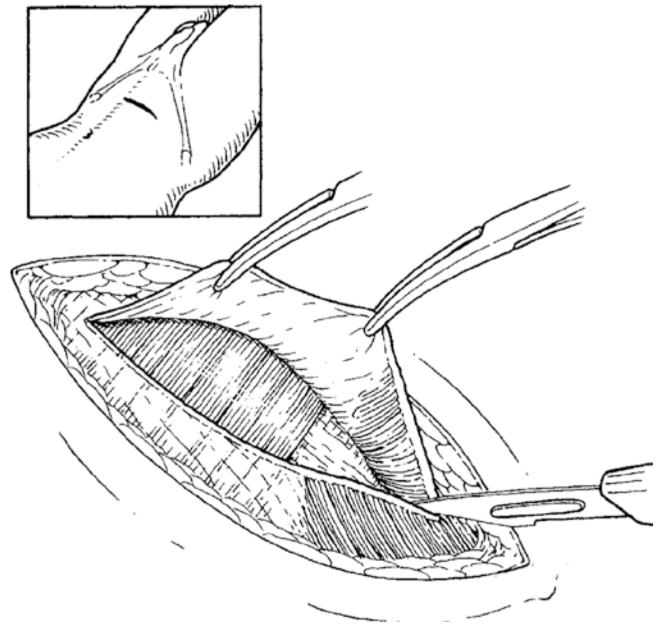

Fig. 13.12 Wantz unilateral procedure makes the transverse incision above the level of the deep inguinal ring, from the midline extending laterally. Incise the rectus sheath and extend laterally into the aponeurosis of the oblique abdominal muscles, and note the yellow fat marking the best entry point into the preperitoneal space

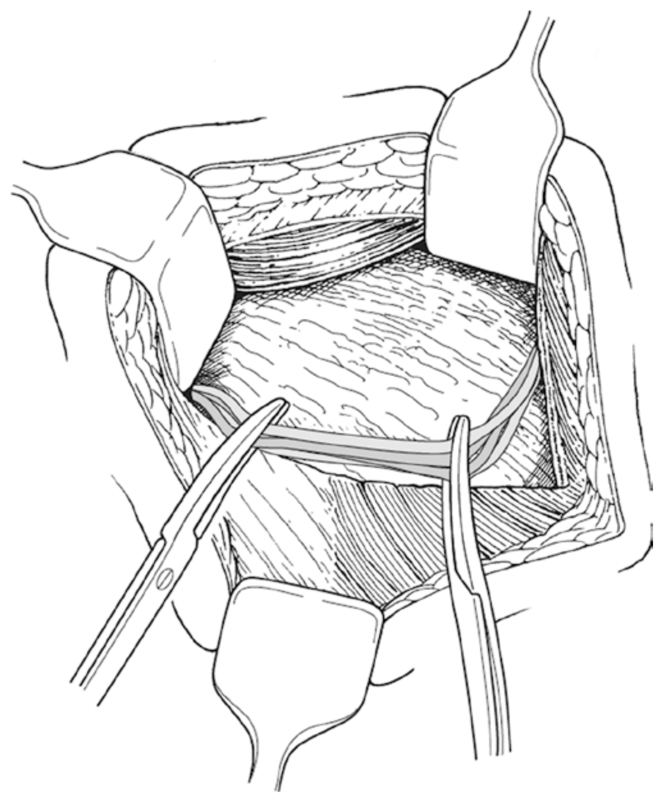

Fig. 13.13 The rectus muscles retracted medially and elevated to expose preperitoneal fat. This is below the arcuate line, so there is no posterior rectus sheath. The transversalis fascia has been incised, and the inferior epigastric vessels are about to be divided. This is not always necessary—they can be elevated and retracted medially with the rectus muscle

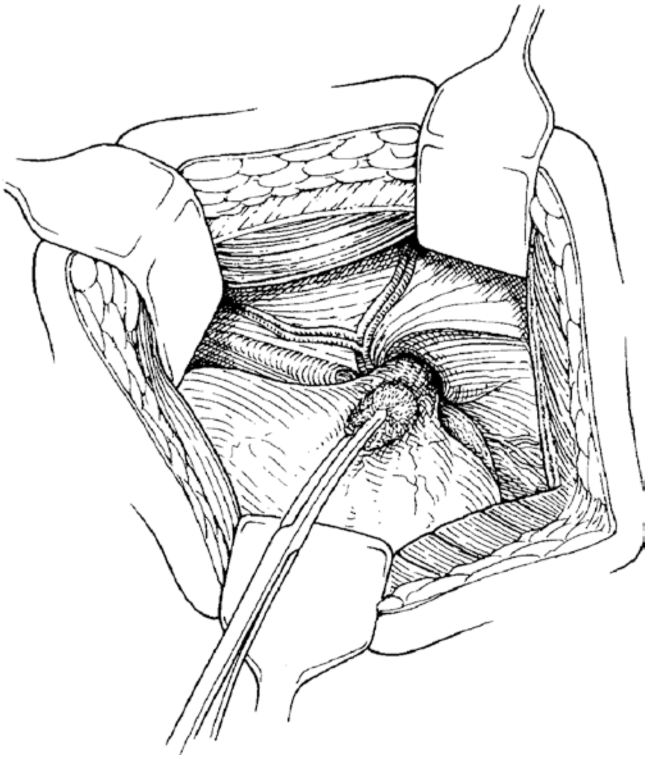

Fig. 13.14 "Teasing" an indirect hernia sac out of the abdominal wall defect

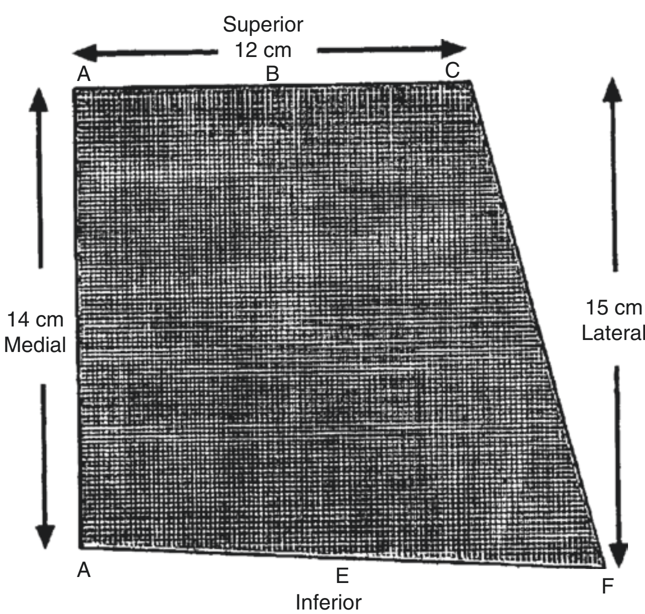

Fig. 13.15 Wantz procedure—trapezoid shape of the mesh to be inserted in preperitoneal space. The letters A–F illustrate the position of the mesh after placement

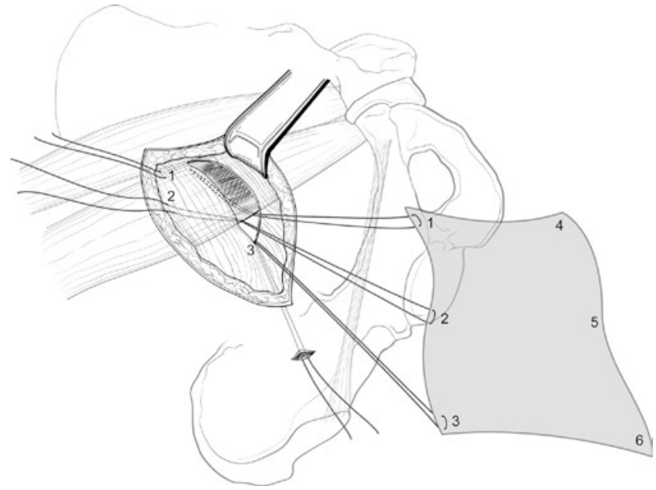

Fig. 13.16 Arrange the mesh so it stretches transversely. Its width is cut equal to the distance between the midline and the anterior superior iliac spine minus 1 cm, and its length is made approximately equal to 12 cm. Wantz had an innovative way of attaching the mesh, drawing it into place underneath the rectus muscle and superior abdominal wall with three slowly absorbable sutures at 1, 2, and 3

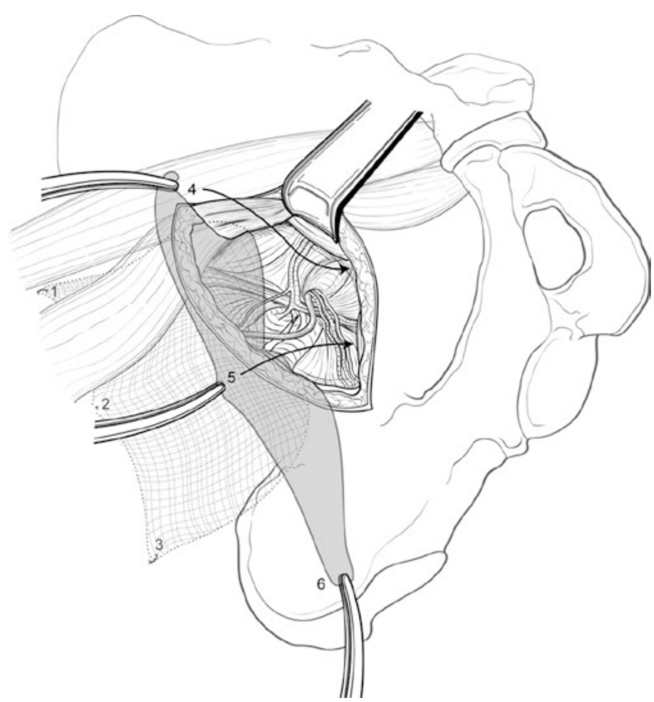

Fig. 13.17 The abdominal wall is retracted and the properitoneal space exposed. The superior portion of the prosthesis (1–3) is depicted indistinctly to illustrate its position after placement beneath the muscles of the abdomen in the preperitoneal space. Clamps nos. 4, 5, and 6 along the distal margins of the prosthesis are poised, ready to implant the mesh inferiorly

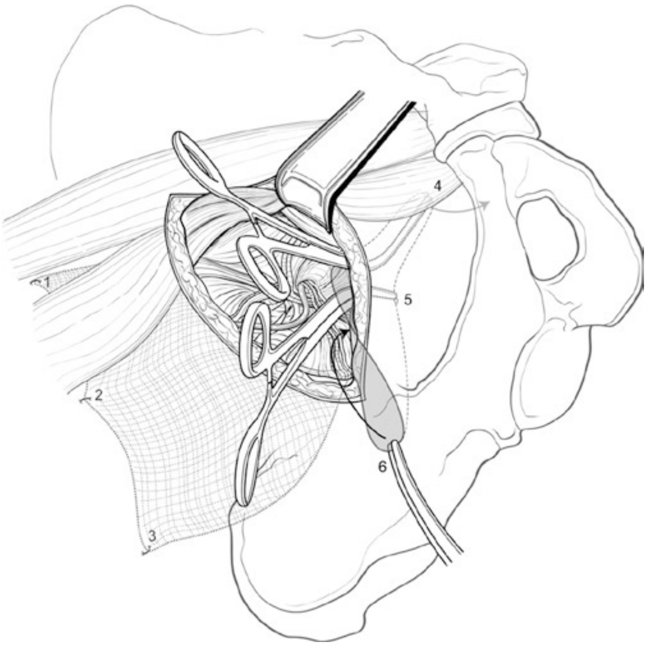

Fig. 13.18 Clamp no. 4 is placed medially deep into the space of Retzius in the midline and is steadied by an assistant. A very large curved or right-angled clamp helps keep point 4 at the midline. Next, clamp no. 5 positions the middle of the inferior edge deep into the pelvis, followed by clamp 6 pushing laterally. Again, a complex maneuver

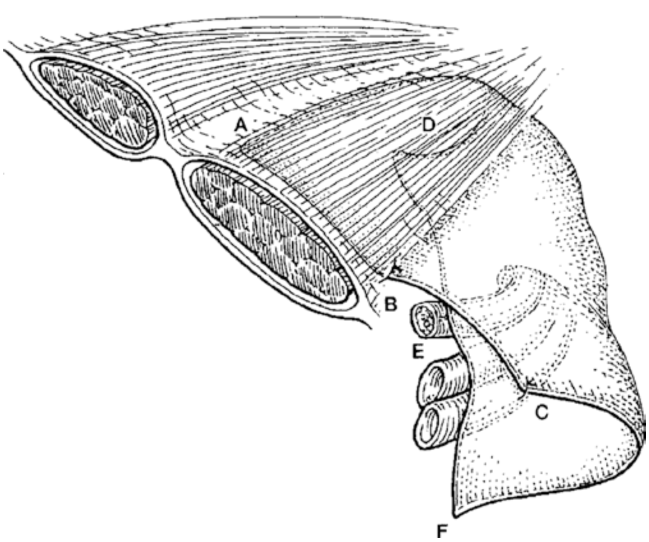

Fig. 13.19 Slightly different view of the position of the Wantz prosthesis. Points D, E, and F are equivalent to 4, 5, and 6 in this figure

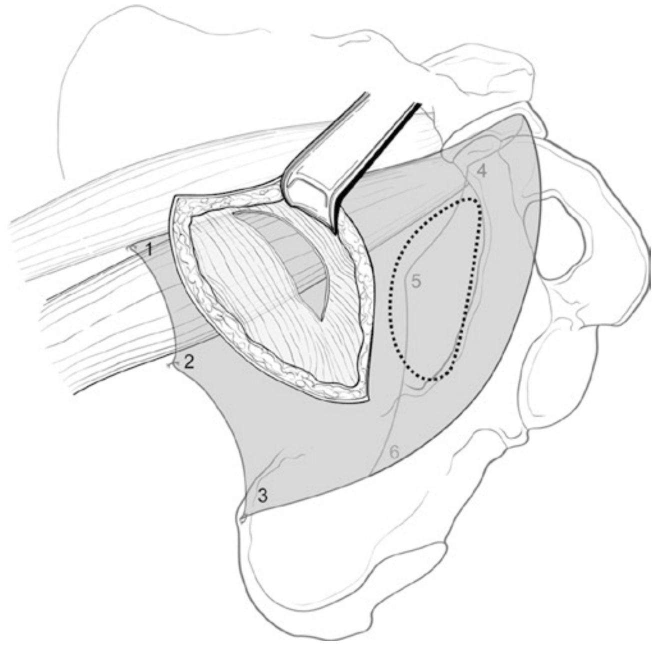

Fig. 13.20 Final position of the prosthesis in unilateral GPRVS. The prosthesis extends far beyond the borders of the dotted outline of the MPO

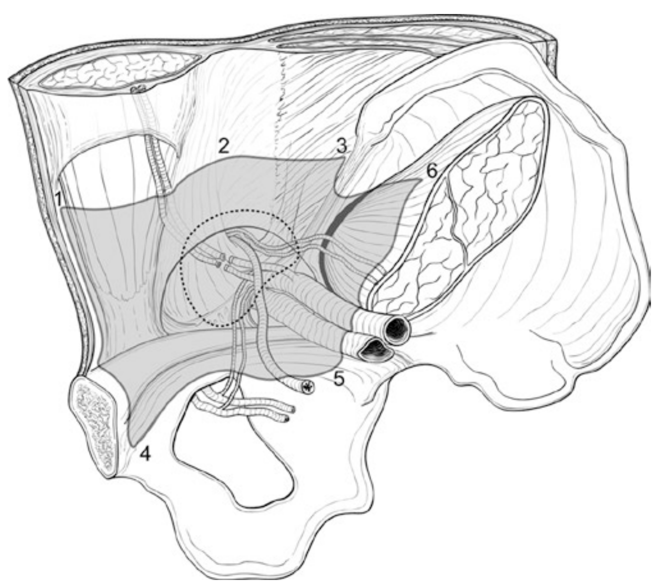

Fig. 13.21 View from within the pelvis of the final position of the prosthesis in unilateral GPRVS. This is essentially the same as the position of the mesh in laparoscopic repair, extending far beyond the borders of the MPO

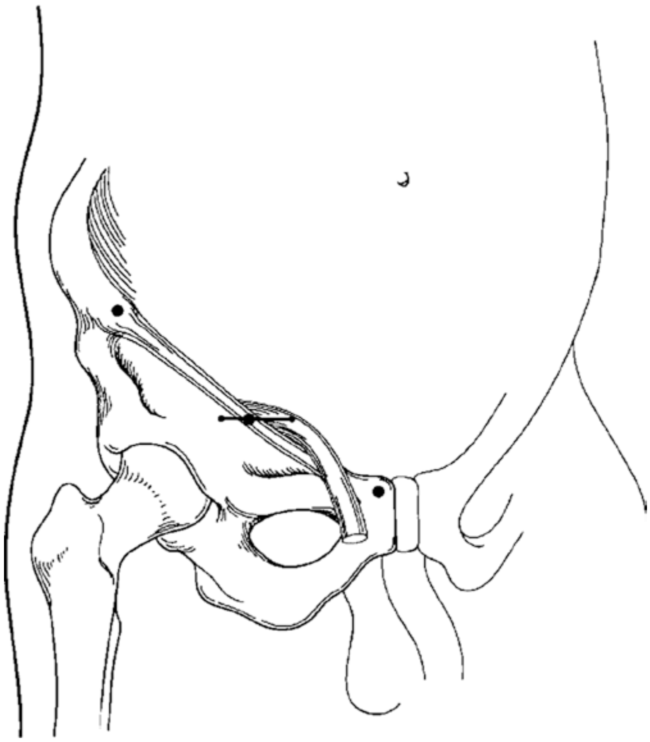

Fig. 13.22 Location of the small incision for the Kugel repair of inguinal hernia. The *left* and *right* dots denote the pubic tubercle and the anterior iliac spine. The incision is positioned between these two structures

More recently Koning [25] has described a 'TREPP' operation, which uses in essence a short Wantz/Nyhus incision, placed slightly more medially, to access the preperitoneal space. A more medial placement of the incision is made intending to avoid the nerves that may lie laterally in the preperitoneal plane. Another preperitoneal procedure named 'Onstep' [26, 27] has been described. Apart from the Ugahary technique, all the 'small incision' operations have required the use of mesh with a preformed, memory or recoil ring in order to assist correct positioning because of limited access.

The TREPP and Onstep developers and advocates wanted to avoid the mesh coming in contact with the nerves in the inguinal canal because of a possible association with chronic groin pain, and they wanted a way of doing this that did not need a laparoscope. The location of the incision is critical to the performance of the procedures in an easy fashion, and they are dependent on the surgeon's understanding of the local anatomy of the preperitoneal space in the inguinal area. Carrying out a preperitoneal repair through a small incision does not allow easy visual inspection of what is a potentially hazardous area. It is also technically challenging. Bladder, large blood vessel and nerve injury has been reported, and these are certainly not procedures for the inexperienced trainee. In theory, if visualisation is difficult, a laparoscope can be inserted into the preperitoneal space to assist in the identification of the structures (negating the economic advantages of the procedure).

Apart from the Ugahary procedure, they all use 'memory ring' prostheses with no or minimal fixation to facilitate placement and positioning through small incisions. Greenburg [28] has sounded a note of caution when using 'devices' with rigid memory or recoil rings, where the follow-up period is relatively short and the long-term performance of the recoil ring is unknown. These devices run the risk of being a fertile source of medicolegal litigation.

In their recent review, Andresen [29] listed nine different preperitoneal operations, but some of these are simply variations on a theme. For instance, the TREPP technique uses an approach that is a variation of Wantz/Nyhus. Preperitoneal inguinal hernia repairs can be grouped as standard incision repairs, Stoppa (bilateral) and Wantz (unilateral); as small incision methods, Kugel, Ugahary, TREPP and Onstep; and as trans-inguinal methods. Trans-inguinal operations are destructive to the inguinal canal and interfere with the nerves during the dissection:

(1) Unilateral Wantz procedure [14]
(2) Bilateral Stoppa procedure [9]
(3) Trans-inguinal (Read [5], Rives [10], Schumpelik [30]), Pelessier [16])
(4) Kugel procedure [24]
(5) Ugahary procedure [20]
(6) TREPP [25]
(7) Onstep operation [26]

Operative Techniques of Small Incision Repairs

Anaesthesia

Local anaesthesia has been advocated for the small incision procedures but is only feasible if the operator is experienced and the patient a slim and co-operative. In practice general anaesthesia is the method of choice for the majority of patients. Regional block (spinal or epidural anesthesia) is an alternative but is likely to result in a high incidence of urinary retention.

The Ugahary Operation

Ugahary has described his operation in detail [20], with numerous technical tips [25]. The incision is made approximately 3 cm above and lateral to the internal ring (Fig. 13.26). The preperitoneal space is entered in a similar way to the

Kugel operation. A flat mesh is used and is inserted tightly rolled around a 300 mm forceps; it is then unrolled in situ requiring quite a lot of technical skills (Figs. 13.23, 13.25, 13.26, 13.27, and 13.28).

The Kugel Repair

Kugel made a 3 cm transverse, slightly oblique incision at the midpoint between the anterior superior iliac spine and the pubic tubercle (Fig. 13.24). The technique has been described in detail. Kugel used a bilayer piece of knitted monofilament polypropylene a ('Kugel Patch™' Surgical Sense Inc.), with an outer polyester 'memory recoil' ring which allows the mesh to open up after insertion.

TREPP operation: This procedure uses a smaller but otherwise similar approach to that used by Wantz and inserts a self-expanding mesh, often without any fixation. According to the developers, a slightly more medial dissection is used to avoid the 'inguinal nerves'

Onstep: from the detailed description and illustrations in the original paper [26], this would seem to be a trans-inguinal procedure, forcing a hole in the posterior wall of the inguinal

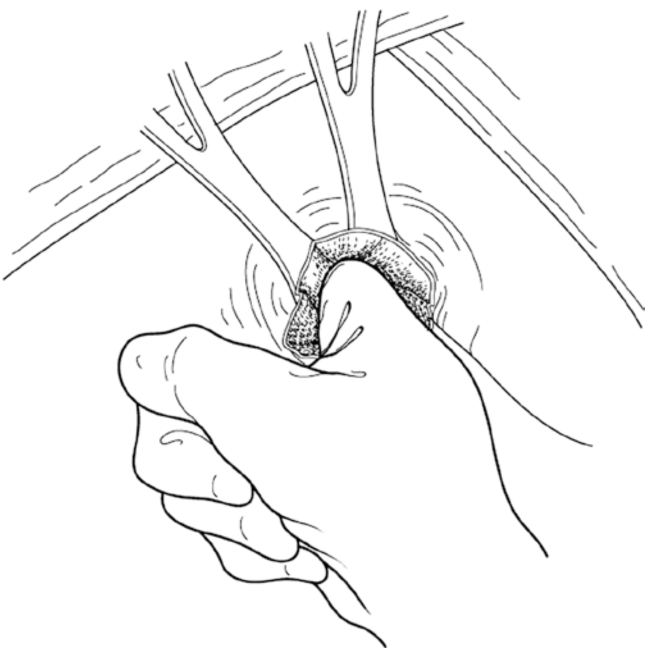

Fig. 13.23 Insertion of the patch is simplified by using a malleable retractor as a shoehorn

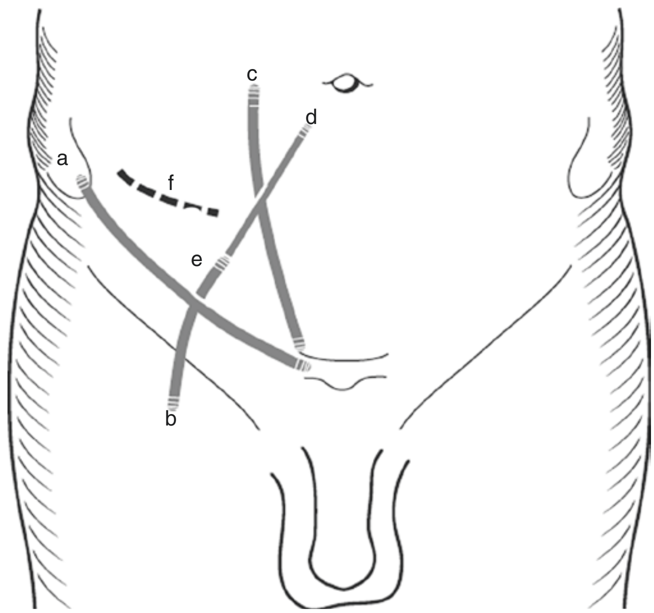

Fig. 13.25 The skin incision (*f*) for Ugahary's operation. Surface anatomy: (*a*) inguinal ligament, (*b*) femoral artery, (*c*) lateral border of the rectus muscle, (*d*) line perpendicular to the inguinal ligament from the femoral artery, and (*e*) the deep or internal ring

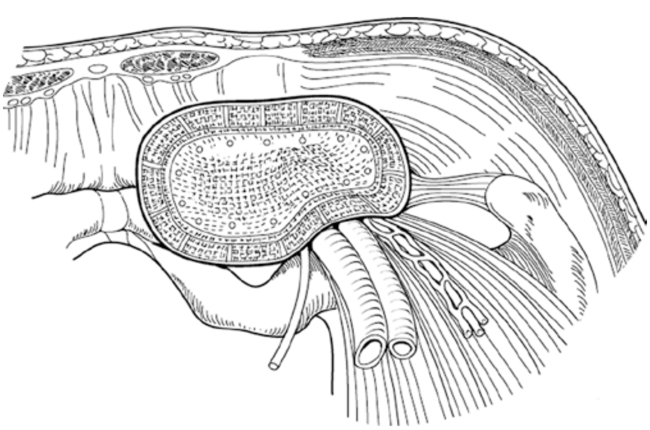

Fig. 13.24 Preperitoneal view showing final position of the Kugel patch (reprinted from Am J Surg. 1999;178:298–302 with permission)

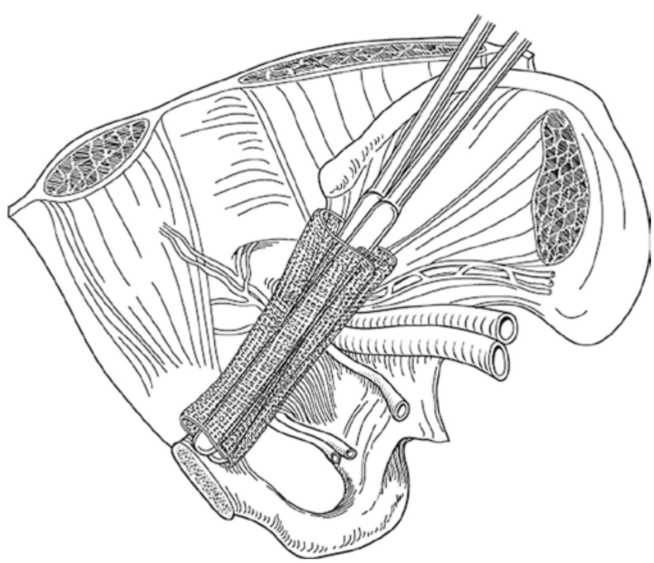

Fig. 13.26 Ugahary operation—insertion and positioning of the rolled up prosthesis

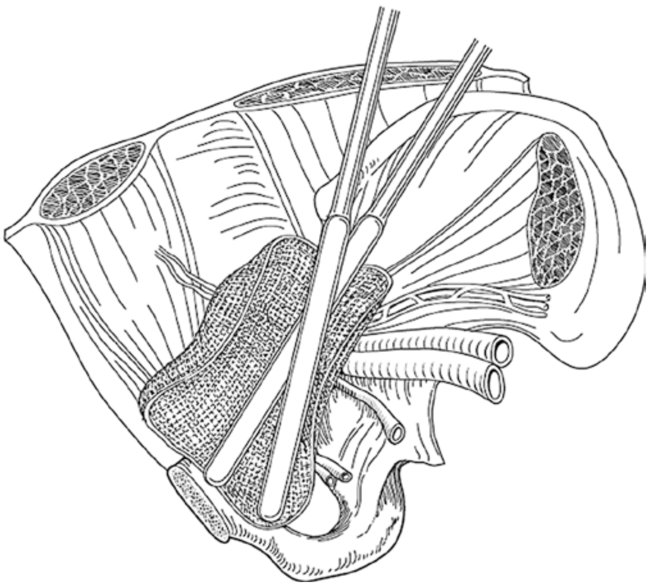

Fig. 13.27 Use of both retractors to spread and position the mesh

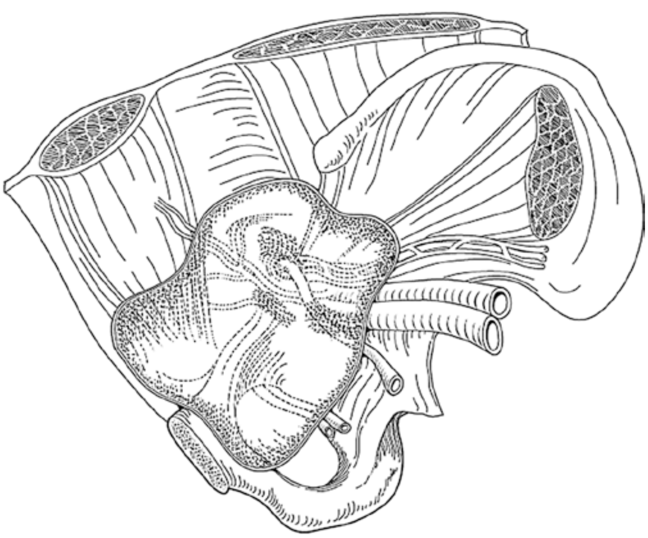

Fig. 13.28 Final position of the mesh

canal with a finger. A mesh with a 'recoil memory ring' is used, the medial portion of which lies in the preperitoneal space, while the lateral portion comes to lie between the internal oblique muscle and the external oblique aponeurosis.

Advocates of these small incision operations maintain that their respective procedures are easy to perform, and indeed in skilled hand, they are. As with most things in life, things are easy when you know how, and when proficiently carried out, these operations can yield excellent results. However they require a detailed knowledge of the local anatomy and are unforgiving of technical errors. The correct plane has to be entered with the minimum of unnecessary dissection, and controlling excess bleeding in a deep hole through a small incision can be problematic. The presence of even a small haematoma is likely to prevent the mesh from sitting properly and will compromise the repair, although enthusiastic surgeons with an interest in hernia surgery have obtained good results as noted above. The preperitoneal space at this level is a hazardous area with major vessels and the bladder at risk. Unless a significant advantage is shown, most surgeons may not wish to, or have the opportunity to, invest the time in attaining technical proficiency [31].

Results

Ugahary's gridiron operation has not been widely adopted, probably because of the technical challenge of placing a flat mesh accurately through a small incision Ugahary [32]. In contrast to the Ugahary procedure, the Kugel hernioplasty and variations that use mesh with a memory ring are supported by numerous publications from other surgical groups who have reported it to be safe and effective, with short operative times, low complication rates, 'minimal' post-op pain and a rapid return to normal activities [33].

Kugel's own results are excellent with an overall recurrence rate of 0.4% [24]. The study by van Nieuwenhove was a multicentre prospective trial in 450 patients with a 1.9% recurrence at a mean follow-up of 18 months [34]. Fenoglio [35] reported a large retrospective series of over 1000 patients with a follow-up of 2–47 months and a recurrence rate of 0.47%. Suwa et al. obtained similar results [36, 37]. However one study [38] of 355 patients undergoing the Kugel operation, with 6 surgeons, reported an overall recurrence rate of 18%, almost 30% for recurrent hernias, and an estimated learning curve of at least 36 cases [38]. The authors concluded, understandably, that the recurrence rate was "unacceptably high, clearly a technically challenging procedure in their hands".

TREPP

TREPP results: Following Koning's initial description, Lange and his colleagues reported 1000 cases operated on with the TREPP technique [39] and provided a detailed description with illustrative figures. The recurrence rate was low, and patient satisfaction was high. Chronic post-operative inguinal pain (CPIP) was reported by 5% of patients. Overall morbidity was low (19/1000:1.9%), and although two patients had to have an infected mesh removed, this is only represented 0.2%

of the cases. However in a commentary to Lange's report, Rosin questioned the effectiveness of this potentially challenging procedure in general surgical practice [31].

A recent Cochrane review [40] sought to compare elective open preperitoneal mesh techniques with Lichtenstein mesh repair in terms of pain. Three eligible trials involving 569 patients were identified. Two trials involving 322 patients reported less chronic pain after preperitoneal repair, whereas one trial, including 247 patients, described more chronic pain after this repair. The authors felt that the lack of homogeneous trials prevented robust conclusions.

Indications For a 'Classical' Open Preperitoneal Repair

- Recurrent or multiple recurrent groin hernias following a previous open, anterior repair. Operating in the unscarred, virgin preperitoneal plane is simpler and safer and reduces the risk of damage to the testicular vessels, and all potential defects can be inspected.
- Combination groin hernias where there are multiple defects, for instance, combinations of pre-vascular, femoral, indirect and direct inguinal and low Spigelian hernias. All potential defects can be inspected.
- Giant inguino-scrotal hernias, either unilateral or bilateral, where replacement of abdominal contents through a groin incision alone would be technically difficult. 'Pulling' the sac contents back from behind through the defect is simpler and safer than 'pushing' from the front.
- Hernias associated with connective tissue disorders (Ehlers–Danlos and Marfan's syndrome).

Indications For a 'Small Incision' Open Preperitoneal Repair

- As a preferred technique for primary inguinal hernia repair where avoidance of the nerves in the inguinal canal is thought to be desirable, laparoscopic repair is not feasible (lack of expensive laparoscopic equipment or wish to avoid a general anaesthetic).

Summary

With all the preperitoneal approaches:

- The learning curve is probably shorter than for laparoscopic repair.
- They require no expensive specialised equipment and therefore have economic advantages over a laparoscopic repair.
- They are suitable for patients unfit for general anaesthesia—by using either local or regional anaesthesia.
- They avoid placing mesh in contact with the nerves that lie in the inguinal canal.

In addition the classical 'larger incision' preperitoneal approaches:

- Are probably the best procedure for repairing large recurrent or multirecurrent inguinal hernias with tissue loss, incarcerated recurrent hernias and large sliding inguinal hernias
- Serve as an excellent 'stepping stone' to laparoscopic TEP repair, providing a means of familiarising trainees with the complex anatomy of the preperitoneal space

Conclusion

There are two categories of open preperitoneal mesh repair of groin hernia. The recently described 'small incision' open operations have been developed to avoid placing mesh within the inguinal canal in a primary repair. No expensive laparoscopic equipment is required, they do not necessarily need a general anaesthetic, and their advocates claim a short learning curve, low morbidity and a low incidence of chronic post-operative pain. It remains to be seen whether or not they prove their usefulness in the long term, in everyday general surgical practice. In contrast the classical open preperitoneal techniques through standard incisions provide excellent access to the myopectineal orifice and thus permit inspection of all potential groin hernia sites in complex hernias. The approach avoids reoperating through the distorted anatomy and scar tissue that are present after a failed anterior operation, and the risk of damage to the testicular vessels and the nerves within the inguinal canal is minimised. They are an important and useful technique even in the laparoscopic era and should have a place in the toolkit of every surgeon who declares an interest in hernia surgery.

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14 Tissue Repairs for Inguinal Hernia

Nicholas H. Carter and David C. Chen

Introduction

Placement of mesh is now favored in both open and laparoscopic repairs of uncomplicated adult hernias. Techniques that rely on tissue-based repair are typically reserved for exceptional circumstances due to an elevated risk of recurrence. Impaired collagen synthesis has been shown to contribute to hernia formation, and the tissues in the presence of a hernia may be regarded as intrinsically abnormal. Suture lines secure tissue under tension which is known to be associated with recurrence. Synthetic mesh materials have been developed to be strong, lightweight, and inert. Mesh-based repairs have been demonstrated in several randomized controlled trials to carry lower rates of recurrence [1–3]. Nevertheless, tissue-based repairs are preferred in certain circumstances where mesh usage is contraindicated, undesirable, or unavailable. In the setting of contamination or infection, implantation of synthetic material is contraindicated. Consideration of mesh-related pain and complications is important and should factor into the shared patient and surgeon decision regarding repair technique. Adolescents and young adults as well as female patients with small indirect hernias may also be better suited for a tissue-based repair when chronic pain and foreign body sensation are taken into account. In underserved settings, where inguinal hernias are more likely to present with strangulation or mesh may simply not be immediately available, tissue-based repair remains the standard of care.

The surgical literature includes references to more than 70 different tissue-based repairs. The most common techniques in modern use include the Bassini, Shouldice, McVay, and Desarda repairs. The latest data from the national hernia registry in Sweden indicated that tissue repairs were used in 0.8% of inguinal operations in 2015 [4]. In this chapter, we will describe these procedures with an emphasis on the details of neuroanatomy and intraoperative technique.

Preoperative Considerations

Preoperative considerations for tissue-based repairs are similar to standard inguinal hernia repairs. Patients presenting with an inguinal hernia regardless of symptoms are appropriate for operative repair barring medical contraindications. Those with elevated cardiac or pulmonary risk can be considered for feasibility of repair under local anesthesia with or without sedation. Patient with prohibitive medical risk may be offered expectant management with the use of a truss for comfort unless severity of symptoms, incarceration, or strangulation necessitate an urgent nonelective operation. The most relevant preoperative consideration is whether the patient is indeed an appropriate candidate for tissue-based repair. Larger hernias and patients with intrinsic hernia-related risk factors should, in general, undergo mesh repair. Since mesh repairs are associated with lower rates of recurrence and pain, prosthetic repairs are generally favored unless contraindicated. Smaller hernias in a patient without increased hernia-related risk factors, adolescents or young adults with a likely small indirect hernia, female patients with a small hernia, and patients that have an aversion or contraindication to mesh should be considered for a tissue repair. Potential contamination of the operative field and prosthetic due to necrotic bowel, active infection, strangulation, or sepsis are considered indications for tissue-based repair. In resource-limited settings where mesh and training in mesh-based techniques are not readily available, tissue repairs remain the standard treatment option for the burden of inguinal hernia disease.

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Patient Positioning and Theater Setup

The patient is placed in the supine position. In most cases, tissue-based repair can be performed under local anesthesia alone. Our preferred technique of infiltration of a mixture of a short- and long-acting local anesthetic into the intradermal, subdermal, deep dermal, and subaponeurotic spaces has been described in detail for Lichtenstein repairs—the same technique works well for inguinal tissue-based repairs [5].

Incision and Access

Each inguinal tissue-based repair begins with a 5–6 cm incision along the Langer line extending laterally from the pubic tubercle. The external oblique aponeurosis is incised sharply with care to preserve the ilioinguinal nerve. On the medial side, the avascular plane between the external and internal oblique aponeuroses is bluntly dissected to reveal and preserve the iliohypogastric nerve. The genital nerve is identified along the lateral aspect of the cord at the lateral crus of the internal ring running parallel and adjacent to the external spermatic vein within the cremasteric bundle. The spermatic cord and hernia sac are each identified and isolated. A direct defect is identified along the floor of the canal medial to the inferior epigastric vessels. The femoral canal may be explored either through the hernia sac in the case of an indirect hernia or through the opened transversalis fascia with a direct hernia.

Operative Steps

Bassini Repair

The Bassini repair involves extensive dissection of the spermatic cord with high ligation of the hernia sac and inguinal floor reconstruction. Once the spermatic cord dissection is completed and indirect hernia sac excised, the inguinal floor is exposed. In a proper Bassini repair, the transversalis fascia is then incised from pubic tubercle to the internal inguinal ring, although this step is often excluded from modern adaptations of the Bassini repair. A triple-layer tissue repair is then performed with fixation of the transversalis fascia, transversus abdominis, and internal oblique aponeurosis to the shelving edge of the inguinal ligament with six to eight nonabsorbable interrupted sutures (see Fig. 14.1). A relaxing incision may be made along the falx inguinalis if required to minimize tension [6].

The transversalis fascia is opened widely to permit a complete three-layer closure. Medially, the sutures catch the falx inguinalis and transversalis fascia. Laterally, the sutures catch the transversalis fascia and the shelving edge of the inguinal ligament:

1. Aponeurosis of the external oblique
2. Internal oblique
3. Inguinal ligament
4. Relaxing incision of the falx inguinalis
5. Transversalis fascia
6. Repair with nonabsorbable suture

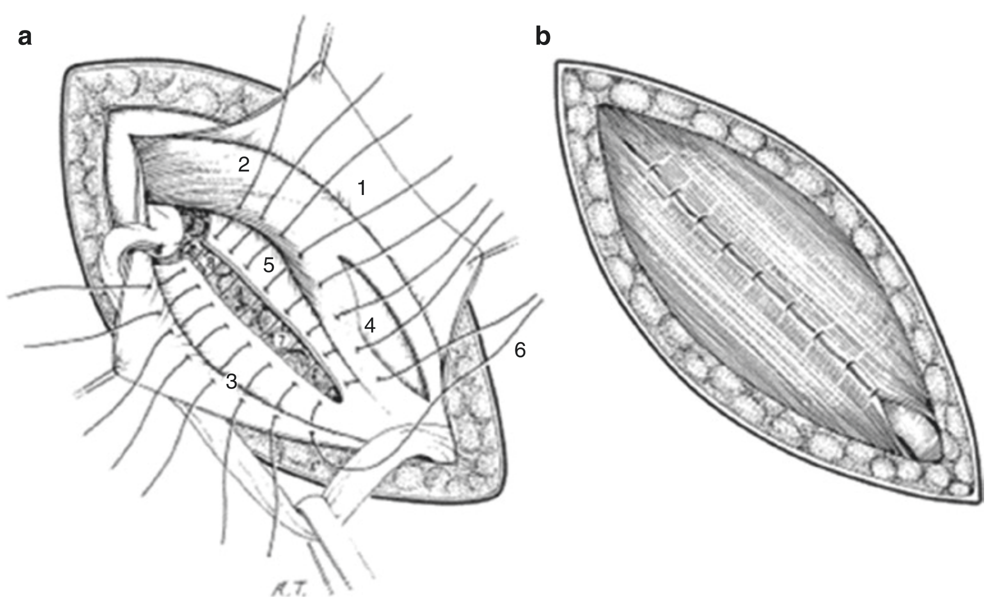

Fig. 14.1 Bassini repair. (Reproduced from [7])

7. Subperitoneal fat
8. Closure of the external oblique aponeurosis anterior to the conjoint tendon

Shouldice Repair

In the Shouldice repair, the surgeon similarly divides the transversalis fascia between the pubic tubercle and internal ring. Medial and lateral fascial flaps are then mobilized by bluntly dissecting the underlying preperitoneal tissue. The layers are then reapproximated using a running, nonabsorbable monofilament suture from the lateral edge of the rectus sheath to the iliopubic tract starting at the pubic tubercle. At the internal ring, this suture includes the lateral cremaster remnant and reverses back toward the pubic tubercle. The medial transversalis fascia flap is approximated to the shelving edge of the inguinal ligament. The suture is tied down at the pubic tubercle. A new running stitch starts at the internal ring and approximates the conjoint tendon to the inguinal ligament (Fig. 14.2c). At the tubercle, the stitch again reverses to progress laterally through the same structures and the lower end of the external oblique aponeurosis until it is tied down at the internal ring (Fig. 14.2d). The external oblique aponeurosis is then closed. An additional feature of the Shouldice repair is the routine division of the genital branch of the genitofemoral nerve during cord dissection.

McVay Repair

The McVay repair is primarily notable for addressing both the inguinal and femoral defects. Once isolation of the spermatic cord is achieved, the transversalis fascia is opened to access the

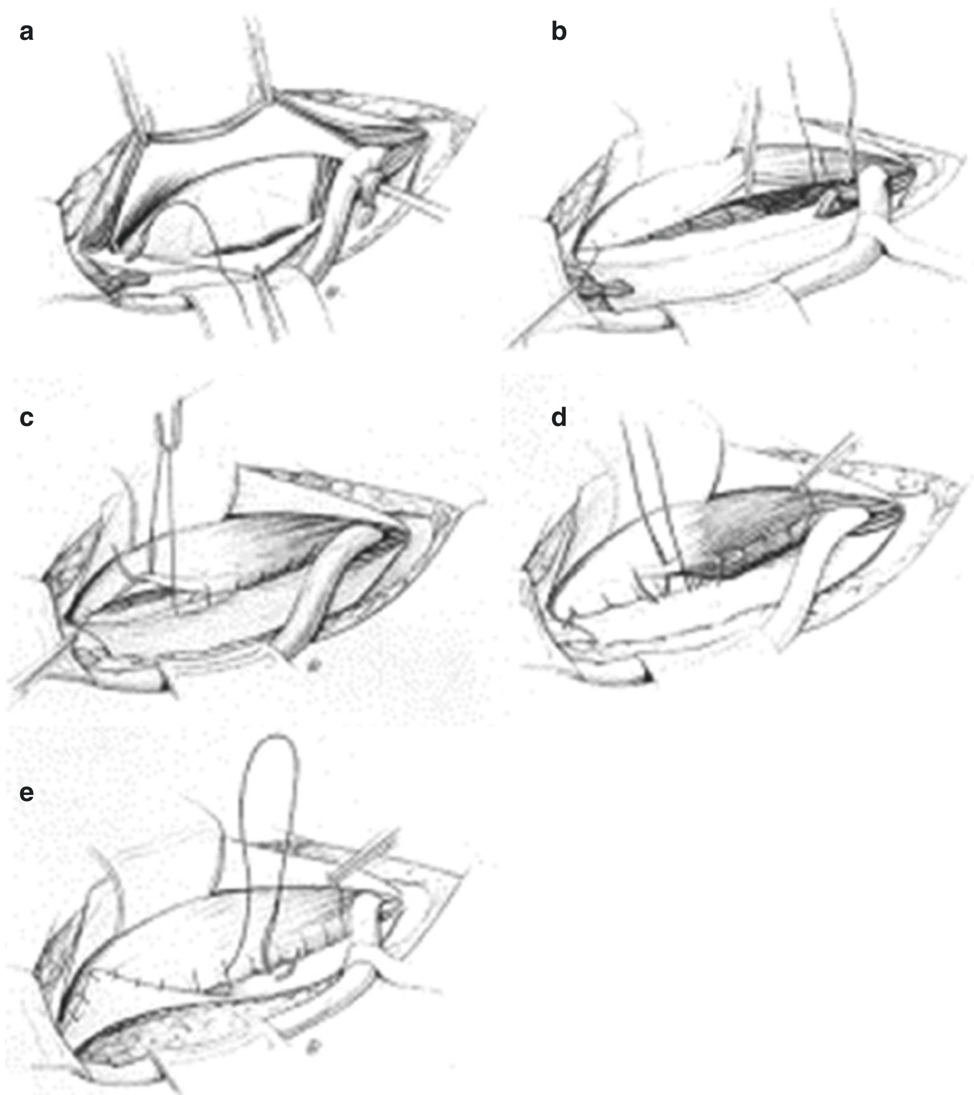

Fig. 14.2 Shouldice repair. (Reproduced from [8])

preperitoneal space. Cooper's ligament is then exposed using gentle blunt dissection. A relaxing incision is then made in the anterior rectus sheath at the pubic tubercle (Fig. 14.3a). The medial flap of the transversalis fascia is sutured to Cooper's ligament and runs laterally to occlude the femoral ring. A transition stitch approximates the transversalis fascia to the femoral sheath and inguinal ligament lateral to the femoral ring. A relaxing incision of the ipsilateral anterior rectus sheath reduces tension on the reapproximated external oblique aponeurosis and is considered a critical step of the McVay repair (Fig. 14.3d).

Desarda Repair

The Desarda repair, a modern variant of the historic Halstead repair, entails reinforcement of the inguinal floor with a laterally based pedicled strip of external oblique aponeurosis [8]. An undetached portion of external oblique aponeurosis is mobilized to the posterior wall of the inguinal canal with interrupted stitches securing it to the internal oblique muscle superiorly and inguinal ligament inferiorly (Fig. 14.4).

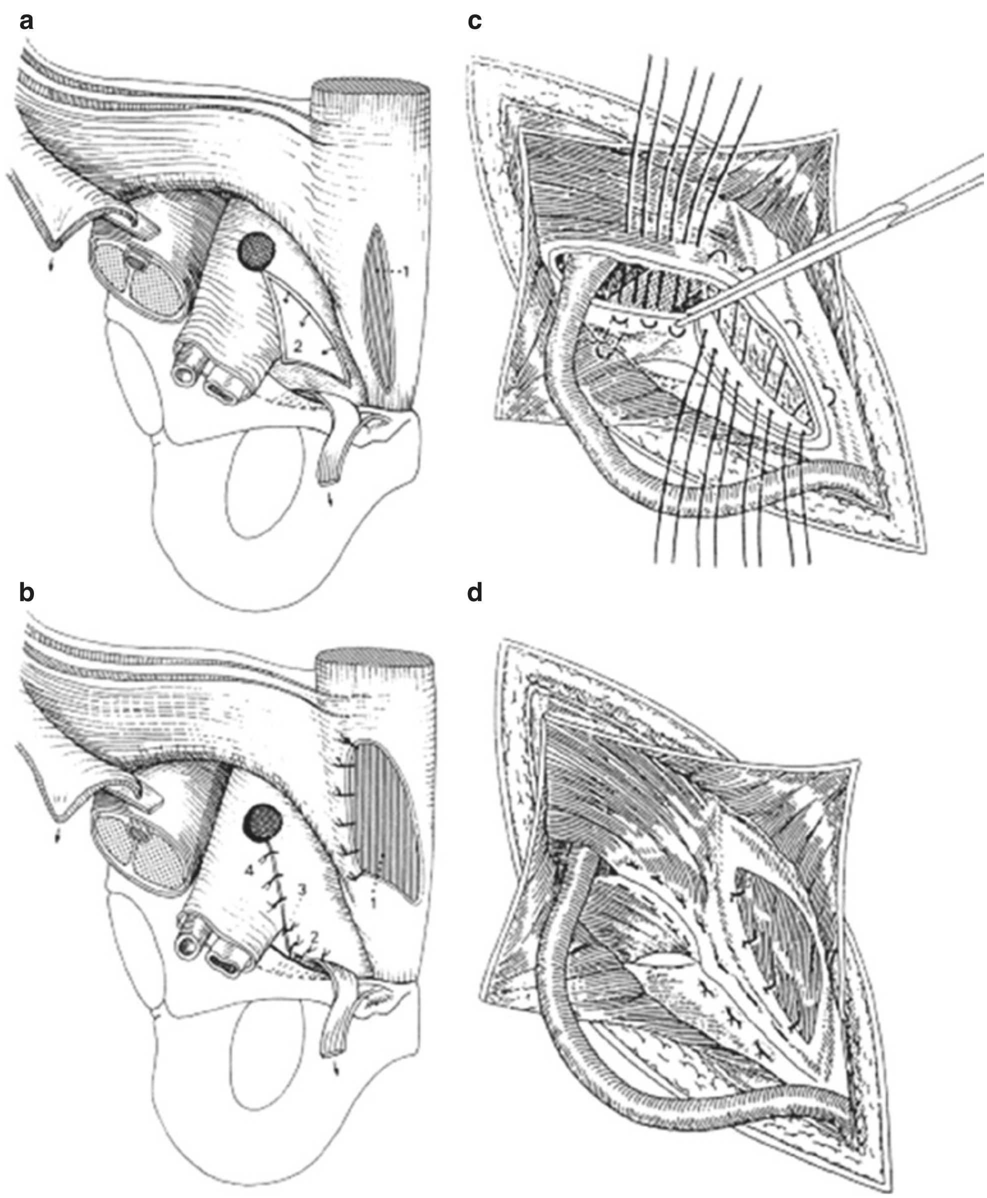

Fig. 14.3 McVay repair. (Reproduced from [7])

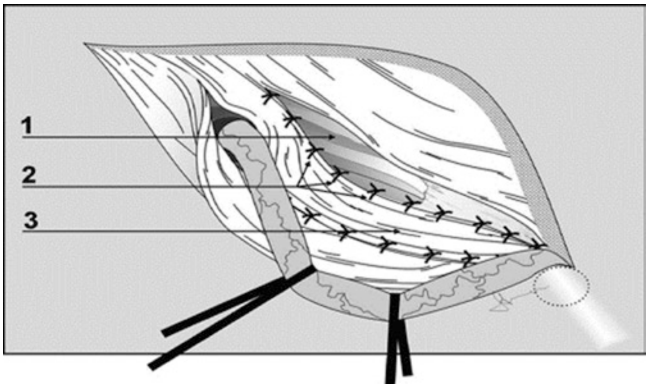

Fig. 14.4 Desarda repair (Reproduced from [9]). (1) internal oblique aponeurosis; (2) upper strip of the medial leaf of external oblique aponeurosis sutured to internal oblique aponeurosis; (3) medial leaf of external oblique aponeurosis that is sutured to inguinal ligament

Closure

Each of these tissue repairs is completed with restoration of the spermatic cord to its anatomic position followed by reapproximation of the external oblique aponeurosis. Scarpa's fascia and the skin can then be closed with running or interrupted sutures according to the surgeon's preference. Drain placement is not typically required or advised.

Postoperative Management

Postoperative management following tissue repair is similar to open mesh-based techniques. If tissue repair was selected in patients with infection, strangulated bowel, or other complicating factors, patients are typically observed in the hospital to assure appropriate return of bowel function and resolution of infection. In elective tissue-based repairs, patients may be discharged from the ambulatory setting once they have recovered from anesthesia. Postoperative activity is typically restricted for 3–4 weeks given that the strength of the repair is based upon tissue scarring and wound healing properties rather than mesh strength. In the longer term, surgeon-driven follow-up regarding recurrence and chronic pain is encouraged to help define the appropriate role for tissue repair and allow for tailoring of ideal technique for different patient cohorts.

Tips and Pitfalls

Nerve identification: As with all open anterior repairs, identification of nerves is crucial to minimize the risk of chronic pain. Since each tissue-based repair includes placement of numerous sutures, care must be taken to avoid nerve entrapment. Rarely, pragmatic nerve ligation may be considered if injury to one of the nerves is recognized intraoperatively or if the course of the nerve predisposes it to injury. In these cases, resection of the inguinal segment of the nerve with proximal intramuscular reimplantation of the upstream segment into the internal oblique is recommended. Prophylactic neurectomy of the inguinal nerves is not typically recommended as it may lead to unnecessary sensory disturbance and the rates of chronic pain are not decreased versus a "nerve-mindfulness" approach.

Inspection for femoral hernia: In the proper Bassini and Shouldice procedures, incising the transversalis fascia at the floor of the canal permits inspection for a femoral hernia. If a femoral hernia is present, a McVay repair is indicated. The Desarda repair does not require opening the canal floor, and thus the surgeon could fail to identify a femoral hernia. We suggest routinely creating a small opening in the floor of the canal to expose the space of Bogros and evaluate for the presence of a femoral hernia or interrogating the femoral orifice through the hernia sac.

Selecting a Tissue-Based Repair

Selection of a particular technique for tissue-based repair depends on surgeon familiarity and comfort with each approach. In experienced hands, the Shouldice repair is associated with recurrence rates that approach mesh repairs and is considered the optimal tissue-based technique. Both European Hernia Society and HerniaSurge guidelines recommend the Shouldice procedure for non-mesh repairs although rates of recurrence are noted to be considerably higher when performed by nonexpert surgeons [10, 11]. Evidence is lacking regarding the specific learning curves of the various tissue-based repairs; however, the Shouldice technique is considered notably challenging to master. Indeed, the Shouldice Hospital is reported to require 300 operations prior to considering a surgeon qualified [4]. Thus, it is reasonable to select a particular technique for tissue-based repair according to a combination of guidelines and individual surgeon comfort and training.

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15 Laparoscopic Inguinal Hernia Repair

Ty Kirkpatrick, Brent W. Allain Jr., and Karl A. LeBlanc

Introduction

The first report of a hernia repair using laparoscopy was made by Ralph Ger in 1982 [1]. In a patient with right indirect inguinal hernia, the neck of the sac was closed with a series of staples using an operating laparoscope and a cannula placed in the right iliac fossa. Although this procedure was carried out in November 1979, Ger stated that the first patient to be treated by laparoscopic closure of the neck of the sac was under the care of Dr. Fletcher of the University of the West Indies, Jamaica.

The use of prosthetic material for laparoscopic repair of an inguinal hernia was introduced by Corbitt and Schultz in 1991 [2, 3]. These repairs involved the use of a polypropylene plug, patch, or both to close the inguinal canal in a tension-free manner. Because of unacceptably high early recurrence rates, these approaches were abandoned in favor of laparoscopic placement of a preperitoneal prosthetic biomaterial. This repair follows the same principles as the open Stoppa repair [4]. After reducing the hernia sac, a large piece of mesh is placed in the preperitoneal space covering the entire myopectineal orifice in the inguinal region. The mesh becomes sandwiched between the preperitoneal tissues and the abdominal wall and, provided it is large enough, is held there by intra-abdominal pressure until such time as it becomes incorporated by fibrous tissue.

The intraperitoneal placement of mesh was introduced by Fitzgibbons and colleagues as a method of laparoscopic hernia repair [5]. This operation is performed using minimal dissection by leaving the hernia sac in situ and covering the defect with mesh, which is stapled to the surrounding peritoneum. The major concerns with this repair are the risk of injury to underlying structures from fixation devices and of obstruction or fistula formation as a result of adhesions between bowel and exposed mesh. Currently, however, this technique is rarely, if ever, utilized in inguinal hernia repair.

The laparoscopic approach for the repair of inguinal hernias is achieving success, and there are some areas of the world where this is the preferred method of repair. However, it does not seem that this methodology will become the standard of care for all inguinal hernias. In skilled hands, the laparoscopic approach is also effective for incarcerated inguinal hernias [6] and recurrent inguinal hernias after a prior laparoscopic repair [7].

Extraperitoneal Operation

Anesthesia

Although totally extraperitoneal hernia repair can be performed using either local or epidural anesthesia, it is our preference to use general anesthesia with complete muscle relaxation and mechanical ventilation. This ensures that the respiratory and cardiovascular changes that occur with extraperitoneal CO_2 insufflation are minimized. These changes are similar to or less than those observed with intraperitoneal CO_2 insufflation and may be related to the size of the space created during the preperitoneal dissections [8]. All patients undergoing totally extraperitoneal hernia repair receive DVT prophylaxis. The use of antibiotic prophylaxis is controversial in this situation with little evidence for or against their use; however, the authors prefer a preoperative dose of a first-generation cephalosporin in most cases.

Position of the Patient on the Table

Before attempting totally extraperitoneal hernia repair, it is important to ensure that the patient's bladder is empty. This can be achieved by asking the patient to micturate before entering the operating theater. Alternatively, a urinary catheter could be inserted, but this is generally unnecessary

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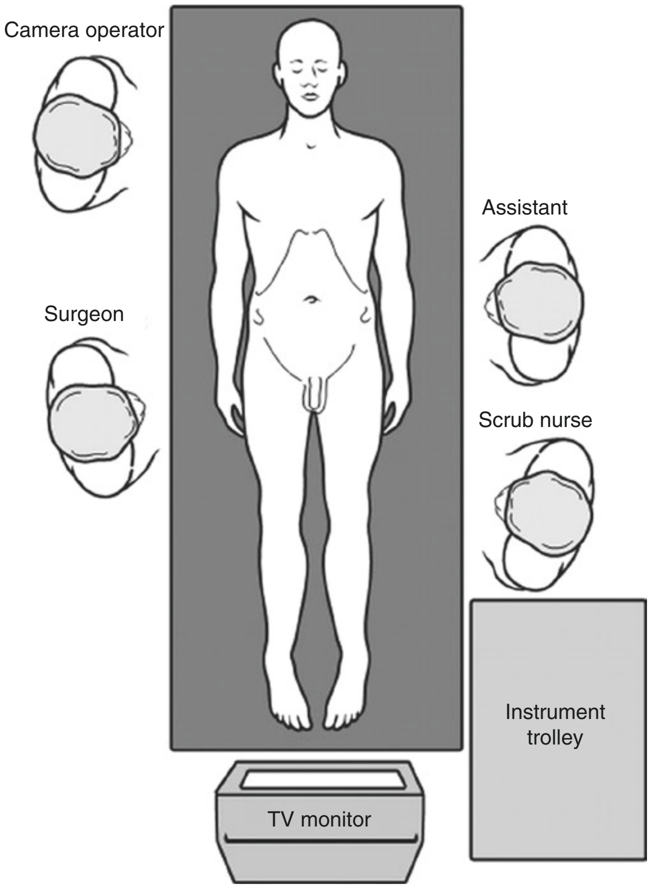

Fig. 15.1 Position of operator, assistants, and television monitor at the operating table for repair of a left inguinal hernia

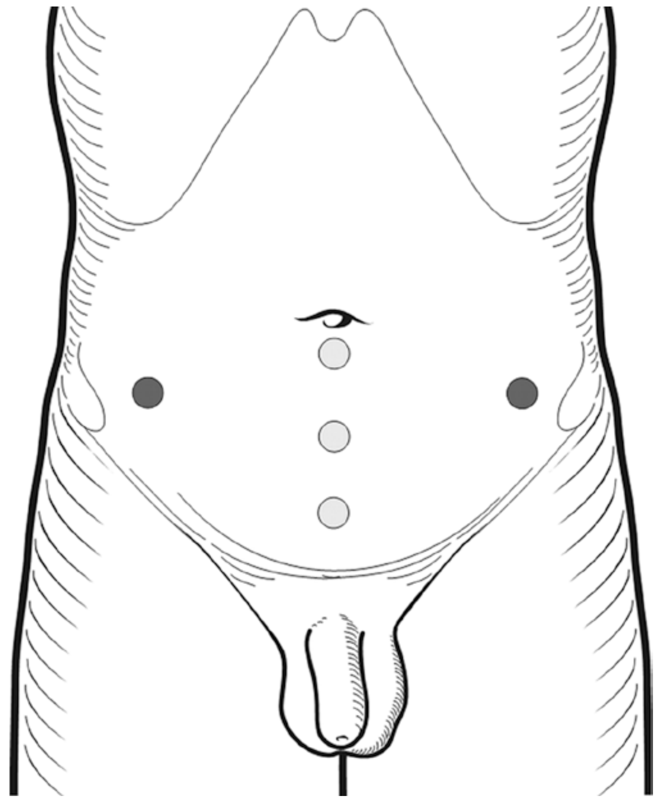

Fig. 15.2 Sites of trocar placements for totally extraperitoneal hernia repair. The mark on either side of the abdomen indicates the alternate location for the 5 mm trocars

unless a prolonged operation is anticipated. The patient should be placed on the operating table in the supine position with a 15° Trendelenburg tilt. Ideally both hands should be placed by the patient's side to allow the operator and the assistant to stand opposite each other at the patient's epigastric level. Care must be taken to correctly pad all pressure points. The operator stands on the side opposite of the hernia being repaired. When bilateral repairs are to be done, the operation can be started by standing on the side of the patient opposite the larger hernia defect. The video monitor should be placed at the foot of the table (Fig. 15.1). If two monitors are being used, one should be placed at either side of the lower end of the operating table.

Trocars and Trocar Position

One 10 mm cannula and two 5 mm cannulas are generally used for this operation. The 10 mm cannula should have a blunt-nosed trocar as it is inserted using an open technique. The 5 mm cannulas that are preferred are those with some method to prevent them from moving in and out of the extraperitoneal space as instruments are passed through. In addition, because of the confined operating space, the 5 mm cannulas should be short (60 mm). All the cannulas can be placed in the lower midline. In this instance, the 10 mm cannula is placed in a sub-umbilical position; one of the two 5 mm cannulas is placed one-third of the way between the symphysis pubis and the umbilicus and the other half way between the symphysis pubis and the umbilicus (Fig. 15.2).

Alternatively, many physicians prefer the two smaller trocars to be placed laterally near the anterior axillary line above the iliac crest on either side of the patient. These latter trocars will usually be positioned after the dissection is nearly completed through the larger midline trocar. This will frequently be accomplished with the use of the laparoscope itself.

Laparoscope

Some surgeons substitute the 0° laparoscope for a 30° laparoscope after developing the extraperitoneal space. We find that this is not necessary and that the operation can be completed satisfactorily with a 0° laparoscope. Currently either the 5 or 10 mm laparoscope can be used for the entire procedure. In particularly difficult cases, the 5 mm laparoscope is preferred as this can be placed in the lateral ports to visualize the anatomy from the contralateral aspect.

Developing the Extraperitoneal Space

A transverse incision of 1–1.5 cm, starting in the lower half of the umbilicus and extending laterally, is made. The tissues are then separated with scissors or hemostats and retracted with two retractors to expose the anterior rectus sheath on the side of the hernia to be repaired or more toward the larger hernia in the bilateral situation. The sheath is opened with a #11 blade scalpel through a small transverse incision. The midline and rectus muscle are identified, and the space between the rectus muscle and the posterior rectus sheath space is developed using hemostats and blunt dissection. A large right-angled retractor (to retract the rectus muscle anteriorly to allow the insertion of a blunt-nosed 10 mm trocar and cannula) is then inserted into this space and moved medially, laterally, and posteriorly to develop the preperitoneal space. Insufflation with CO_2 can commence with insufflation pressure being kept between 10 and 12 mmHg.

A 0° laparoscope is then inserted through the 10 mm cannula and can be gently used as a blunt dissector to further enlarge the space. It is important to feel the pubic symphysis and stay in the midline and immediately posterior to the rectus muscle with the laparoscope during this dissection. Once the appropriate space is visible, two 5 mm cannulas are inserted under direct vision in the positions previously described.

The preperitoneal space may also be developed using balloon dissection. A deflated balloon on the end of a cannula, of which many different types are available (Fig. 15.3), is placed in the preperitoneal space using the access described. The balloon is then filled with air and the space developed under direct vision using a 0° laparoscope. This method is helpful in the learning period when surgeons are still unfamiliar with the preperitoneal anatomy. While balloon dissection is slightly more rapid, it has the disadvantage of adding additional expense to the operation. In addition, it can be associated with bladder and bowel injury in patients who have had previous lower abdominal surgery [9]. In those patients that have had prior lower abdominal surgery or prostatectomy, it is preferred to either perform the entire operation without the use of a balloon dissector or performing a transabdominal preperitoneal operation. Some surgeons will occasionally merge the two techniques. In these cases, the surgeon will enter the abdomen above the umbilicus with a 5 mm port and inspect the lower abdominal contents. If there

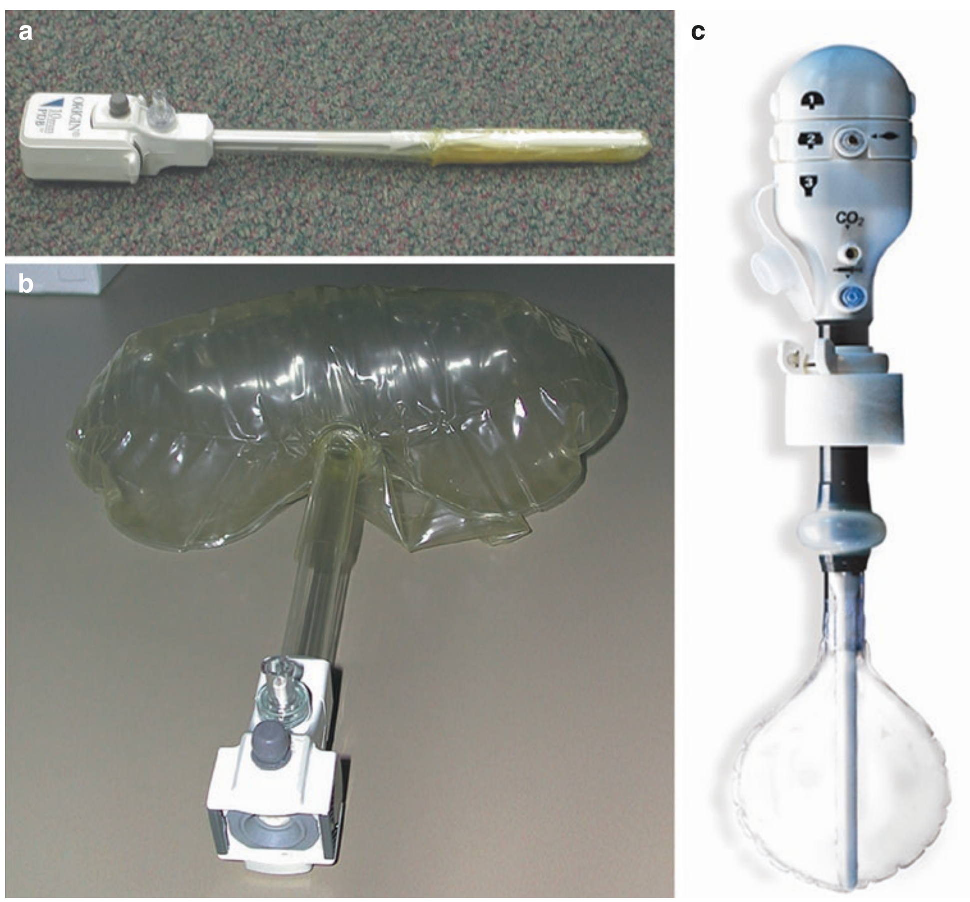

Fig. 15.3 (**a**) The deflated PBD2 balloon for dissection of the preperitoneal space. (**b**) The inflated PBD2 balloon for dissection of the preperitoneal space. (**c**) Spacemaker Plus Dissector System

are no adhesions, which occur frequently, the dissection can be converted to the totally extraperitoneal operation either with or without the use of the balloon dissection.

Dissection

Two atraumatic dissectors, which will grasp but not tear the peritoneum, are important for this part of the procedure. A sharp pair of scissors will sometimes be used but is seldom necessary. It is important to identify the anatomical landmarks in an orderly fashion. The pectineal (Cooper's) ligament on the same side as the hernia should be exposed first. At this stage, in thin patients, you may see the external iliac vein laterally, and accessory obturator vessels, if present, will be found crossing the pectineal ligament. Separation of the perivascular and extraperitoneal fat is performed in the avascular plane between both using gentle blunt dissection and is aided by the CO_2 insufflation. Characteristic filamentous tissue, which breaks down easily, will be observed between the two planes.

The retropubic space can now be developed in the midline and on the side of the hernia to above the level of the obturator nerve and vessels. The inferior epigastric vessels should next be identified and the space between them and the extraperitoneal fat developed. During this part of the dissection, it is important to keep the epigastric vessels up against the rectus muscle using one dissector, while the other is used to separate the tissues. If this is not done, the epigastric vessels will come down into the operating field, and small branches between them and the rectus muscles will be torn, giving rise to troublesome bleeding. Between the inferior epigastric vessels and extraperitoneal fat, a fascial layer is encountered. This represents the deep layer of the fascia transversalis (Fig. 15.4) and should be divided using a combination of blunt and sharp dissection to open up the space lateral to it. This may not always be necessary if the dissection allows the complete separation of these structures.

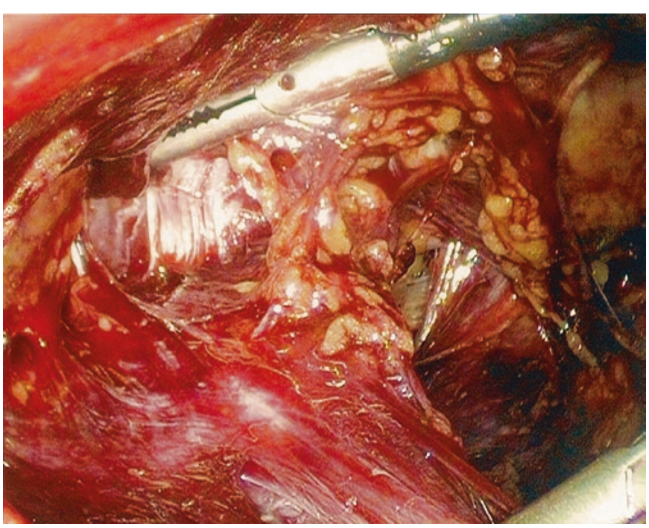

Fig. 15.4 Laparoscopic appearance of the deep layer of fascia transversalis

Much of this will be accomplished with the dissection balloon if this is the chosen technique. The choice of the use of the balloon or blunt dissection has been shown to be equally effective in creating the space necessary to perform this operation [10]. The attention to the epigastric vessels is limited when this is used because the unfurling of the balloon will sometimes pull these vessels down rather than leaving them in situ. This may limit the insufflation of the balloon whereupon the surgeon must complete the dissection manually. Also, for those surgeons that prefer the lateral location of the 5 mm trocars, some of the dissection will usually be necessary with the laparoscope and/or one of the dissection graspers that would be inserted through one of the lateral or midline trocars.

Indirect Inguinal Hernias in Males

At this stage, it should be possible to identify the sac of an indirect inguinal hernia (Fig. 15.5). The sac will be found immediately lateral to the inferior epigastric vessels as it enters the internal ring. The sac should be grasped at the internal ring and reduced by retracting and dissecting the adhesions between it and the inguinal canal. Tension needs to be kept on the sac during this part of the dissection by using both dissectors in a stepwise fashion; otherwise, as the sac is released to regrip it, it will return to the inguinal canal because of its elasticity and inguinal attachments. It is important to dissect all the tissues around the sac down to the peritoneum. These tissues represent attenuated transversalis fascia (see Chap. 2) which invests the cord and indirect sac as it enters the internal ring. Once this has been achieved, the sac can be lifted up, and the vas deferens will be visible at its posterior border and may be dissected off it along with

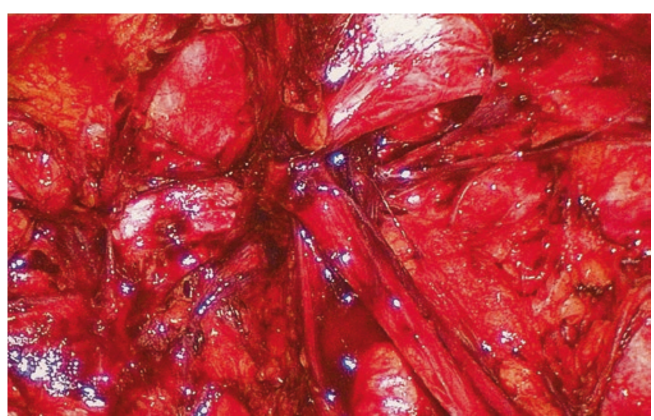

Fig. 15.5 Laparoscopic appearance of a right indirect hernia

the testicular vessels. The vas runs medially and crosses over the iliac vessels as it descends into the pelvis, while the testicular vessels take a course slightly lateral to the iliac vessels. In small to moderately sized indirect inguinal hernias, the apex of the sac can be identified and the sac completely reduced into the extraperitoneal space. If the sac is large and entering the scrotum, it may be wise to divide and ligate it at a convenient point as one would do with open hernia repair. This, of course, will be done with intracorporeal suturing. The testicular vessels and vas deferens should be completely skeletonized of any lipomatous material that may be in the inguinal canal. Not infrequently, a small hole may be made in the sac during its reduction. This should not impair the ability to complete the dissection, and such defects can usually be ignored. However, it should be noted that great care must be exercised to avoid a large tear of the peritoneal sac during these maneuvers. This will result in the insufflation of the intra-abdominal space, which will limit the available preperitoneal space and subsequent "working room" for the operation to continue. Additionally, this could expose the patch material to the intestinal contents of the abdomen with resulting adhesions. If a large tear occurs and cannot be closed with sutures, there are two options. One may convert to the transabdominal preperitoneal technique and use a tissue separating prosthesis as used in the incisional hernia repair or abandon the laparoscopic approach altogether.

Posteriorly the peritoneal dissection should be taken back until the vas can seen descending into the pelvis. Laterally it should go at least to the level of the anterior superior iliac spine, while medially dissection should cross the midline and go well below the pectineal ligament (Fig. 15.6). This is to ensure complete exposure of the myopectineal orifice and that there is adequate space for insertion of the mesh.

Lateral to the testicular vessels, the femoral branch of the genitofemoral nerve and the lateral cutaneous nerve of the thigh can be identified in patients with little adipose tissue (Fig. 15.7). Care should be taken not to damage these or a small branch of the deep circumflex iliac artery, which lies laterally to the cutaneous nerve of the thigh. These structures all lie beneath the iliopubic tract. Therefore, any fixation of the meshes must be placed above this line to assure that these nerves are not in harm's way. Also in thin patients, the external iliac vessels will be easily identified, the artery appearing between the testicular vessels and the vas and the vein lying medial to the artery. In all patients, the characteristic pulsation from the external iliac vessels will be observed in this position. Small peritoneal branches arising from the iliac artery may also be noted during the dissection, and as these are usually at the posterior limit of the dissection, they can be preserved. As all dissection is carried out in an avascular plane, there should be only a limited need to use electrocautery during the operation. Most dissection is performed by gentle separation of tissues using atraumatic dissecting forceps. If there is an injury to larger vessels such as the epigastric artery or vein, then the use of hemostatic clips or suture ligation will be necessary. If this fails, then one could place transfascial absorbable sutures to maintain hemostasis of these vessels.

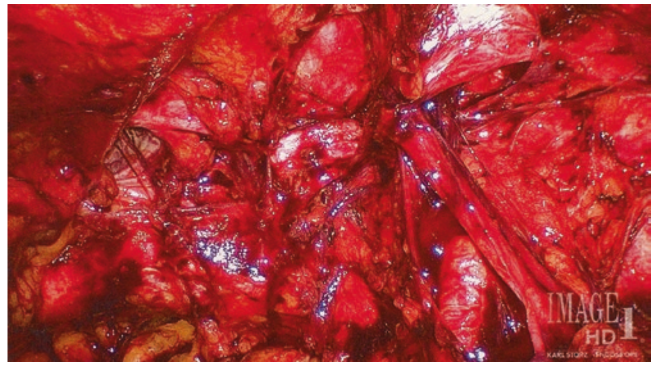

Fig. 15.6 Extent of dissection required with details of anatomy observed at laparoscopy. A left direct inguinal hernia is seen as is the right inguinal hernia from Fig. 15.5

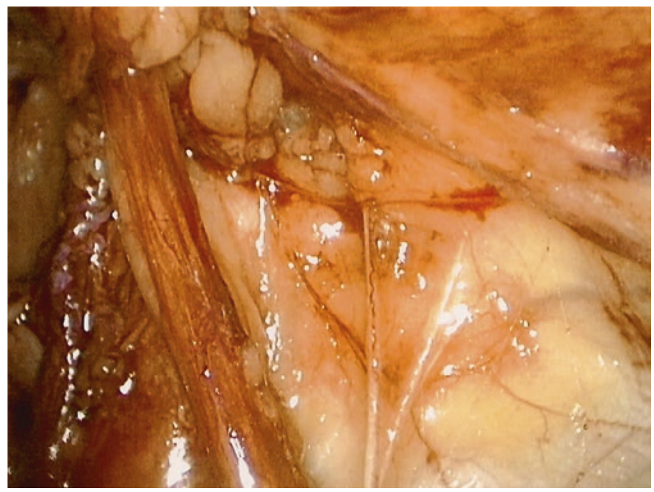

Fig. 15.7 Laparoscopic appearance of femoral branches of genitofemoral nerve and lateral cutaneous nerve of the thigh

Indirect Inguinal Hernias in Females

The approach to these hernias is similar to that of the indirect inguinal hernias in the male patient. Once the sac is reduced, the round ligament can be left in situ or divided and ligated at the internal ring depending on the surgeon's preference. Generally it is very difficult to avoid division of this structure due to the dense adherence of the peritoneum. Separation of the peritoneum and round ligament very often results in a tear in the peritoneum. Early division avoids this issue.

Direct Inguinal Hernias

A direct inguinal hernia will be encountered during the dissection to expose the pectineal ligament (Fig. 15.6). The defect lies laterally to the border of the rectus muscle and is medial to the inferior epigastric vessels except when a combined direct and indirect hernia is present. Sometimes a direct defect can appear to encroach on the femoral canal and in this circumstance may be confused with a femoral hernia. Patients with a direct hernia will also occasionally be found to have a femoral hernia. The direct hernia sac and preperitoneal fat are usually easy to reduce by grasping the sac with atraumatic forceps and simple pulling gently. While the hernia is being reduced, the characteristic appearance of a pseudosac, which is attenuated transversalis fascia, will be displayed. This should be allowed to retract into the defect. As with indirect hernias, the sac is reduced into the extraperitoneal space, and no attempt is made to open or ligate it. The vas deferens and testicular vessels need to be exposed to exclude a synchronous indirect hernia. The extent of the dissection should be identical to that of the indirect hernia repair. It is important to be careful during this part of the operation as the peritoneum is easily torn at the internal ring in patients with a direct hernia. It is generally best if the peritoneum is pushed with the laparoscopic forceps rather than pulled at this location so that this tear may be avoided.

Femoral Hernias

As the pectineal ligament is exposed as far lateral as the external iliac vein in all patients, a femoral hernia should not be missed during totally extraperitoneal hernia repair. This can be reduced in the same manner as for direct hernias. One should be attentive to the possibility of the inclusion of an organ such as the bladder or ovary into the hernia contents. When found, these structures should be carefully reduced to avoid injury. Once this has been done, dissection should proceed as for other groin hernias.

Recurrent Hernias

A reasonable amount of experience with totally extraperitoneal hernia repair is required before dealing with recurrent hernias following an open repair and even more if subsequent to a laparoscopic approach. This is because the anatomical landmarks are often distorted due to the previous surgical dissection and the associated mesh implantation. The inferior epigastric vessels may have been divided and thus be in part absent or visible as a much smaller vessel. Dense adhesions form between the neck of the recurrent sac and the previous repair, and because of this, it is wise to use careful sharp dissection to free it from these adhesions. Elsewhere the peritoneum is often very thin and easily torn, as stitches may have gone through it from the previous repair. Because of the frequent use of a prosthetic biomaterial in the prior repair, the occurrence of a tear in the peritoneum should be expected during the dissection.

Because of these reasons, it is probably best to use a transabdominal approach (TAPP) if mesh material resides in the preperitoneal space. This will allow the surgeon the ability to dissect the peritoneum under direct vision and allows the assurance that there are no adhesions from an intra-abdominal organ.

Bilateral Hernias

Bilateral hernias can be repaired using the same access as for unilateral hernias, and additional trocars are not required. Once dissection has been completed on one side, the operator simply switches to the other side and reduces the contralateral hernia. Although one large piece of mesh can be used for bilateral hernia repair, it is our preference to use two different meshes that are at least 10 cm by 15 cm in size. In this circumstance, it is helpful to fixate one to the pectineal ligament before the contralateral mesh is placed into position (if fixation is to be done at all). Larger hernias will require even larger meshes of 15 × 15 cm.

For all indirect hernias and most direct hernias, a heavyweight mesh generally does not need to be tacked, stapled, or sutured in place. If, however, a large direct defect encroaches upon the femoral canal or there is a femoral hernia, it may be advisable that the mesh be stapled or sutured to the pectineal ligament to prevent the inferior border of the mesh from slipping upward and into the defect. The mesh does not need to be divided to fit around the cord or, indeed, sutured or tacked around the cord.

An exception to the above statement has come about in the last several years. The lighter-weight macroporous meshes are very supple and soft, an advantage in their use. However, this characteristic makes fixation necessary so that the product does not protrude into the hernia defect. The type of device and method chosen for fixation will vary according to surgeon preference.

On desufflating the extraperitoneal space, it is important to ensure that the inferior fold of the mesh does not roll up with the peritoneum. If an adequate dissection has been carried out, this will be unlikely to occur. After desufflation, all cannulas are removed, and the rectus sheath at the subumbilical incision is closed with 2/0 or 0 Vicryl, while the skin is closed with interrupted absorbable subcuticular stitches and/or adhesive tapes.

Fixation of the Mesh

To secure the mesh, a fastener device is generally used; however, there is growing evidence that fixation is not necessary [11–13]. Two or three tacks are usually placed only in the pectineal ligament in the situations previously mentioned. Some surgeons secure the mesh to the rectus muscle medially and the transversus abdominis laterally. Fixation at this position provides no additional support for properly positioned mesh and can be avoided in all but the large inguinal or femoral hernia repairs. Alternatively the mesh can be sutured to the pectineal ligament with a hernia stapler or suture.

When placing these fixation devices, it is often easier to insert them into the pectineal ligament if the instrument is inserted via an ipsilateral trocar. The angle of the ligament is such that a firm grasp of the ligament is best afforded if this approach is used. This will prevent the slippage off of the ligament that is common as the instrument is fired. The contralateral trocar is used for placement of the additional fixators along the muscle above the iliopubic tract. This will vary depending upon the device selected.

Newer absorbable fasteners now are available and are becoming increasingly popular. In general, they last approximately 1 year and they are completely absorbed. There are obvious benefits to this concept, but there are no long-term studies to prove their efficacy. However, given the ingrowth of the respective mesh products, there is little reason to be concerned (see Chap. 7).

Recent randomized prospective studies have shown that it may be efficacious to use a biocompatible fibrin sealant to secure the mesh rather than metal tacking devices [14–17]. This has the obvious advantage that the risk of injury to vascular or neural structures during the repair is virtually eliminated. The subsequent reduction in postoperative neuralgia is thought to lead to quicker return to normal daily and work-related activity. Meta-analysis and systematic reviews have shown that there are no differences in hernia recurrence, operative times, or seroma formation when comparing these two fixation options. Thus, with similar repair results and less chronic pain, fibrin sealant appears to be a good option for fixation [12, 13]. Ongoing controlled studies in such products are warranted and forthcoming and will continue to influence the field of herniology in the future.

Self-gripping mesh has also emerged as a viable option for hernia repairs. The inherent value in using this mesh is to prevent the need for any additional fixation with tacks. ProGrip mesh is a monofilament polypropylene or polyester material woven with an absorbable polylactic acid (PLA) microfiber that acts as microgrips (see Chap. 7). This mesh is well studied and does fixate very quickly and has comparable recurrence rates with less chronic pain [18–20].

Conversion to Open Repair

It is necessary of cases to convert to open preperitoneal repair in approximately 1% or less [21]. This usually occurs as a result of a large tear in the peritoneum or when a very large (estimated defect of 5 cm or greater) direct hernia is encountered. In the latter circumstance, a 15 × 15 cm piece of mesh is required and may be more easily placed at open surgery by some surgeons. If the hernia is unilateral, a small transverse incision is placed over the ipsilateral rectus muscle at the level of the lower 5 mm cannula and the preperitoneal space entered lateral to the rectus muscle. If there are bilateral hernias, a Pfannenstiel incision can be made at the same level to gain access to the preperitoneal space.

In the majority of instances when the prospect of conversion becomes a reality, one may convert instead to the transabdominal preperitoneal repair. With this approach, the entire abdominal cavity will allow a much larger working space and usually obviates the need for conversion to the open approach. The larger piece of mesh can be inserted and placed. The remainder of the procedure will proceed as the traditional TAPP repair.

Contraindications to Totally Extraperitoneal Hernia Repair

Although there are no absolute contraindications to totally extraperitoneal hernia repair in the elective setting, large inguinoscrotal or irreducible hernias are relative contraindications. Previous lower midline or ipsilateral paramedian incisions also come into this category. Extraperitoneal endoscopic repair is difficult and time-consuming in these circumstances such that it is difficult to justify attempting it in the first place. In these instances, one may elect to attempt a TAPP repair or convert to the open operation if it is obvious that a TAPP is not feasible. If there is a concern in regard to the possibility of adhesions that may make the extraperitoneal approach risky, a small laparoscope is inserted into the abdominal cavity, and the areas of suspicion are visually inspected. This is done through an infraumbilical skin incision with the abdominal entry moved to above the potential site for fascial incision for placement of the 10 mm trocar. If there are no adhesions in the area or none that involve the bowel, the 5 mm port can be removed after the abdomen is evacuated of the carbon dioxide. The larger 10 mm port is then inserted via the infraumbilical incision whereupon the extraperitoneal procedure will be performed with assurance that there is no more than the expected risk of injury to the bowel during the creation of this space. Another obvious option would be to avoid the TEP and initiate the procedure as a TAPP.

Transabdominal Hernia Repair

This technique differs from the totally extraperitoneal approach in that the preperitoneal space is entered through a transverse peritoneal incision made above the hernia defect. The abdomen is entered using either closed or open laparoscopy, and two additional cannulas are placed lateral to either rectus muscle at the level of the umbilicus. These can be two 5 mm cannulas or a 5 and 12 mm cannula depending on the requirements of the mesh or fixation method selected. The peritoneal incision should extend from the medial umbilical ligament medially to the level of the anterior superior iliac spine laterally. If the patient has a direct hernia, it may be wise to divide the medial umbilical ligament, which carries the obliterated umbilical artery (see Chap. 2) to ensure adequate exposure of the pectineal ligament and retropubic space beyond the midline.

Once the preperitoneal space has been entered, dissection is virtually identical to the TEP repair. One of the important aspects of transabdominal hernia repair is adequate closure of the peritoneum after the repair. Suturing or stapling the peritoneum can accomplish this closure effectively. Care must be used if the peritoneum is closed with the helical tacks or the newer absorbable fasteners. These devices are of such a size that it can be difficult to effect an adequate closure of the peritoneum especially if there is a paucity of preperitoneal fat. A defect left between tacks, staples, and sutures forms a potential source for internal herniation of the small bowel. Any port site larger than 5 mm should be closed to prevent the development of port-site hernias.

As with the totally extraperitoneal approach, there are no absolute contraindications to this repair; indeed as noted earlier, it can sometimes be easier to perform for patients with large inguinoscrotal hernias or with extensive lower abdominal adhesions. With the advent and popularity of the robotic approach (discussed elsewhere), this technique is increasing in its frequency of use.

Chronic Pain After Laparoscopic Hernia Repair

Acute pain after any hernia repair is to be expected and can be well controlled with a short course of narcotic pain medications. In many cases, avoidance of narcotics can be accomplished with the use of nonsteroidal medications. One of the most frequent sources of morbidity after inguinal hernia repair is persistent pain and thus should be mitigated against as much as possible. It is generally accepted that both the TEP and TAPP approach can offer superior postoperative pain score results compared to the open approach. However, this has not been shown in all studies [22].

The TAPP approach has been shown to have higher postoperative pain scores and narcotic use compared to TEP [23]. They are both well-studied options for hernia repair with little difference in recurrence rates. The TEP approach, of course, does not require approximating the peritoneum back together, which is often done with tacks in the TAPP approach. Thus, it appears that the use of fixation is the most common cause of chronic pain in laparoscopic hernia repairs. Efforts to decrease postoperative pain in these procedures include limitation of the number of fixation devices or elimination of their use altogether. As discussed earlier, this can be achieved with a tissue glue, fibrin sealant, self-gripping mesh, or simply no fixation of the mesh. The senior author routinely avoids the use of any fixation devices to the mesh. A generous dissection that allows the mesh to be seated without movement when closing the peritoneum is required. Mesh selection is critical in this option. The reader is referred to Chap. 7 for a complete discussion of the mesh options available.

Other risk factors for chronic postoperative pain besides fixation have been described. These include younger age, female gender, direct hernias, Lichtenstein or plug repair, and bilateral repairs [24]. Some argue that a heavyweight mesh increases postoperative pain; however, studies to date indicate that there is no statistical difference [22].

Results

There have been many studies that have examined the efficacy of laparoscopic inguinal hernia repair compared to the various open methods that are available today. A few of these are listed in Table 15.1. In several of these papers, the methodology of data collection and the patient selection make firm and accurate comparisons difficult between the series. In fact, in many cases, the data cannot be compared directly. Nevertheless, as shown in these series, it appears that the rate of complications in the laparoscopic patients does not exceed that of the open patients. Additionally, the rate of recurrence is not statistically different between the various methods. What is not shown in this table is the fact that the laparoscopic repair nearly always requires a general anesthetic and the hospital costs can be more expensive. Most of these series are consistent in finding that laparoscopic patients return to normal activities and work sooner. This saving in costs to the community makes the overall costs of the laparoscopic operation less than the open operation. However, there are a few centers that forgo the balloon dissection trocars and disposable instruments. This, along with the considerable experience of these surgeons, has dropped the hospital costs to levels comparable to that of the open method.

Table 15.1 Randomized trials of inguinal herniorrhaphy

Author and year	Method	Median follow-up (years)	Number of hernias	Rate of complications (%)	Rate of recurrence (%)
Payne et al. (1994) [25]	TAPP	N/A	48	12.0	N/A
	Lichtenstein		52	18.0	N/A
Stoker et al. (1994) [26]	TAPP	0.6	75		0
	Lichtenstein		75		0
Maddern et al. (1994) [27]	TAPP	N/A	44	40.0	N/A
	Double Darn		42	47.0	N/A
Barkun et al. (1995) [28]	TAPP	1.2	43	22.0	2.0
	Darn/Lichtenstein		49	12.0	0
Leibl et al. (1995) [6]	TAPP	1.3	54	N/A	0
	Shouldice		48	N/A	0
Lawrence et al. (1995) [29]	TAPP	N/A	58	12.0	N/A
	Darn		66	2.0	N/A
Vogt et al. (1995) [30]	IPOM	0.7	30		0
	Multiple types		31		0
Schrenk et al. (1996) [31]	TAPP	N/A	28		5.0
	TEP		24		16.7
	Shouldice		34		2.9
Liem et al. (1997) [32]	TEP	2.0	493		3.0
	Open		509		6.0
Johansson et al. (1997) [33]	TEP	1.7	179		1.0
	Open mesh		168		3.0
	Anterior repair		177		0
Champault et al. (1997) [34]	TEP	3.0	51	4.0	6.0
	Stoppa		49	29.5	2.0
Beets et al. (1998) [35]	TAPP	1.8	42	67.0	12.5
	GPRVS		37	62.0	1.9
Wellwood et al. (1998) [36]	TAPP	N/A	200		N/A
	Tension-free		200		N/A
Cohen et al. (1998) [37]	TAPP	N/A	78		1.9
	TEP		67		0
Khoury et al. (1998) [38]	TEP	3.0	150		2.5
	Plug and patch		142		3.0
Johansson et al. (1999) [39]	TAPP	1.0	604		No statistical significance
	Open preperitoneal mesh				
	Tissue repair				
MRC Laparoscopic Hernia Trial Group (1999) [40]	Laparoscopic	1.0	468	29.9	1.9
	Open		433	43.5	0
Lorenz et al. (2000) [41]	TAPP	2.0	86	11.0	2.3
	Shouldice		90	9.0	1.1
Sarli et al. (2001) [42]	TAPP		20	34.7	0
	Tension-free		23	35.0	4.3
Wright et al. (2002) [43]	TEP	5.0	149	N/A	2.0
	Tension-free		107		0
	Stoppa		32		9.4
	Sutured		12		0
Bringman et al. (2003) [44]	TEP	2.0	92	9.8	2.2
	Plug and patch		104	15.4	1.9
	Lichtenstein		103	20.4	0

(continued)

Table 15.1 (continued)

Author and year	Method	Median follow-up (years)	Number of hernias	Rate of complications (%)	Rate of recurrence (%)
Liem et al. (2003) [45]	TEP	3.7	487	4.9	4.3
	Open		507	13.6	8.5
Andersson et al. (2003) [46]	TEP	1.0	80	N/A	2.5
	Lichtenstein		86		0
Lal et al. (2003) [47]	TEP	1.1	25	N/A	0
	Lichtenstein		25		0
Neumayer et al. (2004) [48]	TAPP/TEP	2.0	989	39.0	10.1
	Lichtenstein		994	33.4	4.9
Eklund et al. (2007) [49]	TAPP	5.1	73	13.6	19.0
	Lichtenstein		74	19.0	18.0
Hallen et al. (2008) [50]	TEP	7.3	73	26.0	4.1
	Lichtenstein		81	33.3	4.9
Pokorny et al. (2008) [51]	Laparoscopic	3.0	129	10.9	5.0
	Open		236	14.6	2.8
Eklund et al. (2009) [52]	TEP	5.1	665	N/A	2.4
	Lichtenstein		705		1.2
Kouhia et al. (2009) [53]	TEP	5.3	49	8.2	0
Wauschkuhn (2010) [54]	Lichtenstein		47	27.7	6.4
	TAPP	5	2880	0.52	0.42
Froylich (2017) [55]	Open	0.08	7645	N/A	N/A
	TEP/TAPP				

GPRVS giant prosthetic reinforcement of the visceral sac (open)
IPOM intraperitoneal onlay mesh repair (laparoscopic)
TAPP transabdominal preperitoneal repair (laparoscopic)
TEP totally extraperitoneal repair (laparoscopic)

While the majority of information in the literature reveals that the laparoscopic repair is associated with less pain, Picchio found that the tension-free open hernia repair is superior to the TAPP in terms of postoperative pain with no important differences in recovery [56]. This finding is in the minority, however, as most studies consistently show that the pain is less with the minimally invasive approach particularly if an objective analysis such as measured treadmill walking is used as a measure of return to physical work comparing open hernia repair to laparoscopic repair. Rosen found that the laparoscopic repair offered an early advantage to the open repair by this measure [57]. This study reaffirms the clinical setting regarding the laparoscopic repair. Other reports have found similar findings regarding the lessening of postoperative pain with this repair [40, 41, 44–47, 49, 53].

There are some areas that prefer that the laparoscopic repair be limited to bilateral and recurrent inguinal hernias (although the number of such areas is waning). The results for this indication are excellent. A few studies reported no recurrences with the laparoscopic approach as compared to the open approach [42, 53]. Another study found that the incidence of recurrence after bilateral repair was 0.6% [58]. Wauschkuhn performed 2880 bilateral TAPP hernia repairs and states that the laparoscopic approach for bilateral hernias should be the gold standard approach. This study had great results at the 5-year follow-up mark [54]. Felix recommends this repair for recurrent hernias following laparoscopic repair [7]. However, Eklund reports no long-term differences in repair of recurrent hernias with the laparoscopic or open approach [49]. Nevertheless, the results for primary repair are impressive. Kapris reported a 0.62% recurrence rate over a 7-year period. Past the learning curve, the recurrence rate was 0.16% after 45 months. The total complication rate exclusive of recurrence was 3.68% (2% were due to urinary retention) [21].

When there is no proven superiority of one surgical method over another, the cost-effectiveness of the operations is an important consideration. It is frequently stated that due to longer operative times and more expensive equipment, the laparoscopic method is more expensive than an open approach for the index operation. Many patients who undergo an open repair are able to do so under local or regional blocks, whereas most laparoscopic procedures are done under general anesthesia which increases the cost also. Most studies do not include postoperative visits, sick leave, and community costs into the total expense of an operation.

Eklund reported upon the total hospital cost of the index operation, costs associated with recurrences and complications, and community costs associated with sick leave. He found that the index operation was significantly more expensive for the TEP repair vs. open (Lichtenstein) and that the TEP repair was associated with more complications and recurrence. This led to increased cost as well. However, the TEP patients returned to work 3 days earlier than the open repair patients, which reduced the cost difference [59]. Hynes et al. reported the cost-effectiveness of all laparoscopic vs. open inguinal hernia repairs. They reported the day of surgery costs for laparoscopic vs. open was significantly more (US$1589 vs. US$773). They then followed these patients up to 2 years, and the total healthcare use was not significantly different (US$9564 vs. US$8926) per patient. In subgroup analyses, the laparoscopic approach was found to be cost-effective for unilateral primary and recurrent hernias. On cost-effectiveness alone, the authors found that the open repair was superior for bilateral inguinal hernias. This could be attributed to greater healthcare cost for reasons other than their hernia repair over than 2-year follow-up [60]. Beets et al. found that the costs associated with the giant prosthetic reinforcement of the visceral sac (GPRVS) repair were similar to that of the laparoscopic TAPP repair (US$1150 vs. US$1179). In Beets' report, the TAPP patients returned to work 10 days sooner than those with the GPRVS [35]. As shown in Table 15.1, however, there were approximately six times as many recurrences with the laparoscopic procedure, but these operations were performed with relatively inexperienced surgeons. Many patients who undergo hernia repairs are still an integral part of the workforce, and it is important to consider the cost of an operation to the community as well.

A summary of all of these comments can be found in the follow-up report by Fingerhut at a European consensus conference [61]. This conference convened in 1994 and again in 2000. At that time, there were more than 60 clinical trials and more than 12,500 patients entered into them. The members of this conference concluded that laparoscopic inguinal repair was associated with less postoperative pain and more rapid return to normal activities but took longer to perform, was more costly, and might increase the risk of rare complications. A meta-analysis of all randomized trials by the EU Hernia Trialists Collaboration Group found, in addition to the above, that laparoscopic patients had less chronic pain and numbness, while hernia recurrence was similar to that observed with open mesh repair.

The choice between the TAPP and the TEP is merely a matter of personal preference, however. There is no clinical difference between the conversions to open, the complications seen, or the recurrence rates between these two operations in experienced hands [62]. The only difference noted in this study was that the TAPP took 32 min longer to complete than did the TEP. This was due to the need to close the peritoneal flap. This would indicate, then, that the TEP may be the more expeditious and less costly procedure based upon the operating room expenses. The MRC trial group did not find any clinical difference between the use of the TAPP and the TEP operation [40]. McCormack et al. looked at all published reports on TAPP versus TEP. They found only one randomized controlled trial and nine additional nonrandomized, observational studies comparing the TAPP operation to the TEP operation. The one randomized trial found no difference in terms of length of stay, recurrence, hematomas, length of the operation, and return to normal activities between the two operations. The nonrandomized studies reported an increased number of port-site hernias and visceral injuries in the TAPP operation [63]. Recent publications show that there is no difference in outcomes with either technique if the surgeon is skilled in that method [64–66].

Disadvantages of Laparoscopic Hernia Repair

One of the drawbacks of laparoscopic surgery has been the steep learning curve associated with its use. This was particularly evident in the early stages of development of the operative procedure. In large part, the surgeons that were attempting to perform this operative procedure had limited experience with the laparoscopic methodology and the laparoscopic anatomy or an adequate understanding of the need to cover the entire myopectineal orifice. As with other forms of hernia repair, recurrence rates and complications were notably higher in this learning period. Such recurrences are often not true recurrences but failure to repair the hernia in the first instance; for example, an indirect sac may be missed or inadequately reduced, and mesh size may be too small or incorrectly placed. If any of these circumstances arise, a persistent hernia will usually be apparent within days or weeks of the attempted repair. In a study by Liem et al., evaluating the learning curve for four laparoscopic surgeons inexperienced in totally extraperitoneal repair, the actuarial recurrence rate was 10% at 6 months postoperatively [67]. Over 50% of recurrences were due to overlooking or insufficiently reducing an indirect hernia sac. However, with laparoscopy now being routinely taught during training and laparoscopic inguinal hernia gaining wide acceptance, one would presume continued improvement in minimally invasive hernia repairs. It appears that the adoption of the robot technology into inguinal hernia repair has decreased this learning curve and has resulted in an increased adoption of the laparoscopic method of repair.

We estimate that it may take as many as 100 laparoscopic hernia repairs before an inexperienced laparoscopic surgeon can bring the operating time for laparoscopic hernia repair into a range similar to that for open hernia repair. On the other hand, the surgeon that is experienced with other advanced laparoscopic operations will take approximately 30–50 cases to build an adequate experience and a decreased operative time [68]. Since operating time is expensive, this has significant cost implications. Added to this, laparoscopic hernia repair can be more costly than open repair, principally because of the use of disposable instruments. These costs, however, can be brought into a range similar to that of open repair by using reusable rather than disposable instruments and by suturing rather than stapling or tacking when indicated.

The relative difficulty in performing laparoscopic hernia repair using local anesthesia is often cited as a drawback of this operation. This only applies, however, when safe general anesthesia is not available at an institution. Despite its many proponents, there is no evidence that the use of local anesthetic is safer than general anesthesia for hernia repair. Edelman, however, has reported satisfactory results using local anesthesia with a laryngeal mask for the TEP as compared to the open repair of inguinal hernias [69].

Conclusions

Laparoscopic hernia repair is technically more demanding than open anterior approaches. There is no place for poor knowledge of the preperitoneal anatomy by surgeons attempting this method. These techniques have demonstrable advantages in terms of reduced postoperative pain, lower wound morbidity, a more rapid return to normal activity, and less chronic pain and numbness than open repair. The benefits that are realized to the individual patients can be expanded into the societal advantages because these patients are returned to the work force more rapidly. These advantages need to be balanced against increased costs and a high recurrence rate in the learning curve period. Results from large randomized clinical trials evaluating laparoscopic hernia repair have shown it to be an effective method for the repair of the inguinal hernias.

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16 Robotic Transabdominal Preperitoneal Inguinal Hernia Repair

Stephanie Bollenbach, Filip E. Muysoms, and Conrad D. Ballecer

Introduction

Despite the well-established benefits in minimally invasive (MIS) inguinal hernia repairs, it is only offered by a minority of surgeons in the United States with adoption rates ranging between 14 and 19% [1, 2]. Many attribute low penetration rates to the difficulty of comprehending the anatomy of the retroinguinal space. This approach not only requires a thorough understanding of the anatomy, of the myopectineal orifice (MPO), but also requires the operative skill set to safely navigate within this space.

There has been a rapid adoption of robotic inguinal hernia repair in the armamentarium of general surgeons across the United States (Fig. 16.1). Surgeons boast the enabling quality of the robotic instrument in terms of visualization, tremorless precision, instrumentation articulation, and improved ergonomics [3]. We contend no distinction between conventional laparoscopic and robotic approaches all converging with a singular goal of a durable repair conferring low recurrence rates and a low incidence of postoperative chronic pain.

This chapter will introduce the concept of the critical view of the myopectineal orifice. Daes et al. recently published the importance of the critical view MPO in hopes of standardizing a technique inherent with surgeon variability [4, 5]. Common questions including but not limited to extent of preperitoneal dissection, rules of fixation, and minimum mesh size are addressed by this mandate and cover all approaches including laparoscopic TEP/TAPP or rTAPP. We conclude that mesh should not be placed prior to confirming the critical view of the MPO has been established.

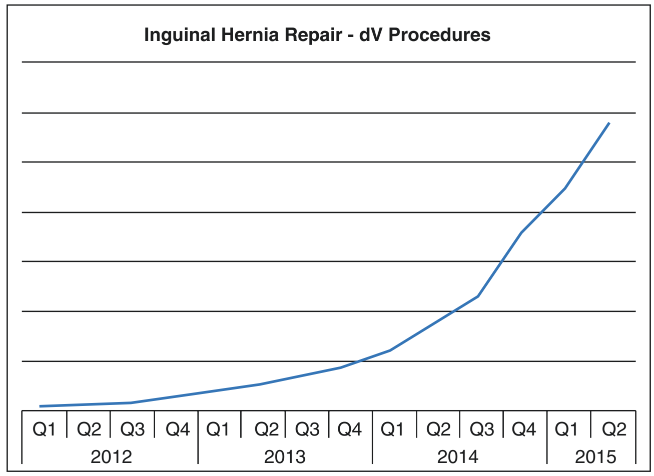

Fig. 16.1 Adoption of robotic inguinal hernia repair (courtesy of intuitive surgical)

This chapter utilizes the well-established principles of conventional laparoscopy to describe the robotic transabdominal preperitoneal (rTAPP) inguinal hernia repair technique.

Preoperative Conditions

Intolerance to general anesthesia represents the only true contraindication for rTAPP inguinal hernia repair. A history of multiple intra-abdominal surgeries, history of prostatectomy, previously failed MIS inguinal repair, large inguinoscrotal hernias, and coagulopathy are all important considerations that must be taken into account [6].

Imaging is generally not performed for primary inguinal hernias. Imaging is performed in the setting of incarcerated or strangulated inguino-femoral hernias, multiple recurrent hernias, concomitant ventral hernias, and large inguinoscrotal hernias in order to establish an effective operative strategy.

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Patient Positioning, Trocar Setup, Docking, and Instrumentation

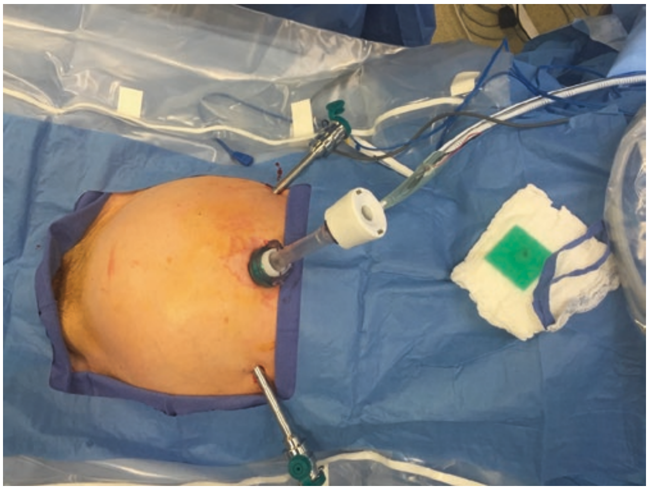

Fig. 16.2 Port position

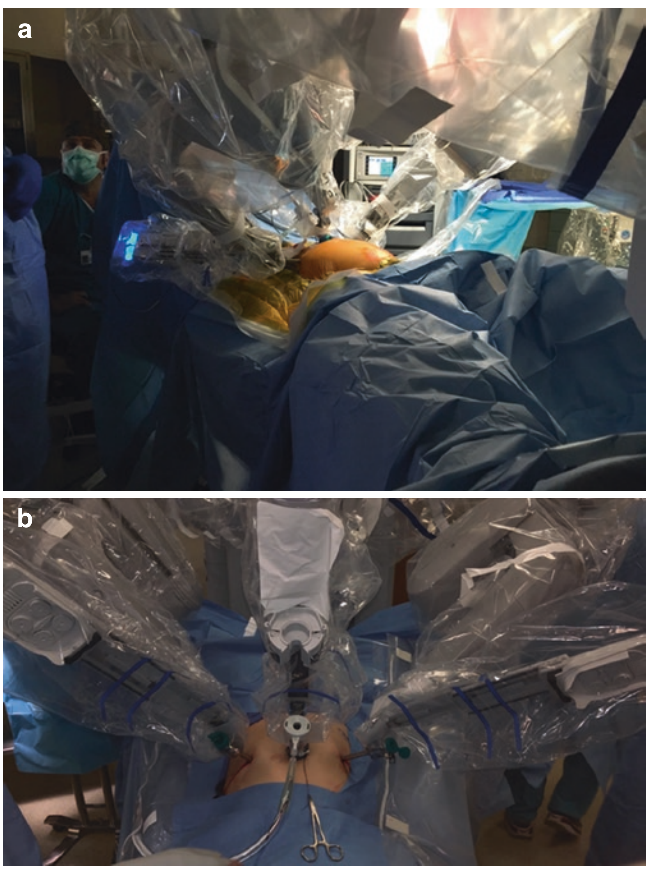

Fig. 16.3 (**a**, **b**) Docking in a supine lithotomy position

The patient can be placed in either a conventional supine or lithotomy position. Port placement and trocar setup are analogous to that of traditional laparoscopic repair (Fig. 16.2). We prefer an open supraumbilical entry with a 12 mm trocar, although an 8.5 mm da Vinci (dV) trocar for the 8 mm camera may also be utilized. Either 5 mm or 8 mm instrument trocars are then placed 10 cm lateral to the camera port. Users of the da Vinci Xi system (Intuitive Surgical) utilize an 8 mm camera and do not require 10 cm separation in between port sites. Patient positioning (Trendelenburg) must be complete prior to docking the robot.

While there are many ways to dock the robot (which also will vary depending on the type of system used), we prefer docking in between the legs with the patient in a supine lithotomy position (Fig. 16.3a, b). In the setting of bilateral hernias, adequate access to both right and left groins may be obtained by docking over either hip. After the robot is docked, the instruments are placed under direct vision. Although the choice of scope is at the surgeon's discretion, we prefer the 12 mm zero degree scope.

For most cases, we utilize two instruments including the dV prograsp and dV monopolar scissors (Fig. 16.4). A suture-cut needle driver can also be utilized for blunt preperitoneal dissection, sac reduction, and suture mesh fixation and re-approximation of the peritoneal defect. A dV Maryland bipolar grasper may be favored to facilitate reduction of hernia sac in those with large inguinoscrotal hernias.

Technical Steps

Reduction of the Hernia Content

As with any hernia repair, after gaining safe intraperitoneal access, the first step involves reduction of the hernia content. Bowel contents incarcerated through an inguino-femoral hernia must be handled safely and meticulously (Fig. 16.5). Should aggressive bowel handling be necessary, lower grip strength graspers are preferred.

Following successful reduction of any incarcerated hernia, the bowel contents must be examined for viability. We frequently utilize Firefly™ technology as an adjunctive measure to assess perfusion of the intestinal segment (Fig. 16.6a, b). This technique is similar to the use of fluorescein and a Wood's lamp to evaluate bowel viability. Five milliliters of indocyanine green (IcG) is administered intravenously, and within 1 min of infusion, intestinal perfusion can be assessed. If the bowel demonstrates a green tone under Firefly view, it is confirmed to be viable.

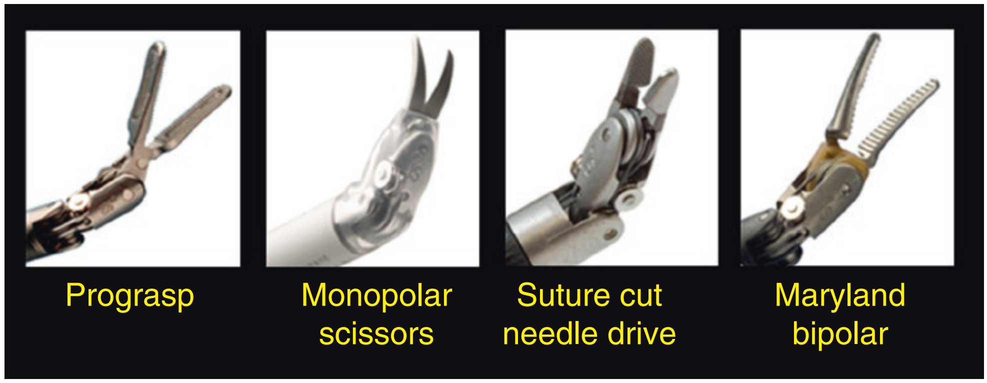

Fig. 16.4 dV instrumentation

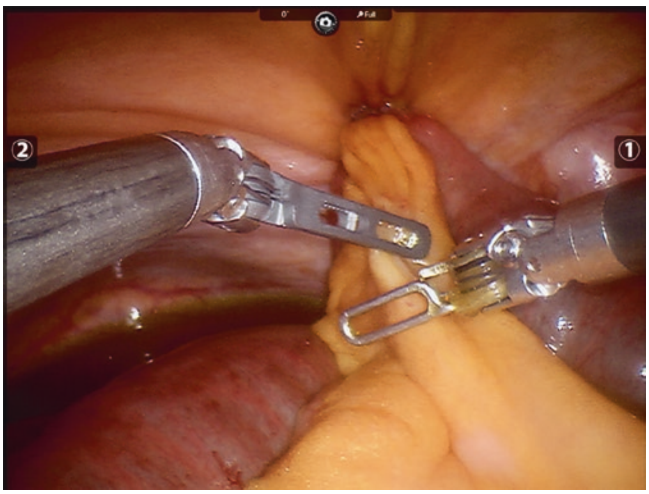

Fig. 16.5 Incarcerated femoral hernia

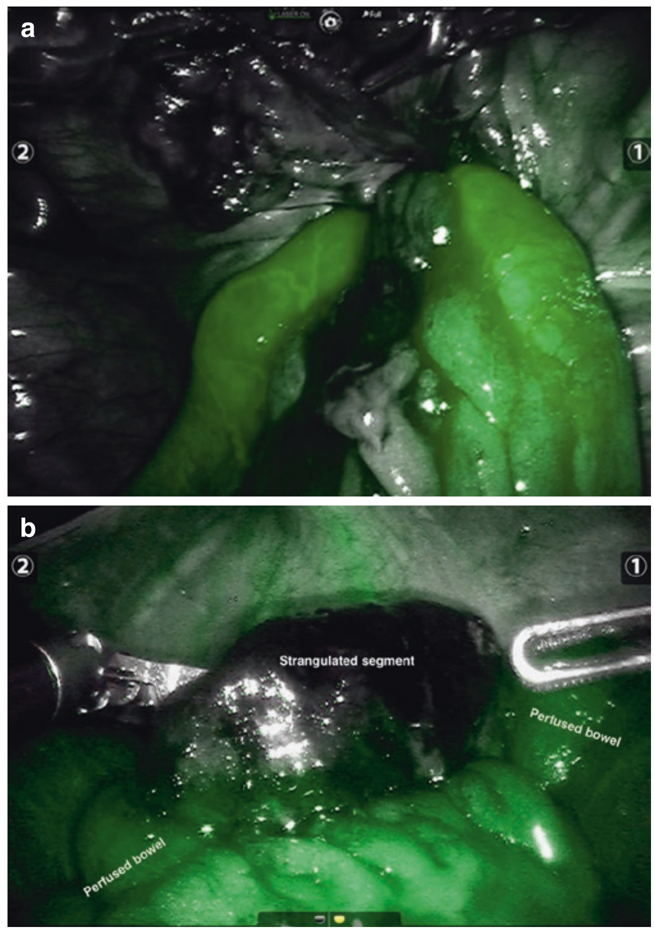

Fig. 16.6 (**a**, **b**) Firefly assessment of bowel viability

Evaluation of the Surface Anatomy

Following the successful reduction of the hernia content, key anatomical landmarks are identified (Fig. 16.7a, b). This will delineate the type of hernia present, as well as provide a guide to peritoneal incision and subsequent dissection.

Peritoneal Incision and True Preperitoneal Dissection

A transverse incision is made at a minimum of 5 cm over the level of the hernia defect, above ASIS, and extending medially to the level of the median umbilical ligament. This permits sufficient cephalad overlap of the mesh, as well as development of a redundant peritoneal flap to facilitate mesh re-peritonealization. While it is not uncommon to include the transversalis fascia in the initial peritoneal flap dissection, it is important to maintain dissection in the true preperitoneal space (Fig. 16.8). True preperitoneal dissection orients the operator within the correct avascular plane for hernia sac reduction and final flap development. Utilization of this space allows avoidance of perforating vessels to the overlying rectus muscle (pretransversalis plane), thereby minimizing unnecessary bleeding which can obscure effective dissection.

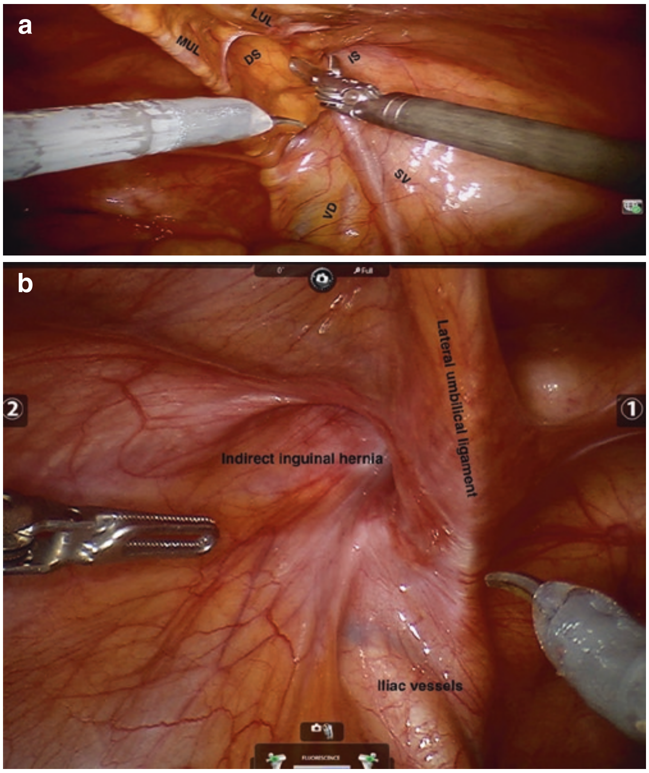

Fig. 16.7 (**a**) Surface anatomy. (**b**) View of left inguinal hernia. *MUL* medial umbilical ligament, *LUL* lateral umbilical ligament, *VD* vas deferens, *SV* spermatic vessels, *DS* direct space, *IS* indirect space

Fig. 16.8 Preperitoneal dissection

Hernia Sac Reduction

To ensure proper plane dissection during reduction of the hernia sac, all attempts should be made to "follow the peritoneum." Direct hernia sacs found medial to the epigastric vessels and above the iliopubic tract are often easily reducible. The peritoneal sac is dissected free from the transversalis fascia (pseudosac) (Fig. 16.9). With indirect hernia sacs, dissection is performed both medially and laterally to isolate the sac and associated cord structures or female equivalents (FEs). The peritoneum is parietalized from the cord structures or the FEs. Electrocautery must be judiciously used to minimize bleeding while also minimizing potential injury to the somatic and autonomic nerves intimately associated with the cord. The peritoneum is bluntly dissected off the vas deferens and spermatic vessels. The round ligament is typically divided in females to facilitate posterior peritoneal dissection.

Cord lipomas represent retroperitoneal fat that transit the deep inguinal ring and are positioned lateral to the cord structures (Fig. 16.10). Lipomas must be distinguished from the normal fat associated with cord vessels. Skeletonizing these elements may lead to unnecessary bleeding. Lipomas can be found in all potential sites of herniation including the femoral and obturator spaces. These lipomas are reduced for two reasons: to minimize the risk of postoperative bulging and to clear the MPO for flat approximation of mesh against the retroinguinal space.

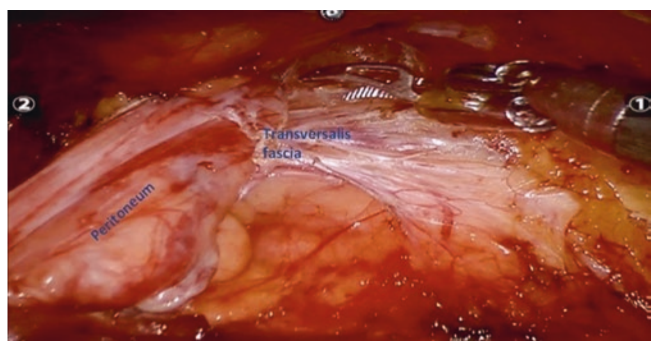

Fig. 16.9 Hernia sac reduction

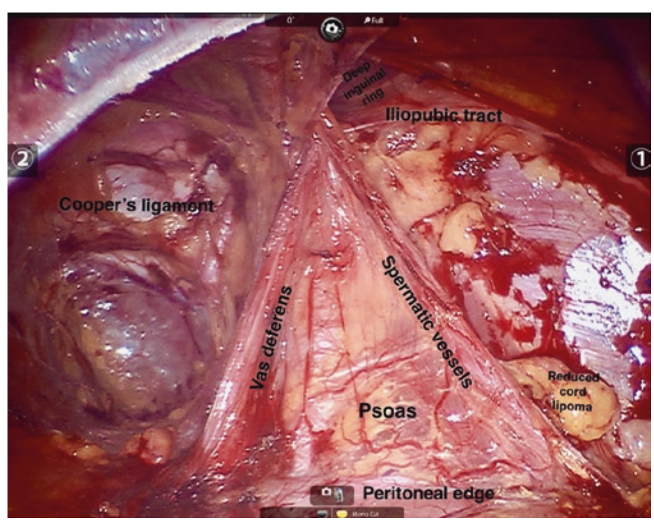

Fig. 16.10 Cord lipoma

Critical View of the Myopectineal Orifice

Similar to the rule in laparoscopic cholecystectomy where the critical view must be obtained prior to placing any clips, the authors believe that the critical view of the myopectineal orifice must be established prior to placing the mesh. Essential elements of the critical view include exposing all four potential sites of herniation (indirect and direct space, femoral and obturator foramina), adequate posterior peritoneal dissection exposing the peritoneal edge overlying the psoas muscle, and adequate lateral dissection that is confluent with the wide retroinguinal dissection plane. Conceptually, dissection of the retroinguinal space is divided into three zones: medial dissection, psoas dissection, and lateral dissection.

Zone of Medial Dissection

Exposure of the direct space, the femoral canal, and the obturator foramina should be exposed by dissecting medial to the inferior epigastric vessels (Fig. 16.11a–c). Cooper's ligament should be exposed with dissection extending across the midline, revealing the pubic symphysis. Just below the pubis, the bladder is bluntly dissected away from the bone, exposing the space of Retzius. Dissection should continue below the pubic bone exposing the obturator foramen and into the space of Retzius thereby creating a deep medial pocket for large medial and inferior mesh overlap.

Zone of Psoas Dissection

With the reduction of the peritoneal sac, the cord structures or the female equivalents are parietalized. There must be adequate posterior peritoneal dissection to minimize the potential of peritoneum invaginating under the inferior edge of the mesh which represents one of the most common causes of recurrence after MIS inguinal hernia repair. Meticulous dissection is crucial to avoid injury to the cord structures, iliac vessels, and sensory nerves, which could result in testicular ischemia and chronic pain (Fig. 16.12a–d). The triangle of doom will be well defined with adequate posterior peritoneal dissection (Fig. 16.13). Posterior peritoneal dissection is complete when the posterior peritoneal edge approximates the level of the umbilicus thereby exposing its association with the psoas muscle. Adequate posterior peritoneal dissection can be tested by manipulation and retraction of the peritoneum. If the cord structures move or lift during peritoneal manipulation, further posterior dissection is required. This test is based on the concept that if the cord structures lift, the subsequently placed mesh can also shift or clamshell during re-approximation of the peritoneal flap, resulting in a pathway to recurrence. The hernia sac is completely returned to the intraperitoneal cavity (Fig. 16.14).

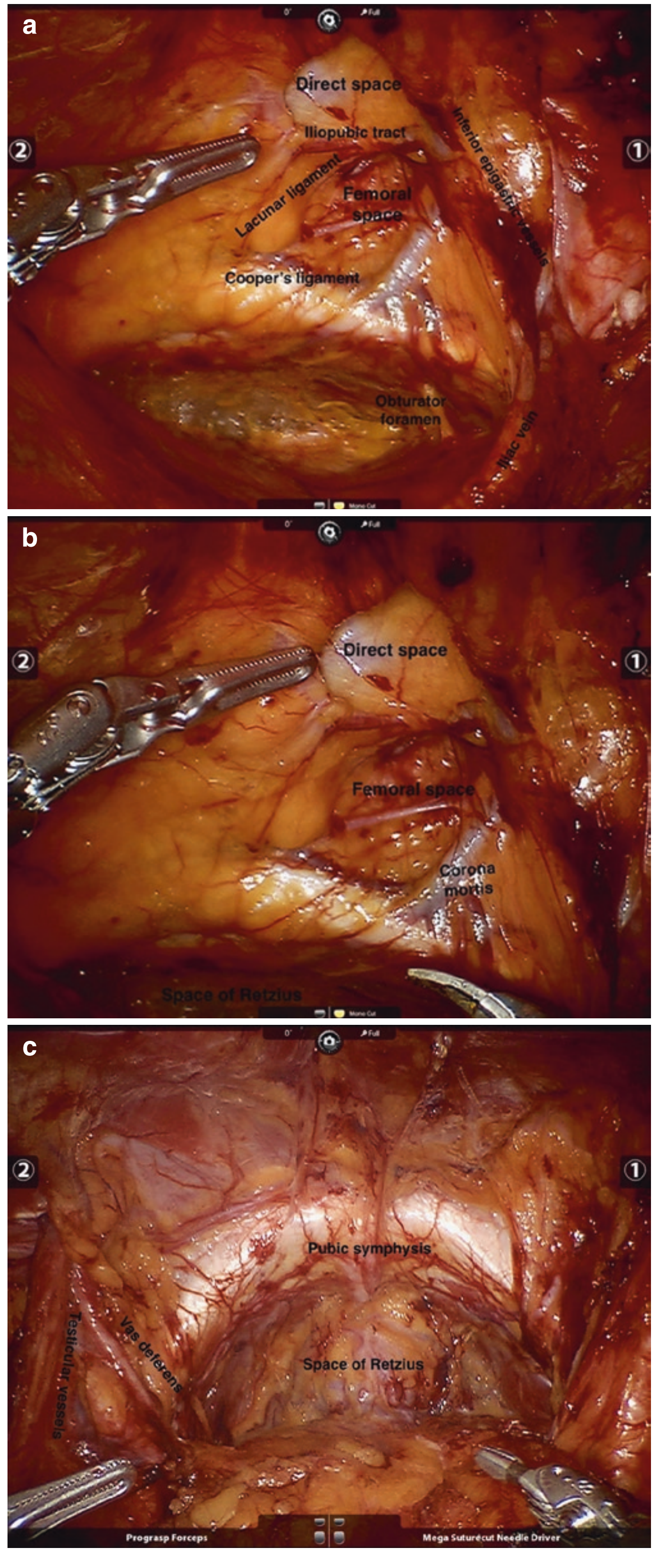

Fig. 16.11 (**a**–**c**) Zone of medial dissection

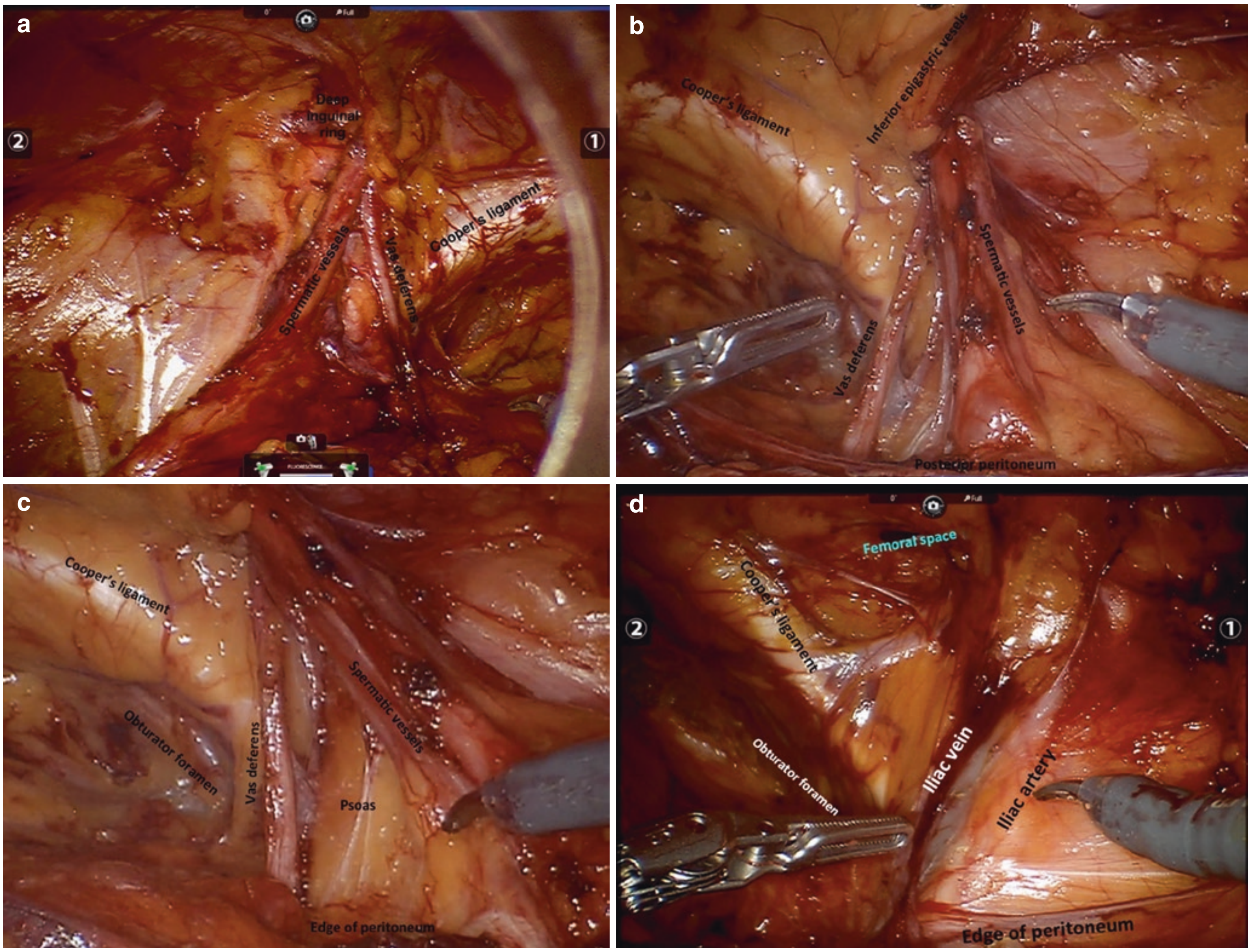

Fig. 16.12 (**a**, **b**) Zone of psoas dissection. (**c**, **d**) Female equivalent dissection after transection of round ligament

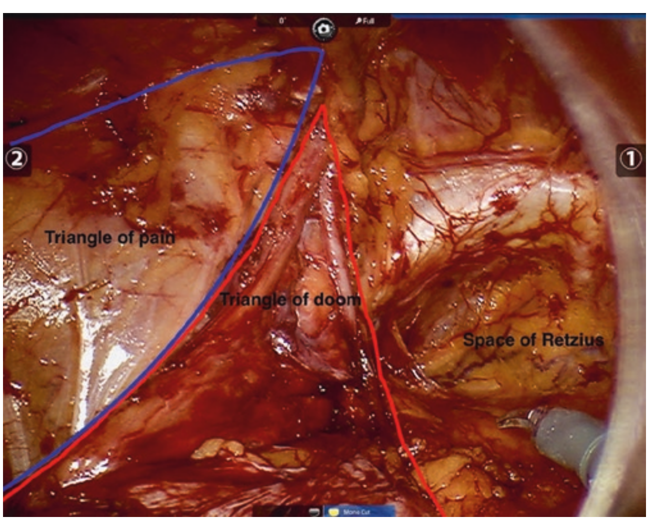

Fig. 16.13 Triangles of the MPO

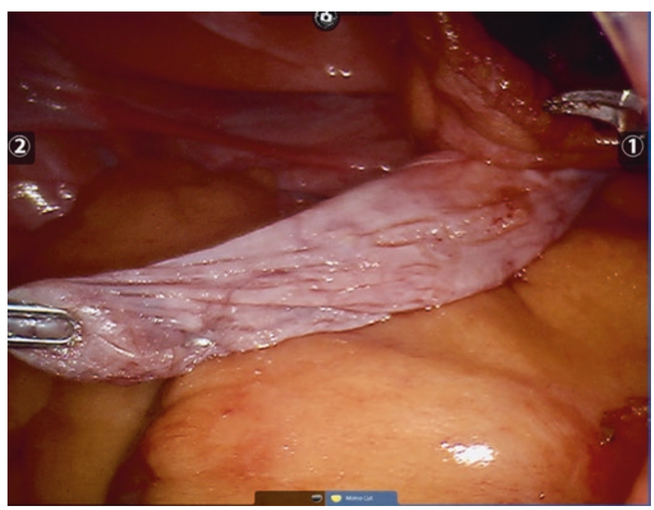

Fig. 16.14 Completed reduction of the hernia sac

Zone of Lateral Dissection

The myopectineal orifice must be adequately dissected laterally in order to place a large mesh with sufficient overlap of all four potential spaces. The posterior peritoneal dissection should be confluent from the space of Retzius, contouring over the psoas and extending to the level of the ASIS. The triangle of pain exists within the lateral MPO, requiring caution, to preserve the genitofemoral and lateral femoral cutaneous nerves, thereby minimizing the risk of postoperative chronic pain (Fig. 16.15).

Mesh Placement and Fixation

At minimum, a 10 × 15 cm mesh should be used in all MIS inguinal hernia repairs. Mesh sizes smaller than these are believed to be inadequate [4]. The authors prefer to use larger sheets of mesh to confirm adequate dissection and critical view. If the mesh doesn't fit flat on the floor of the retroinguinal space and contour over the cord structures and psoas muscle, preperitoneal clearance is deemed inadequate, and further dissection must ensue (Fig. 16.16a–c)

There are numerous options for both the introduction and fixation of the mesh to cover the MPO. The mesh and suture may be introduced prior to the preperitoneal dissection. We prefer to place our mesh once dissection is complete. Flat mesh can typically be introduced through the 8.5 mm trocars. The robotic arm ipsilateral to the hernia defect is undocked, and the mesh is placed by the bedside assistant, aiming toward the pubic symphysis. In order to lay the mesh flat with sufficient coverage of the potential spaces, there must be coordination between the operator and the bedside assistant. Alternatively, the trocar may also be re-docked, and using two grasping instruments, the operator can lay the mesh in its final position. Mesh placement is confirmed prior to fixation. This is done by manipulating the peritoneum to

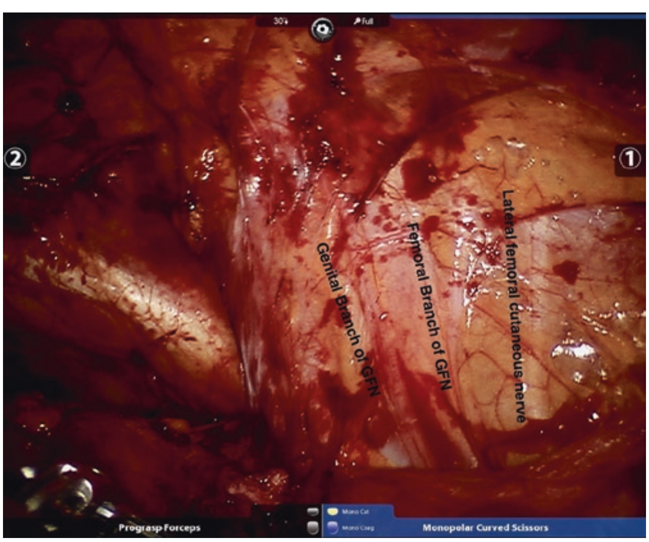

Fig. 16.15 Zone of lateral dissection

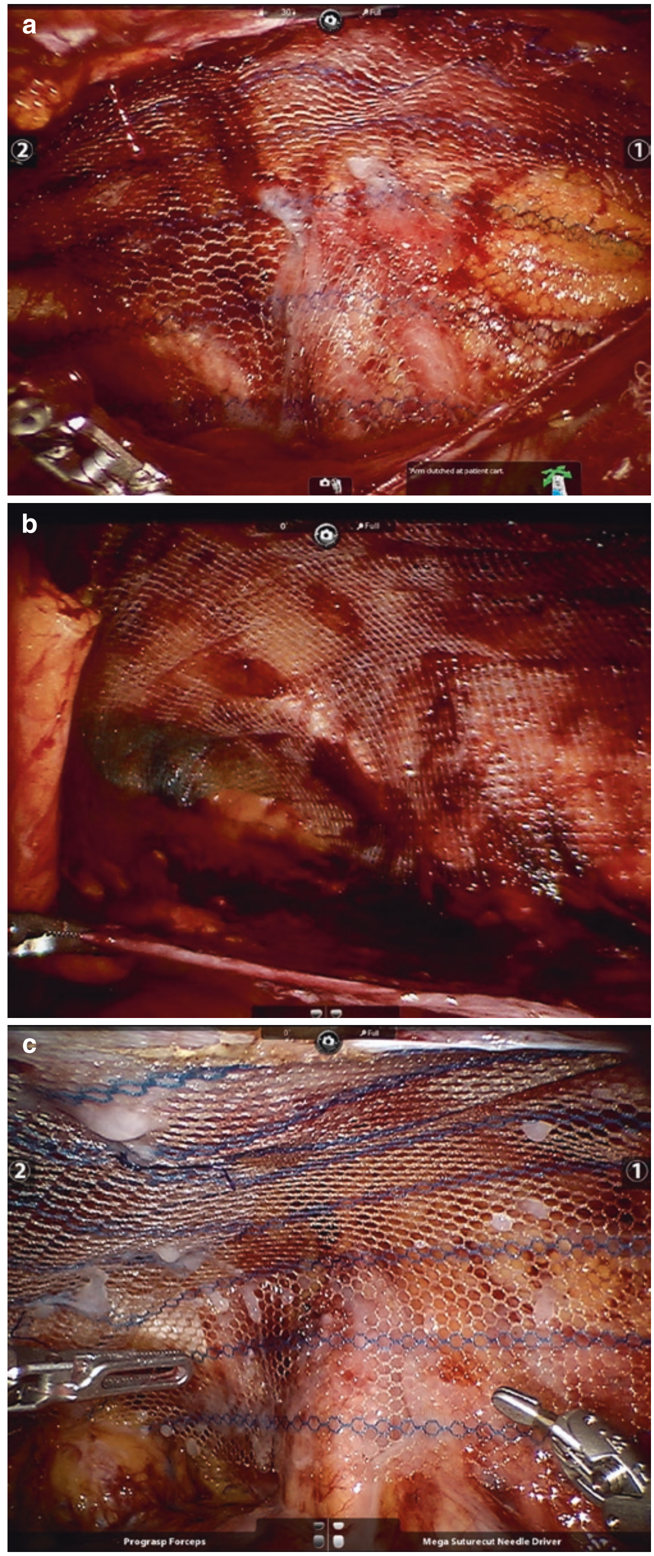

Fig. 16.16 (**a**–**c**) Mesh placement

assure the mesh does not fold or buckle, paying particular attention to the inferior edge of the mesh.

Depending on surgeon preference and choice of mesh, there are options for no fixation or fixation with glue, sutures, or tacks. All four options have been applied in our practice. We generally secure the mesh with three absorbable tacks: on Cooper's ligament, high superomedial, and high superolateral. In order to avoid major vascular injury and nerve entrapment, fixation is never employed below the iliopubic tract nor in the area of the triangles of doom or pain.

Re-peritonealization of the Mesh

The peritoneal flap is re-approximated to completely cover the mesh, using either tacks or running suture (Fig. 16.17a, b). While the use of barbed suture facilitates closure of the peritoneal flap, we attempt to minimize barbed suture exposure to the intraperitoneal content. To minimize the risk of early postoperative small bowel obstruction, gaps in the closure should be avoided. Any peritoneal tears may be covered using the hernia sac or closed using sutures.

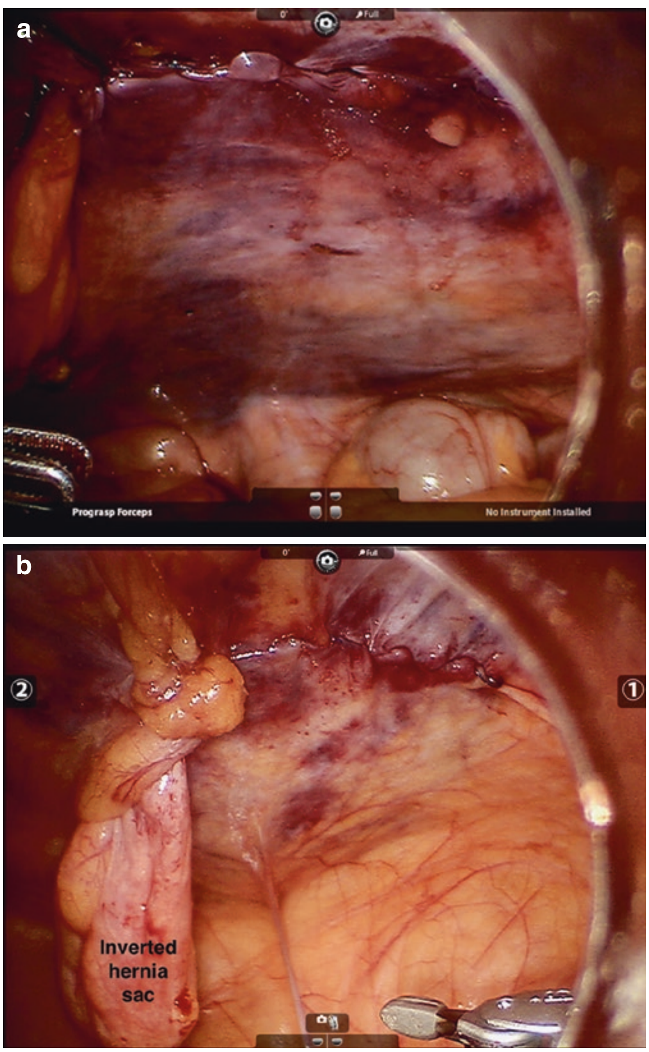

Fig. 16.17 (**a**, **b**) Re-peritonealization of mesh

Postoperative Management

Generally, all patients are treated as outpatients and discharged from the recovery room. Clinical indications to admit are based on the discretion of the physician. Patients are given a 20 lb. lifting restriction for 2 weeks after which time are allowed to resume unrestricted activity. Protocol for patient follow-up consists of a 2-week, 6-week, 6-month, and 1-year schedule.

Conclusion

The rapid adoption of rTAPP inguinal hernia repair emphasizes the importance that this technique be recognized as an operative equivalent to that of conventional laparoscopic TAPP repair, adhering to well-established principles of MIS repair. MIS inguinal hernia repairs demand a thorough appreciation of the anatomy of the MPO and a proper skill set to safely execute the approach. Strict adherence to the principles of the critical view of the myopectineal orifice can aid in achieving this goal of achieving a durable repair with a low incidence of postoperative chronic pain.

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17 Single Incision Laparoscopic Inguinal Hernia Repair

Hanh Minh Tran, Mai Dieu Tran, and Wayne John Hawthorne

Introduction

Since the first laparoscopic inguinal hernia repair in 1988 [1], the technique was refined and standardized over the next two decades such that the laparoscopic technique increasingly became acceptable as a safe, quicker, and more cost-effective alternative to the open repair. Indeed, in Australia, where Medicare Australia keeps accurate data, the laparoscopic inguinal hernia repair increased from 9.7% in 2000 to 54% in 2016 which coincided with the fact that some 50% of surgeons were performing laparoscopic inguinal hernia repair as part of their practice [2].

Parallel with the increasingly standardized technique of endoscopic repair is the development of mesh prosthetics resulting in the development of a plethora of meshes varying from "mosquito net" [3, 4] to biological mesh [5]. Apart from making general surgeons increasingly confused as to what they should use in a particular patient, laparoscopic skill development also became stunted. This changed with the advent of natural orifice transluminal endoscopic surgery (NOTES) [6–8] and its offshoot, single incision laparoscopic surgery (SILS). It was suddenly possible to perform scarless or virtually scarless surgery from a single incision whether it was from a natural orifice, such as the vagina, or a carefully crafted incision of a natural "scar" such as from within the umbilicus. Opponents of the new technique point to loss of triangulation as the main reason for not learning the newer skills, while proponents reassert the relative ease of adapting the new procedure by simple modifications of the dissection techniques such as "chopsticks" and "in-line" dissection [9, 10].

Like all new techniques, SILS is needed to be carefully investigated, and unfortunately most studies, mainly in SIL cholecystectomy, lacked scientific rigor and uniformity and included the learning curve through eagerness of the "young guns" to publish [11]. This resulted in suboptimal results of the new procedure. Lessons learned from such failures allowed some leading hernia centers to perform well-conducted randomized controlled trials (RCTs) comparing single- and multiport TEP repair well past the learning curve. Currently, three RCTs with 100 or more patients [12–14] have been published, and all have confirmed the safety of the single incision laparoscopic repair, and two have confirmed its efficacy [13, 14] meaning that the procedure could be performed in the same time period as conventional multiport repair. In fact, one study [15] showed that SIL TEP repair was highly cost-effective compared to multiport repair once balloon dissection of the extraperitoneal space was replaced with telescopic extraperitoneal dissection which negated the cost of the balloon dissector and hence minimized the total cost of disposables.

Having adopted SILS for virtually all cases of inguinal and ventral/incisional (including parastomal) hernia repair since 2009, the principal author has performed some 2000 cases and has amassed unparalleled experience with SILS so that the readers may enjoy and, hopefully, be inspired to adopt the new technique knowing that SIL TEP repair is a proven acceptable alternative to multiport repair with no adverse side effects and with the potential to improve patient care with potential cost savings [16, 17].

Preoperative Considerations

For hernia repair, the eligibility for TEP repair applies equally to SIL and multiport surgery. During the learning curve of the surgeon for SIL TEP, it is advisable to start with simple cases such as ventral hernias and not perform complicated cases such as inguino-scrotal hernias. Equally important is the delicate but necessary question of informed consent. If the surgeon is technically competent (i.e., having performed more

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than 250 cases of multiport repair) [18], then it becomes a simple matter of informing the patient of the safety and efficacy of SIL TEP repair and reassuring them of willingness to convert to multiport repair, without any adverse side effects, should SILS become difficult for any reason. It is reasonable to expect the first few cases to take significantly longer than normal, and hence care is taken to adjust the operating list to accommodate for increased operating time.

The surgeon needs to be familiarized with the new devices, instruments, and modified techniques so that he/she can confidently project knowledge to his/her scrub staff who too will need to be trained. More often than not, companies promoting single-port devices will have well-trained staff to assist with the transition to SILS. Such companies may even run SILS courses and assist surgeons with proctorship with an experienced SIL practitioner.

There are bare minimum number of instruments and equipment that are necessary to successfully undertake SIL TEP repair; these are detailed below:

1. An operating table which can be tilted sideways as well as being able to be positioned in Trendelenburg and reverse Trendelenburg position
2. Two monitors for clear angle of observation for the principal surgeon, assistant and scrub nurse
3. Two S-shaped retractors (Fig. 17.1)
4. A 30° angled, 52 cm, and 5 mm laparoscope (Fig. 17.3)
5. A pair of "Dolphin" and "Merryland's" forceps with diathermy pin below the handle (Precision Endoscopic Instruments, Baulkham Hills, NSW, Australia) (Figs. 17.3 and 17.4)
6. Single-port device (Figs. 17.3, 17.4, 17.5)

Patient Positioning and Theater Setup

Prior to entering the operating theater, the patient should be asked to empty their urinary bladder. Urinary catheterization should be used in selective cases, especially those with history of prostatic symptoms or in complicated cases such as inguino-scrotal hernias, where it is anticipated that the operation may take much longer than an uncomplicated case. Additionally, judicious fluid administration, by the anesthetist, during the operation may also limit urinary production so as not to overfill the bladder. After the patient is anesthetized, their arms are tucked into their sides of their body by using pillowcase wraps, and the use of an extension intravenous line may assist the anesthetist with ease of access to administer medications. Patients must always have calf compressors in place during the procedure, and the use of lower body warmer and upper body blankets (the author avoids the upper body warmer due to its bulkiness which may interfere with ease of maneuvering instruments) will assist in keeping the patient warm during the operation. The patient is shaved from 5 cm above the umbilicus to mid-thighs and prepped with aqueous iodine solution (or chlorhexidine if there is an iodine allergy). In particular, care is taken to clean out the umbilicus with a small iodine-soaked gauze to ensure sterility of the incision site. The patient is then draped so that only 2–3 cm of the skin is exposed from 2 cm above the umbilicus to pubic symphysis so that there is minimal skin exposure (Fig. 17.1). In cases where SIL TEP is combined with open groin exploration, e.g., tri-neurectomy with or without removal of the mesh, an iodine-impregnated adhesive drape is also used to cover the side of the abdomen to be operated on.

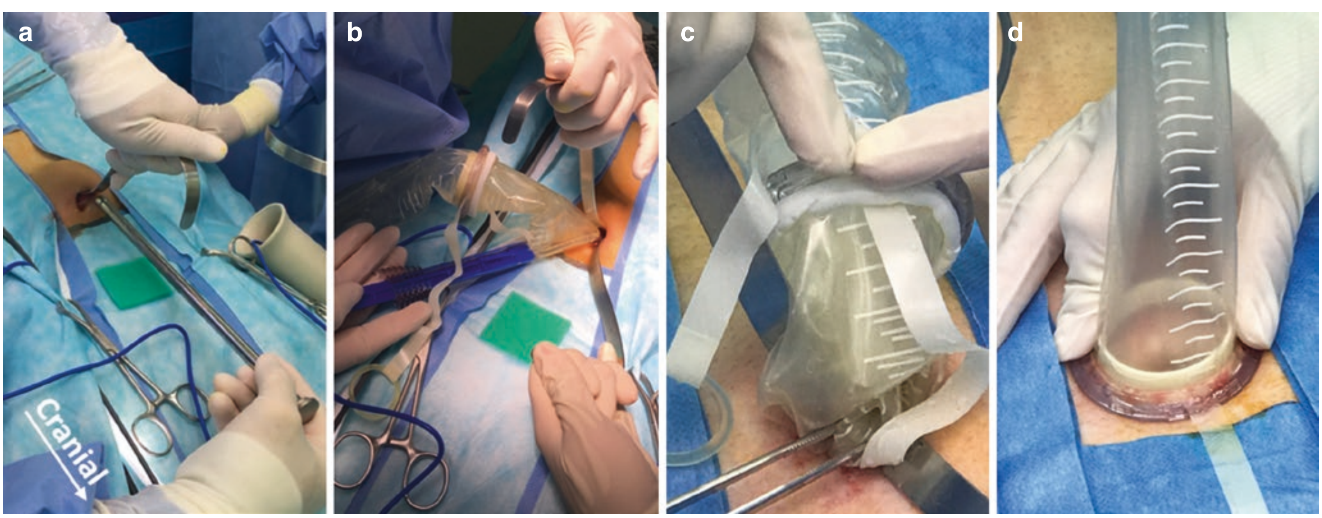

Fig. 17.1 (**a**) shows insertion of a blunt metal probe into the extraperitoneal space toward the pubic symphysis; (**b**) shows the surgeon's left hand retracting the S-shaped retractor infero-laterally, while the assistant retracts superolaterally as the tip of the introducer is placed at the entrance of the anterior rectus sheath incision before the inner ring is deployed; (**c**) shows the remainder of inner ring being inserted into the extraperitoneal space with a pair of broad and blunt tissue forceps; and (**d**) shows the outer ring being snugged down

Irrespective of the side of the inguinal hernia to be repaired, the surgeon starts on the left side of the patient while the assistant on the right side. Monitors on each side of the operating table permit ease of the surgeon and assistant moving to the contralateral side to the hernia, especially for bilateral cases, without having to move the monitor while allowing the scrub nurse full view of the operative fields so that he/she can respond in a timely fashion to the needs of the surgeon. During laparoscopic dissection, the assistant stands cranial and medial to the surgeon holding the camera head with his/her hand corresponding to the side of the hernia to be operated on so that there is minimal interference with the surgeon's arms/hands (Fig. 17.3). The extra-long laparoscope further minimizes clashing of the surgeon and assistant's arms/hands.

Incision and Port Placement

Following appropriate positioning of the patient, prepping and draping the incision site are infiltrated with local anesthetic; once ready, a crescentic 1.5 cm incision is made within the confines of the umbilicus. The incision is deepened using electrocautery until the anterior rectus sheath is reached. The muscle belly of the rectus is usually visible, and a transverse 1.5 cm incision is made into the anterior rectus sheath with care taken to avoid the intersection of the rectus, which would result in entry into the peritoneal cavity. If the latter is encountered, then the incision should then be moved 1 cm inferiorly or superiorly. The side of the rectus to be dissected should be the same side of the hernia so that only the extraperitoneal space of the side of the hernia is dissected to minimize disturbance of the contralateral space for a potential future contralateral extraperitoneal repair. The S-shaped retractors are effective in retracting the wound edges while permitting wider vision into the incision due to their shape. The inferior edge of the rectus sheath is then grabbed with a pair of broad blunt forceps, while a pair of Metzenbaum scissors is used to sweep the rectus muscle belly laterally, while the inferiorly placed S-shaped retractor (Fig. 17.1) is then repositioned to lie just deep to the rectus muscle belly, i.e., extraperitoneally. Then the other S-shaped retractor can then be inserted into the extraperitoneal space superiorly. The balloon dissector, if used, can then be inserted at this stage to create the extraperitoneal space. The superiorly placed retractor is now used to further dissect this space to allow the single-port device (see later) to sit evenly and snugly deep to the rectus muscle. The use of a particular commercially available single-port device depends on availability, cost considerations, individual patient characteristics, and personal preference. Three different devices will be discussed in detail:

The TriPort⁺ (Olympus Winter & Ibe GmbH, Hamburg, Germany)

In the author's view, this port requires a little extra preparation and a few steps beyond the manufacturer's recommendations, but it offers unrivaled flexibility of instrumentation while minimizing the incision length and is the author's preferred device in most cases for SIL TEP repair. The TriPort⁺ has three 5 mm ports which are not all necessary for inguinal hernia repair, and the middle of the 5 mm ports is amputated, plugged with a bung (Safesite injection site, B. Braun Medical Inc., Bethlehem PA, USA), and taped to secure and maintain air seal (Fig. 17.2). The plastic sleeve is next pre-

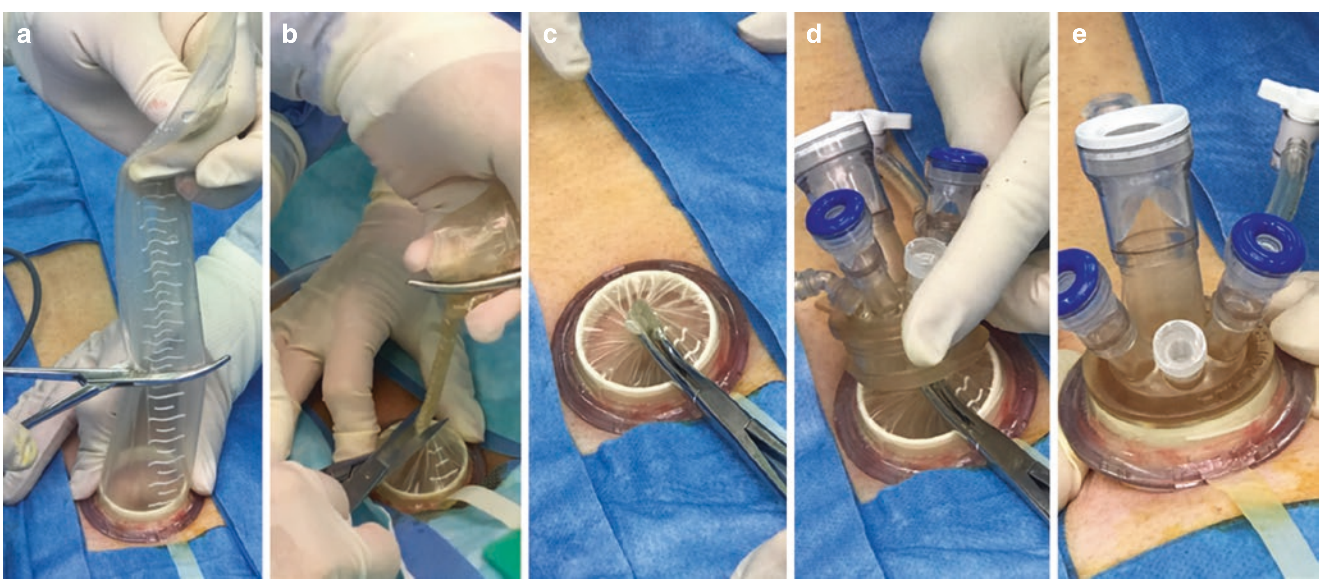

Fig. 17.2 (**a**) shows application of a pair of Kocher's forceps in the lower part of the plastic sheath which is then twisted to allow the excess sheath to be removed (**b**), the plastic sheath stump is then inverted into the outer ring (**c**), and (**d**, **e**) show placement of the top platform of the TriPort⁺ into the outer ring

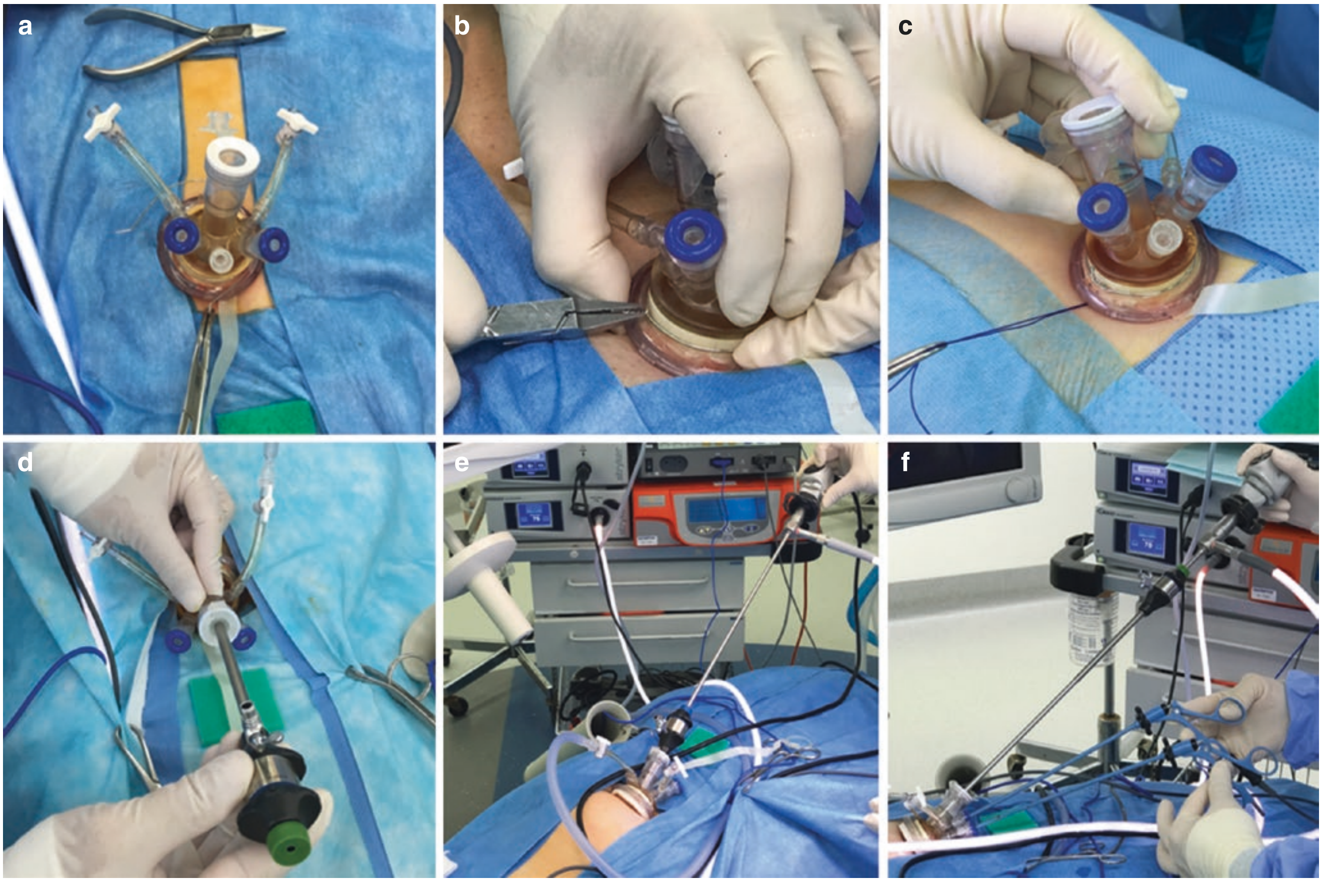

Fig. 17.3 (**a**, **b**) demonstrate how a wire loop is applied around the outer ring and is tightened to prevent slipping, (**c**) shows a figure-of-8 suture placed in the attenuated anterior rectus sheath to prevent dislodgement of the inner ring, (**d**) demonstrates the placement of a 5 mm non-disposable port into the extraperitoneal space, (**e**) is of the 5 mm scope being inserted into the extraperitoneal space, and (**f**) the 5 mm port being pulled back along the 5 mm scope with insertion of the dissecting instruments below the scope (note the inferiorly placed diathermy pin)

pared by lubricating the sheath both from outside and inside with gel before the inner ring is placed inside the introducer (Fig. 17.1). These preparative steps can be performed by the assistant while the surgeon preps and drapes the patient without increasing operative time. The incision for the TriPort⁺ is kept to no more than 1.5 cm, and this requires discipline by the assistant not to over-retract with the S-shaped retractors which would lead to tearing of the anterior rectus sheath. Furthermore, the tip of the introducer is placed at the entrance to the rectus sheath opening, and the inner ring is deployed into the extraperitoneal space (Fig. 17.1), without placing the entire width of the introducer into the extraperitoneal space, as this will increase the risks of dislodgement of the inner ring. In some patients, the anterior rectus sheath is very attenuated in which case a figure-of-8 suture is placed at the lateral edge, without tying it, and once the inner ring is introduced, this can be tied to restrict the opening to assist with keeping the inner ring in place (Fig. 17.3). On rare occasions, placement of the same suture medially is also necessary. It must be borne in mind that placement of these sutures will decrease maneuverability of the instruments and hence are only placed if the inner ring becomes dislodged during placement. Once the inner ring is in place, the outer ring is then snugged down in one swift motion (Fig. 17.1). With the assistant holding the outer ring down, the surgeon applies a pair of Roberts forceps to the plastic sleeve and turns it in one direction, and then another pair is applied closest to the outer ring before the excess is removed (Fig. 17.2). The top platform is then placed inside the outer ring with the assistant slowly wriggling the pair of Roberts forceps out before the top platform is placed fully inside the outer ring (Fig. 17.2). As opposed to the original TriPort system [13], where there was a locking outer ring to minimize the risks of the plastic sleeve from sliding through, the author has experienced significant slippage of the plastic sleeve during surgery, especially if surgery is prolonged in more difficult cases, and so a wire is always applied and twisted outside of the outer ring until it indents the ring (Fig. 17.3). This has been found to significantly minimize slippage of the plastic sleeve. Furthermore, while other ports such as SILS and

GelPorts can be removed and placed as many times as necessary (see later), once the excess plastic sleeve of the TriPort⁺ is cut, any reapplication of the inner ring into the extraperitoneal space is usually impossible necessitating the use of another new device which unnecessarily increases the cost of the disposables and hence the operation.

While the 5 mm port of the SILS port allows for placement of the 5 mm laparoscope directly into the extraperitoneal space (see later), the inverted plastic sleeve provides an obstacle to the introduction of the laparoscope which often becomes smudged. This can be overcome by placing a non-disposable 5 mm port, which is long enough to go past the plastic sleeve, into the extraperitoneal space (Fig. 17.3). Once the scope is inside, the non-disposable port can then be pulled back along the long scope toward the head so that it does not interfere with the dissecting instruments (Fig. 17.3). Should the scope need to be cleaned, then the non-disposable port can be inserted into the extraperitoneal space again, while the scope is withdrawn.

The SILS Port (Covidien, Norwalk, Connecticut, USA)

To allow for appropriate insertion, the foamy SILS port is grasped with a pair of Roberts forceps so that the tips of the Roberts forceps lie close to the insufflation hose (Fig. 17.4). While the surgeon retracts the inferiorly placed S-shaped retractor, the assistant retracts superiorly and laterally, and the well-lubricated SILS port with gel is then placed firmly into the extraperitoneal space (17.4). If the device is in the correct space, then the device will appear “sucked” down (Fig. 17.4). Failure to be able to insert it into the correct space usually means the skin incision and/or the rectus sheath incision is too small. For the SILS port, the incisions need to be approximately 2–2.5 cm which will still result in excellent cosmetic result for a moderately large and deep-seated umbilicus. For small and shallow umbilici, the relatively larger incision would offer a poorer cosmetic result, and an alternative single-port device should be used (see later).

Fig. 17.4 (**a**) Insertion of the SILS port with the surgeon retracting the inferiorly placed S-shaped retractor (*short arrow*) infero-laterally, while the assistant retracts superolaterally (*long arrow*); (**b**) the foamy part of SILS port appears “sucked” down, when correctly placed, with 3 × 5 mm ports inserted; (**c**) the long scope with conventional straight dissecting instruments; and (**d**) dissection can also be accomplished by a 10 mm/30°/52 cm scope inserted into a 12 mm port; the latter allows for placement of the mesh into the extraperitoneal space

Once the SILS port is in the correct position, it is then grasped with two pairs of Roberts and rotated 180° so that the insufflation hose is posterior to the three 5 mm holes so that 5 mm ports can then be inserted. Initially only the anterior 5 mm port is placed into the extraperitoneal space so that the 5 mm laparoscope can be inserted directly into it before insufflation with CO_2 to ensure one is in the correct space. Once more space is created with gas, the other two posteriorly placed ports can be fully inserted into the extraperitoneal space. Once dissection has been completed, the laparoscope can be moved into one of the posteriorly placed 5 mm ports, while the anteriorly placed 5 mm port is removed, and the well-lubricated 12 mm port can then be inserted so that the mesh can be introduced into the extraperitoneal space (Fig. 17.4). Insertion of the 12 mm port can be assisted by partially pulling the "free" 5 mm port out beyond the rectus sheath to increase the space within the foam and the rectus sheath opening.

The GelPort Laparoscopic System (Applied Medical, Rancho Santa Margarita, CA, USA)

To provide easier insertion of the GelPort, an Alexis wound retractor is utilized being placed into the wound by grasping the lubricated inner ring of the Alexis wound protector/retractor with a pair of Roberts forceps, and this is then introduced directly into the extraperitoneal space (Fig. 17.5). Due to the relatively thicker, stiffer, and larger inner ring (compared to the TriPort+), the skin and rectus sheath incision is about 2 cm. However, the stiffer and larger inner ring also results in more secure inner ring placement so that dislodgement is rare during any procedure. The outer ring of the plastic sleeve is then turned inward, assisted by the assistant, turning it in with the surgeon until the outer ring is fully snugged down against the skin (Fig. 17.5). The GelSeal cap can be preprepared by the assistant by placing two 10 mm ports posteriorly and 12 mm port anteriorly through the gel with equal distances between them (Fig. 17.5). As the ports have inbuilt reducers, placement of 5 mm instruments or laparoscope will maintain the air seal. This is then clicked over the outer ring, and the outer lock is applied (Fig. 17.5). During insufflation, the gel membrane bellows out further separating the ports to minimize clashing.

The Surgery and Specialized Techniques

The central tenet of laparoscopic surgery has, up until now, been about triangulation with instruments free of clashing with each other or with the laparoscope. Therefore, the relative lack of triangulation with SILS (and NOTES) must be overcome for safe and efficient operation. This is relatively easily overcome by firstly reducing the size of the laparoscope from 10 to 5 mm and increasing the length so that the side arm of the laparoscope moves away from the dissecting

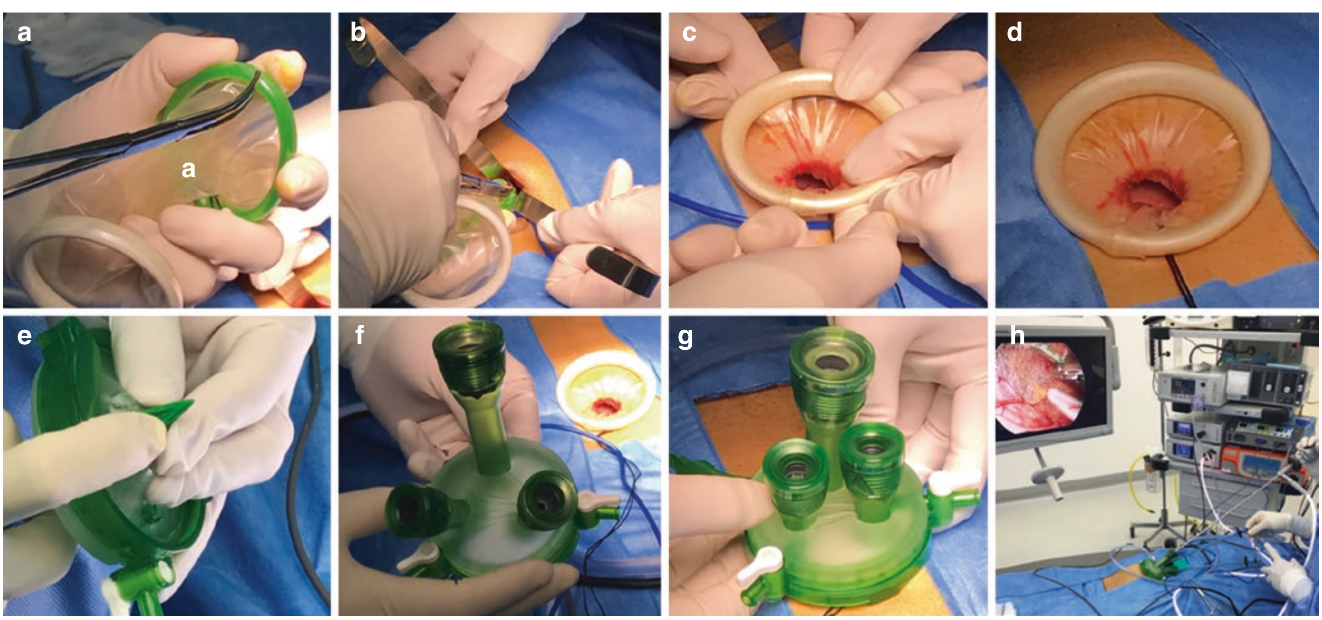

Fig. 17.5 (**a**) The inner ring of the Alexis wound protector/retractor held by a pair of Kocher's forceps, (**b**) being inserted into the extraperitoneal space, with (**c**) showing how the surgeon and assistant simultaneously invert the outer ring, and (**d**) is of the outer ring snugged down against the skin. (**e**) placement of the ports into the GelSeal cap with (**f**) being the correct placement of the ports (2 × 10 and 1 × 12 mm) into the GelSeal cap. (**g**) demonstrates the placement of the GelSeal cap onto the outer ring of the Alexis wound protector/retractor and (**h**) the positioning of the dissecting instruments and scope during telescopic dissection of the extraperitoneal space

instruments (Fig. 17.3). The laparoscope is inserted in the direction of the area of dissection and by advancing it carefully, at least initially, until more extraperitoneal space is created. The dissecting instruments are then inserted parallel and inferior to the laparoscope (Fig. 17.3). If there is any resistance, the laparoscope is pulled back until the tips of the instruments are visualized before they are inserted any further as this prevents accidental puncture of the posterior rectus sheath and/or peritoneum. Secondly, modified dissection techniques, namely, "in-line" and "chopsticks," are used:

"*In-line*" *dissection:* the dissecting instruments are moved parallel "in-line" with each other but in the opposite direction (Fig. 17.6). This movement is useful for reducing an indirect sac. However, the range of movement with "in-line" dissection tends to be more limited.

"*Chopsticks*" *dissection*: where the fulcrum of the instruments is at the rectus sheath defect, the dissecting instruments are moved in the opposite direction on either side of the laparoscope, preventing clashing (Fig. 17.6). Significant range of movements can be achieved with this dissection in a singular movement, such as dissecting the peritoneum away from the anterior abdominal wall as dissection continues down to the symphysis pubis. Any blood vessels in the fibroareolar tissue in the extraperitoneal space can be cauterized safely with the assistant pulling the scope back until the metal parts of the dissecting instrument can be fully visualized to prevent inadvertent heat application to important structures including the peritoneum and underlying viscera (Fig. 17.7). In practice both techniques are employed at the same time in varying proportions to achieve efficient dissection.

The steps of the dissection for a TEP repair are otherwise standardized: firstly, dissecting the extraperitoneal space toward and identifying the pubic symphysis to minimize the risks of accidental injury to the urinary bladder; secondly, identifying and dissecting high and lateral to the inferior epigastric vessels to create the lateral space sufficient for placement of the mesh; thirdly, identifying and reducing an indirect sac, often with its accompanying lipoma of the cord; fourthly, dissecting the peritoneum proximally so that the mesh can be comfortably placed without the inferior edge curling up; and finally, medially dissecting the peritoneum away from the vas deferens and external iliac vein. One point of difference with the multiport dissection is that the dissection of single-port totally extraperitoneal dissection with telescopic dissection starts superiorly into the inferomedial and lateral direction, whereas the multiport dissection begins inferiorly and continues laterally and superiorly. Telescopic dissection allows for cautery of all small blood vessels crossing the extraperitoneal space, thus potentially minimizing post-op bruising and pain [15] while specifically allowing for preservation of a thin layer of areolar tissue overlying the retroperitoneal nerves (Fig. 17.7), as achieved during a transabdominal preperitoneal (TAPP) repair, which may be protective against post-herniorrhaphy chronic groin pain.

For a unilateral inguinal hernia repair, the extraperitoneal space is dissected across to the contralateral side by approximately 2 cm especially for a direct hernia. Any significant direct hernia sac is reduced and plicated to the posterior pubic ramus with a couple of nonabsorbable tacks to minimize the risks of post-op seroma formation [13]. Reducing the sac by ligation is not necessary as this increases operative time, costs, and complexity.

For bilateral inguinal hernias, the surgeon and assistant must move to the contralateral side of the patient to resume dissection. In these cases, the dissection starts at the level of the symphysis pubis and continues laterally and superiorly. Depending on whether the median raphe is well developed or not, one may encounter some difficulties dissecting the lateral aspect of the second side in which case the inferior

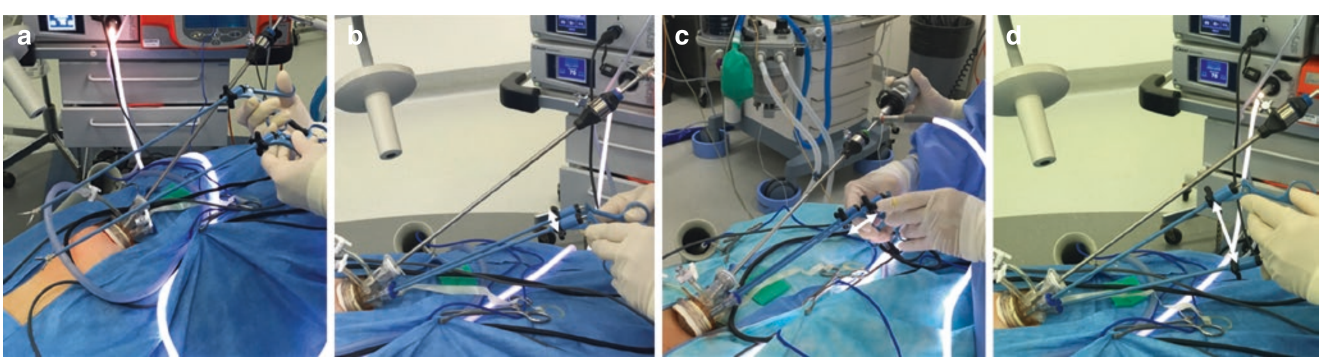

Fig. 17.6 (**a**) demonstrates how to best set up the dissecting instruments with the Merryland's in the dominant (*right*) hand and the Dolphin forceps in the nondominant (*left*) hand, (**b**) shows neutral position of the dissecting instruments below the scope. (**c**) is of the "in-line" dissection technique with instruments moving in and out in opposite direction indicated by the increased separation of the rotating wheels of the dissecting instruments (*double arrow*). (**d**) demonstrates the "chopsticks" dissection technique where the instruments move in the opposite direction on either side of the scope as shown by increased length of the *double arrow*

portion of the raphe can be divided to ease dissection. It is usually possible to complete the repair of the contralateral side within 20 min of starting the dissection [13]. The anesthetist is warned (unless they are very familiar with SIL TEP repair) so that reversal of muscle relaxant can be instituted in good time to allow the patient to wake up without significant delay. This ensures that the procedure can be completed with the patient completely paralyzed to the end of the procedure, since the fascial and skin closure only takes a few minutes, the so-called fast finish.

Mesh Insertion

In order to best insert the mesh while using the TriPort⁺: the scope is placed into one of the 5 mm ports into the extraperitoneal space, and it is then withdrawn until its tip lies within the plastic sheath but beyond the rectus sheath. The 5 mm reducer is then removed, and the mesh is then rolled along the shortest dimension and folded half way and grasped with a pair of Dolphin forceps (Fig. 17.8). With the laparoscope pointing in the direction of the pubic symphysis, the mesh is introduced parallel and in the same direction, with a swift pass until the mesh is well past the rectus sheath opening when one would anticipate loss of "pneumoperitoneum" which is quickly regained once the Dolphin forceps are removed. With a pair of the latter then reintroduced into the other 5 mm port, the scope can now be reinserted into the 10 mm port via 5 mm reducer so that the mesh can now be positioned into the correct orientation.

For insertion of the mesh while using the SILS port: this is efficiently done by replacing the anterior 5 mm port with 12 mm port while introducing the mesh into the latter with the process being observed by the scope placed in one of the other 5 mm ports in the extraperitoneal space (Fig. 17.4). A 5 mm port then replaces the 12 mm port, and the operation continues as for before insertion of the mesh.

By far the simplest mesh insertion is done while using the GelPort: the mesh can simply be grasped with a pair of Dolphin forceps and inserted into the large 12 mm port directly through into the extraperitoneal space (Fig. 17.5).

With the medial and lateral ends of the rolled-up mesh correctly oriented into their appropriate space, the mesh can then be unrolled. Fixation of the mesh can be achieved using tacks (both absorbable and nonabsorbable) as well as with the addition of fibrin sealant (Fig. 17.8). The international guidelines for the management of adult groin hernias [18] recommend tack fixation for large direct inguinal hernias.

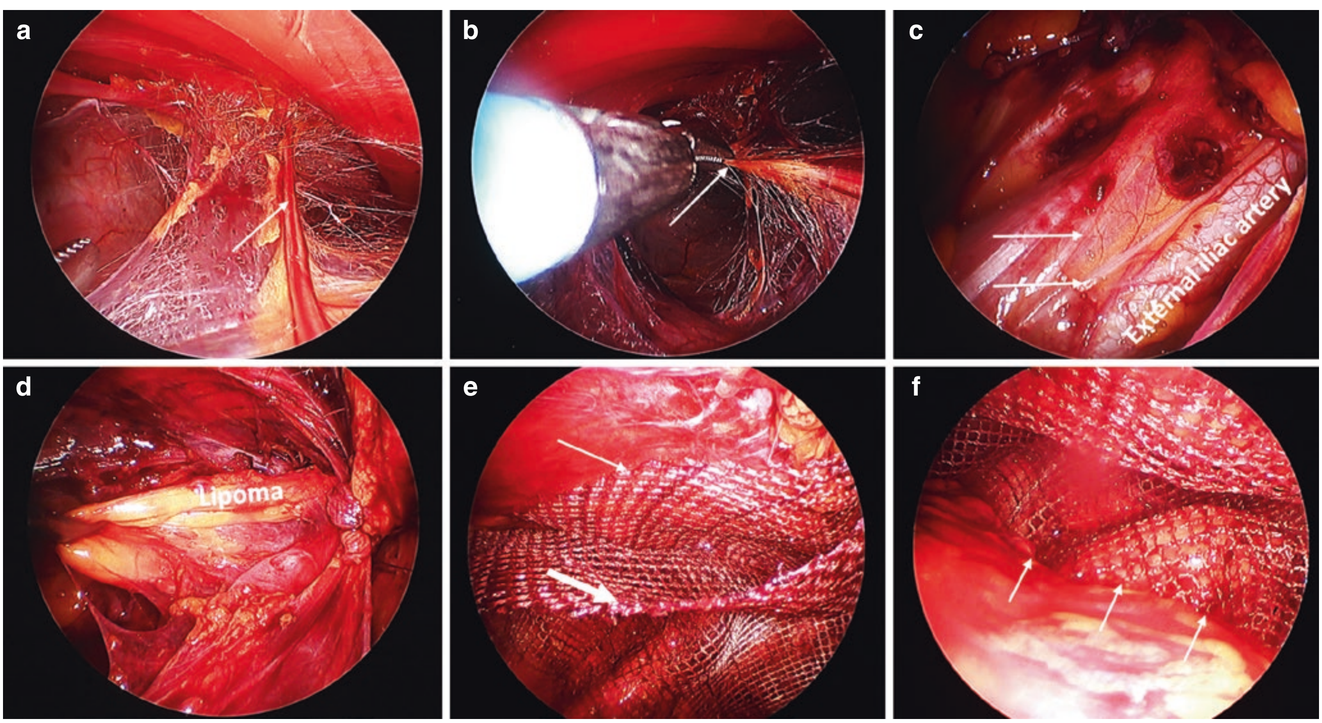

Fig. 17.7 Intraoperative views of SIL TEP repair. (**a**) The *white arrow* indicates a small blood vessels crossing the extraperitoneal space, (**b**) is of telescopic dissection which allows for electrocautery of such vessels, (**c**) preservation of the fibro-alveolar (glistening) membrane overlying the retroperitoneal nerves is indicated here by the *white arrows*. (**d**) is an image of a reduction of a lipoma of the round ligament (in a female patient), whereas (**e**) is of a male patient with bilateral direct hernias where a mesh was placed centrally covering both direct defects (*thin white arrow*), while an additional mesh (*thick white arrow*) was placed on each side to cover the deep inguinal ring, and (**f**) the peritoneum (*thin white arrows*) descending onto the mesh during deflation

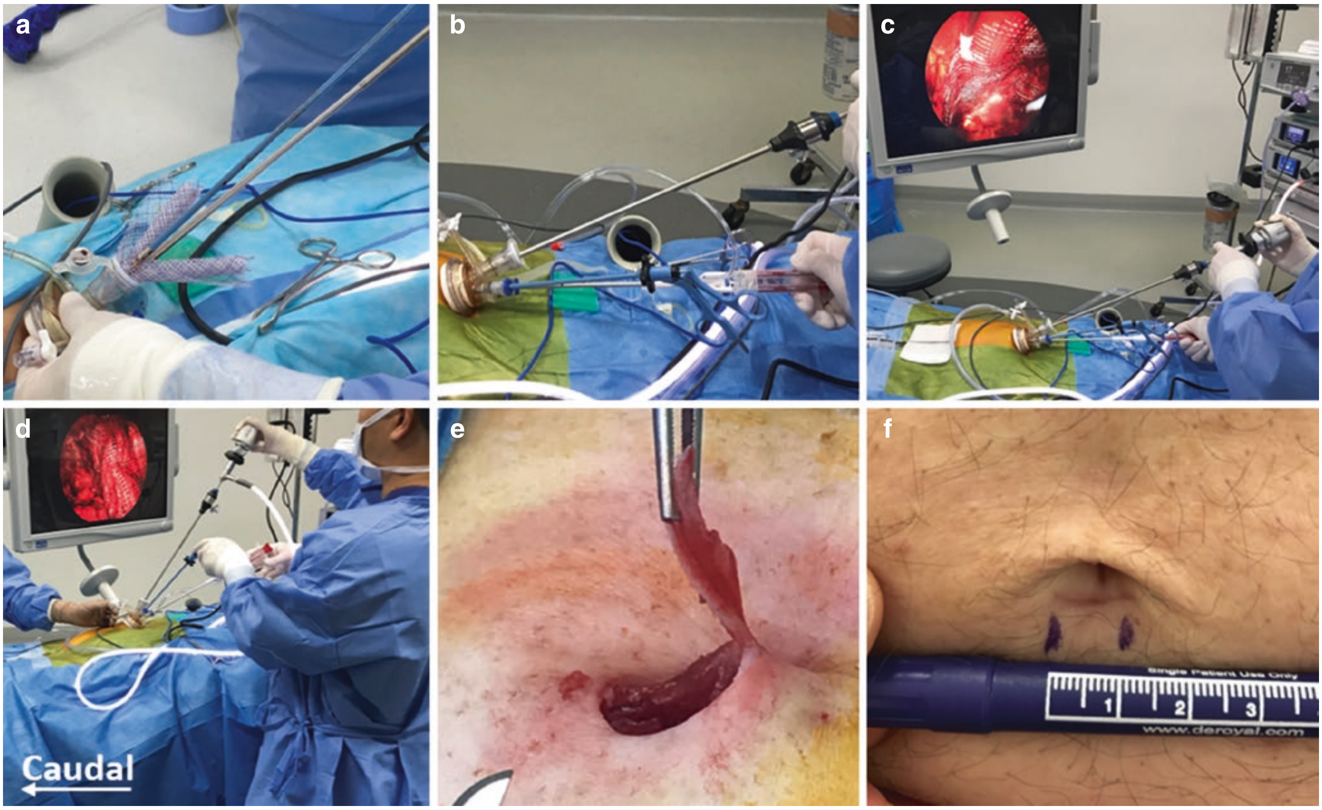

Fig. 17.8 (**a**) demonstrates a scope in one of the 5 mm port to observe insertion of the mesh through the 10 mm port placed with a pair of Dolphin forceps, and (**b**, **c**) show application of fibrin sealant for mesh fixation. (**d**) The patient placed in the reversed Trendelenburg position during deflation with the scrub nurse releasing the gas in a controlled manner, (**e**) is excision of the traumatized inferior wound edge, and (**f**) the barely visible 1 cm scar 6 weeks post-op

For bilateral indirect inguinal hernias, the author prefers to sequentially fix the mesh one side at a time after completion of dissection of one side. For bilateral direct inguinal hernias, the author prefers to complete the dissection of both sides and then place the meshes sequentially, with one placed centrally and high up to cover both direct defects (Fig. 17.7) and then one on each side being slightly more inferior to the centrally placed mesh as it more adequately covers potential or actual femoral and indirect defects (Fig. 17.7).

Once the mesh is in the correct position, for unilateral inguinal hernia, the patient can then be placed in the reversed Trendelenburg position before CO_2 insufflation is stopped. Then, with the tap open, deflation can be carefully observed to ensure that the inferior aspect of the mesh is not rolled up, which would then cause a recurrence of the defect due to incomplete mesh coverage. This process can take mere seconds, but cooperation of the assistant and scrub nurse is essential (Fig. 17.8). If there is any doubt as to the positioning of the mesh, then re-insufflate (and if necessary placing the patient back into the Trendelenburg position) to ensure the peritoneum has "fallen" onto the mesh (Fig. 17.7) rather than rolling the mesh up.

Wound Closure

Once the port has been removed, and due to the repeated insertion of the instruments and constant uneven tension, the inferior wound edge nearly always becomes traumatized, and the author routinely excises a 1 mm sleeve of the wound edge to ensure a healthy skin edge (Fig. 17.8) to prevent proper healing which could also lead to wound infection. The anterior rectus sheath is then closed with a 0 suture of slowly absorbable monofilament, and the skin wound is closed with 4.0 absorbable monofilament. Meticulous fascial closure is necessary to achieve very low port-site incisional hernia rate, similar to multiport repair, as the incision does not involve entry into the peritoneum via the linea alba [19]. The wound is cleaned and dressed with adhesive tapes and a waterproof dressing.

Some 95% of patients undergoing SIL TEP repair can go home on the same day with adequate adult supervision [13], while most of the remaining are kept in for nonmedical reasons including patients who live more than 2–3 h from the hospital or those without adequate postoperative care. Patients are warned during the initial consultation of potential scrotal bruising and to wear firm and supportive underwear to minimize discomfort should swelling occur. It is the author's practice to see his patients 1 week, 6 weeks, and annually for 5 years.

Tips and Pitfalls

While most of the novel techniques have been described previously, some additional tips include the following:

- Due to the very limited extraperitoneal space available initially during telescopic extraperitoneal dissection, the patient must be fully paralyzed. It is paramount for the patient to be on an infusion of muscle relaxant during the procedure as this results in a smoother operation due to reliable muscle relaxation. On rare occasions, it has been noticed that the patient "appeared" to be not fully paralyzed as the rectus muscle could be seen to be moving in and out but not in synch with the respirator. This was found to be due to partial obstruction of the insufflation hose internally, since the extraperitoneal space is only minimally dissected initially for placement of the single-port device. This caused the apparent movements because the insufflation machine struggles to overcome the obstruction and consequently pumps gas in intermittently. Simple solutions include rotating the port slightly and/or changing the insufflation hose to the other side.
- During the dissection, the assistant may lift the head of the scope excessively which can result in the end of the scope moving between and below the tips of the dissecting instruments [13]. If this happens, the dissection becomes impossible. This situation can be remedied by lowering the head of the scope to neutral position and pulling the dissecting instruments back to the fulcrum and then reintroducing them below the scope. Note that pulling the scope back into the fulcrum and reintroducing it above the instruments can achieve the same result except this risks dislodging the scope out of the extraperitoneal space altogether and/or smudging of the scope.
- Even if there is an obvious direct hernia, the spermatic cord must always be pulled back some 5 cm, with or without external pressure in the groin to ensure that any cord lipoma is fully reduced. If this is missed, the patient can present later with pain due to a persistent lipoma of the cord. In fact, this is classified as a recurrence and may necessitate an open anterior operation to excise it.
- As the surgeon becomes more competent with SILS, he or she can undertake more difficult cases and even cases that are normally almost impossible, if not unsafe, with multiport TEP repair. For example, for irreducible inguinoscrotal hernias, it is possible to place the single-port device intraperitoneally on the contralateral side to the hernia, via the same mode of entry (i.e., avoiding entry into the peritoneal cavity via the linea alba) [19] except the posterior rectus sheath and peritoneum are entered. The incarcerated abdominal viscera can then be reduced with bowel graspers, with or without enlarging the defect to assist with the reduction. Once reduced, the single-port device can then be removed and the fascial incision closed in layers. The device can then be introduced on the opposite side, extraperitoneally, in the normal fashion for successful SIL TEP repair. The use of the SILS or GelPort in these cases allows repeated placements without additional costs.
- Always warn patients of scrotal bruising and reassure them that if it occurs, it will settle down after a week or so. This will minimize phone calls from potentially distressed patients, especially young ones, who are worried of damage to their manhood.
- Educate the patients during the consultation that they can and should return to normal activities as soon as the pain settles and to take adequate analgesia to allow them to mobilize immediately post-op.

For any surgeon contemplating SIL TEP repair, the author strongly advises careful studying of the procedure by reading this chapter and viewing videos of different surgeons performing this procedure, for example, via "YouTube" videos [20]. Ideally, proctorship from a qualified SIL practitioner will greatly speed up the learning process as well as provide confidence during the transition to SILS. In the author's experience, if the surgeon is competent with multiport repair, mastery of SIL TEP repair should not take more than 25 cases [21], i.e., an average of a year for a general surgeon performing the same number of TEP repairs. Furthermore, mastery of SIL TEP repair can then be simultaneously applied to other hernias including ventral/incisional hernias [22–25]. Just like surgeons who have accomplished the art of laparoscopic repair, one would never go back to open mesh repair. Similarly, once accomplished with SILS, the surgeon, such as the author, would never go back to multiport repair unless it is absolutely necessary.

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Massive Inguino-scrotal Hernia

18

Michael Ohene-Yeboah

Introduction

Inguinal hernia is very common worldwide. In Ghana, nearly 11% of men either have a detectable inguinal hernia or a groin scar indicating a previous repair [1]. Large and long-standing inguinal hernias are common in countries in which access to hernia repair surgery is severely limited due to a lack of patient knowledge, trust in the health system or funds to pay for treatment.

This is so in many low- and middle-income countries (LMIC) as in sub-Saharan Africa. In Ghana, the estimated repair rate is 30 per 100,000 population per year [2]. Much higher rates of repair are reported from Europe and North America. This chapter will detail the repair of these types of hernias in LMIC, but the principles presented can be used in any part of the world.

Anatomic Considerations

Inguinal hernia is the more common type of the groin hernias, about 20 times more frequent than the femoral hernia. It occurs in the inguinal canal. The inguinal canal is found in the groin: the part of the anterior abdominal wall that is below the level of anterior superior iliac spines. The inguinal canal is the site of one defect (the internal inguinal ring) and one weak area (the posterior wall of the canal). The internal inguinal ring is a defect in the fascia transversalis and transmits the spermatic cord in the male and the round ligament of the uterus in the female. The posterior wall of the inguinal canal is bereft of muscle and constitutes a design defect in the structure of the abdominal wall. The positive pressure in the abdomen means that abdominal viscera or contents often bulge or protrude through these two areas. The inferior epigastric artery is a useful anatomic landmark in the groin. The internal ring is lateral, and the posterior wall is medial to the artery: we can distinguish the lateral from the medial inguinal hernia.

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Inguino-scrotal Hernia

Definition and Classification

There are various gradings or classifications of inguinal hernia. Large inguinal hernias have also been referred to as giant inguinal hernia. In Table 18.1, the clinical classification focuses on aspects of the surgical procedure such as difficulty and duration of operation as well as selection of appropriate anaesthetic technique and level of surgical expertise required.

H3 and H4 hernias that are 20–30 cm or more below the pubic crest are massive (Fig. 18.1). In many LMIC, inguinal hernia repair is often performed by non-surgeon physicians. The value of this classification is that it is clinical and provides for the selection of the level of expertise and the type

Table 18.1 A clinical classification of inguinal hernia according to Kingsnorth [3]

Grade	Site	Reducibility	Further grading for H3 and H4. Distance from pubic crest in cm
H1	Groin hernia	Spontaneously reducible	
H2	Groin hernia	Reducible with gentle manual pressure	
H3	Inguino-scrotal hernia	Reducible after considerable manipulation	H3-10
			H3-20
			H3-30
H4	Inguino-scrotal hernia	Irreducible	H4-10
			H4-20
			H4-30

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Fig. 18.1 A massive inguino-scrotal hernia

of anaesthesia required for the repair. Experienced surgeons may also find the classification useful when deciding to delegate the procedure to a junior. Massive inguinal hernias are often operated on by very experienced surgeons under general anaesthesia with endotracheal intubation.

Pathology of Massive Inguino-scrotal Hernia

The massive contents inside the hernia sac and outside the abdominal cavity lead to a reduction or contraction of the intra-abdominal cavity over time: loss of domain. Abrupt and forced reduction of the massive contents into the contracted abdominal cavity is associated with an increase intra -abdominal pressure: intra-abdominal hypertension. The associated physiological derangements include a decreased of the venous return, cardiac output and the systemic blood pressure. The respiratory rate and mean airway pressure are both increased, but the tidal volume and the pulmonary compliance are reduced. These changes are mainly due to splinting of the diaphragm.

Clinical Features of the Massive Inguino-scrotal Hernia

These massive hernias often cause difficulty in walking, sitting or lying down, with mobility dramatically restricted. The penis may be buried inside the scrotum causing dribbling of urine over the scrotal skin, which is already congested by lymphatic and venous oedema, leading to excoriation, ulceration and infection. Patients may also complain of difficulty in voiding and recurrent urinary tract infections, especially when the bladder is contained within the hernia sac.

Diagnosis: The diagnosis of massive inguino-scrotal hernia is clinical. Most patients have had a long-standing inguino-scrotal hernia (Fig. 18.1). They tell the doctor that they have a hernia.

Basic investigations to be done include:

Blood for haemoglobin, sickling and haemotocrit and urine for sugar, protein and casts

Stool for worms and amoebae

For patients above 40 years or hypertensive:

A chest X-ray

An electrocardiogram

Fasting blood sugar

Liver function tests

Preoperative Assessment

Smoking must stop for at least 4–8 weeks.

Cough must be treated until no sputum.

Excoriations of the scrotal skin must be treated.

Bladder catheterization prevents further excoriation of the scrotal skin.

Medical conditions, such as high blood pressure and diabetes, must be controlled.

Testicular ultrasound can detect testicular atrophy.

A barium enema is safer than a colonoscopy to avoid perforations.

A retrograde cystogram to outline the bladder that may be in the hernia sac.

A CT scan of the hernia mass.

The surgeon has to inform the patient that he may lose a testis and half of the scrotum.

Preoperative Preparations

Massive inguino-scrotal hernia may contain in the hernia sac large parts of the large bowels which may require resection to reduce volume. As part of the preoperative preparations, it is expected that the surgeon arranges to group and save two pints of blood and to cleanse the large bowel for possible resection and anastomosis. Procedures to increase the intra-abdominal volume require special considerations.

Emergency surgery for strangulated massive inguino-scrotal hernia requires the replacement of fluid loses and correction of any electrolyte deficiencies. A urine output of at least 1 mL per kilogramme body weight in an hour prevents acute renal injury. It is advisable to administer an antibiotic before operating on these emergency cases.

Patient Positioning and Theatre Setup

It is enough to use the standard supine position (Fig. 18.2) with general anaesthesia and endotracheal intubation. This position ensures adequate exposure of the anterior abdominal wall. Piped oxygen is preferred to the use of cylinders. Where there is no piped oxygen, cylinders are used with the usual precautions. The setup must include suction machines, monitors and pulse oximeters that are functioning and have been tested just before use. The overhead operative theatre lights must be functioning, bright and mobile to ensure proper illumination of the operative field. The surgeon may consider transferring the patient if his theatre lacks these basic equipment.

Incision and Access

Once the patient is fully anaesthetized, an attempt is made to reduce the hernia, and many H3 or H4/20–25 cm massive hernias may reduce. In most cases, the standard oblique groin incision that is extended 1 or 2 centimetres beyond the pubic tubercle onto the crest adequately exposes the mass of tissue entering the scrotum. Attention must be paid to bleeding, and careful haemostasis at all stages of the procedure is rewarded with small or no post-operative haematomas. An experienced assistant is needed, and the operative trolley of the scrub nurse must be adequately supplied with a wide range of retractors.

Fig. 18.2 Patient in position for the repair of a right massive inguino-scrotal hernia

Operative Steps

The aponeurosis of the external oblique muscle is exposed once the superficial epigastric, superficial circumflex iliac and the superficial external pudendal vessels in the subcutaneous layer have been divided and securely tied with number 2/0 vicryl ligatures. The inguinal canal is opened with the standard procedure of dividing the external oblique aponeurosis at the point level with medial crux of the external inguinal ring. An attempt is made to mobilize the spermatic cord in the usual way. This requires considerable gentleness to minimize bleeding. If this fails, the cord coverings are excised at the level of the pubic crest to expose the sac of the hernia. An attempt is made to deliver the contents of the hernia sac onto the operative field. If this procedure fails, the internal ring is extended lateral, and the hernia is reduced. The anaesthetist is then requested to assess the respiration. For most massive hernias, there is a significant reduction in the lung volumes and breathing capacity. This is an indication to perform a volume reduction procedure.

The greater omentum is a regular content of the sac of a massive inguino-scrotal hernia; an omentectomy of variable extend may make it possible to reduce the hernia and yet preserve adequate respiration. Other volume or mass reduction procedures that may be considered at this stage include colectomy of variable extent or some other form of bowel resection as the case may be. There is always the option of a second incision: a lower midline abdominal incision. Many junior surgeons find that this incision makes it easy to return the contents of the sac into the abdominal cavity. It also allows the performance of a major volume reducing procedure such as a hemi-colectomy without difficulty. This second incision may be optional in elective repair, but in emergency situations and in the hands of an inexperienced operator, it is so useful as to be considered mandatory. Once the contents of the sac are in the abdomen, the sac is divided at some point proximal to the fundus and closed securely with a vicryl number 00 or 1 or even 2 ligature. Again careful haemostasis is advised. The distal sac must not be closed.

The dissection of the posterior wall can now start with the reidentification of the iliohypogastric, ilioinguinal and genital branch of the genitofemoral nerves. In these massive hernias, this step may not be easy. The anatomic situation and the attenuated condition of the tissues in massive long-standing inguino-scrotal hernias provide an absolute indication for the mesh or the Lichtenstein procedure. Tissue repair techniques are contraindicated in this situation. The operator must clearly demonstrate the anatomic landmarks for mesh insertion: the internal ring, the conjoint tendon, the inguinal ligament and the pubic tubercle. A polypropylene mesh of standard and appropriate size is sutured into place with number 2/0 Prolene sutures [4].

There are other techniques apart from bowel resection that may be used when there is evidence of loss of domain to prevent intra-abdominal hypertension. Preoperative progressive pneumoperitoneum is often quoted in the literature [5]. The drawback here is that the pneumoperitoneum causes expansion of the thin hernia sac rather than the contracted abdominal cavity. It requires prolonged preoperative hospitalization but has a high failure rate.

There are plastic surgery techniques or procedures such as rotation of viable tissue with extended abdominal wall reconstruction by the use of mesh [6]. These procedures may be considered in the case of severe weight loss associated with extreme contraction of the abdominal cavity. A new technique is the open or laparoscopic component separation to increase the capacity of the abdominal cavity.

Closure

Provided there is no increased intra-abdominal pressure, the groin and the lower abdominal incisions are closed in the standard manner. The operator must always leave a drain of any kind in the scrotum. Redundant skin will recover once there is no post-op infection. However, extensive redundant flabby skin is best excised.

Post-operative Management

These patients do not require continuous monitoring as in an ICU. In the immediate post-operative hours, close monitoring of the blood pressure and the urine output in a standard recovery ward are critical to reveal very early any signs of intra-abdominal hypertension. Nasogastric decompression must continue if there was a bowel resection until the ileus is over. A clinical chest examination is useful to detect atelectasis and other complications of prolonged anaesthesia. A scrotal support may facilitate early ambulation. The patients can be discharged within the week and reviewed at 2 weeks and 1-year post-operative.

Tips and Pitfalls

The surgeon needs to arrange to start the operation early. A second case on the list is ill-advised. If your assistant failed to pass a bladder catheter, then the surgeon must do it. Lack of a catheter significantly increases the risk of bladder injury. If the groin incision does not expose the pubic tubercle, it is not possible to identify the anatomic landmarks. To rush is to court disaster: arrange for ample time. Rough handling of the tissues can result in large, unsightly and embarrassing post-operative scrotal oedema and haematoma. If the patient is pale post-operative, do not hesitate to transfuse at least two pints of blood.

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Management of Abdominal Wall Hernias, Sports Hernias, and Athletic Pubalgia

19

Wen Hui Tan and L. Michael Brunt

Groin injuries are a common occurrence in sport, especially in elite-level athletes. Most of these injuries are muscular strains that resolve completely with standard conservative management measures. However, some groin injuries result in a significant loss of playing time and can be a source of persistent pain that limits performance. Over the last 20 years, a subset of athletes with chronic, unremitting groin pain known commonly as "sports hernia" has become increasingly recognized. These injuries present challenging diagnostic and therapeutic management problems for athletic trainers and physicians because of the broad range of diagnostic possibilities, the subtle physical exam findings, and the anatomic complexity of the lower abdominal and groin region. In this chapter, the clinical presentation, diagnostic evaluation, and treatment options for athletes with a possible sports hernia will be reviewed. The differential diagnosis of athletic groin pain will also be discussed since surgeons who treat these athletes must understand the spectrum of injuries in order to make an accurate diagnosis.

Background and Epidemiology

Athletes who play certain sports, such as ice hockey, football, soccer, and baseball are especially vulnerable to groin injury because of the rapid acceleration/deceleration movements and repetitive twisting and turning motions carried out at high speeds. The reported incidence of groin injuries varies by sport and level of play: ranging from 5 to 28% in soccer players [1–3] and 6 to 15% of ice hockey players [4, 5]. In one study, groin injuries accounted for 10–43% of all muscle injuries in elite Scandinavian league hockey players [6, 7]. Another review found that 5–9% of hip/groin injuries were found in high school athletes, compared to 3–11% in Olympic-level athletes and 10–18% in professional soccer players [8]. Though an increasing number of female patients are being diagnosed with sports hernias, the vast majority of patients are male [9]. Unlike most other sports injuries, athletic groin injuries are soft tissue in nature and do not result from direct physical contact.

Risk factors for groin injury have been examined by several groups. Emery and colleagues [10] analyzed injury reports from six NHL seasons from 1991 to 1992 through 1996–1997 involving 7050 players with a subset analysis of the 1995/1996 and 1996/1997 seasons. Six hundred seventeen injuries were reported for an injury rate of 13.3–19 abdominal and groin injuries per 100 players. Not surprisingly, injuries were more common during training camp and early in the season. One-fourth of injuries were abdominal muscle strains, and 56% of reinjuries occurred in same season. The median time lost was seven practice or game sessions (range 0–180), and time loss was greater with abdominal injuries (median 10.6 sessions) than adductor injuries (median 6.6 sessions). Their group subsequently carried out a prospective study of National Hockey League (NHL) players over the 1998–1999 NHL training camp and regular season. Risk factors associated with an increased risk of injury were (1) <18 sports-specific training sessions (e.g., on ice) in the off-season (RR3.4), (2) history of previous groin or abdominal strain (RR 2.9), and (3) veteran player status (veteran > rookie) (RR 5.7) [11].

Reduced adductor strength relative to abductor strength was also found to be associated with a higher rate of groin injury in one study of NHL hockey players [12]. Tyler et al. prospectively study hip strength and flexibility in one NHL

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team and found that players whose preseason adductor strength was <80% of abductor strength were 17 times more likely to sustain an adductor strain. Perhaps more importantly, they showed that an adductor strengthening program reduced the incidence of groin injury from 3.2/1000 to 0.7/1000 player game exposures.

Differential Diagnosis

The causes of groin pain in athletes are numerous and most commonly include muscular strains of the adductors, lower abdominals, and hip flexors. In addition to sports hernia, other conditions that can cause groin pain are osteitis pubis, stress fractures, hip and pelvis injuries, inguinal hernia, and various non-musculoskeletal-related conditions including intra-abdominal pathology. In one recent review, the five most common surgical causes of groin pain in athletes were femoroacetabular impingement, sports hernia/athletic pubalgia, adductor-related pathology, inguinal-related pathology, and labral pathology [8]. A detailed discussion of the clinical presentation and management of these various entities can be found in recent reviews on this subject [13–19].

Stress Fractures: Stress fractures of the pelvis and hip typically are associated with extreme athletic endurance activities such as with long-distance runners and military recruits. The mechanism is thought to be due to the bone breaking down faster than it can remodel and is related to overuse. Women at risk for osteoporosis may be especially vulnerable. Associated factors may include a change in training duration or intensity and change in foot gear or training surface. The most common sites in the groin region are the inferior pubic ramus and femoral neck. An unrecognized stress fracture of the hip can lead to avascular necrosis; therefore, early diagnosis and treatment are essential. Plain X-rays may not reveal a fracture, and as a result, MRI is indicated in suspected cases. Pubic ramus fractures should be treated by rest and other conservative measures and usually resolve within 4–6 weeks. Femoral neck fractures may require orthopedic fixation.

Osteitis Pubis: Osteitis pubis is a condition of unknown etiology that is most likely due to overuse/repetitive trauma and abnormal biomechanics of the pubis. It is most common in runners and soccer players but can also occur in swimmers, soccer, and hockey players. The clinical presentation consists of midline pubic symphysis pain that may be referred to adjacent areas including the adductor region. In one series, 80% had adductor pain, 30% abdominal pain, and 12% hip pain [20]. Radiographic findings in osteitis pubis may include widening of the symphysis, sclerosis along the pubic rami, and edema on MRI. Bone scans typically show increased uptake on both sides of the pubic symphysis (Fig. 19.1). Treatment consists of a reduction in activity, pelvic stretching (especially of adductors), anti-inflammatory medications, and, for acute or refractory cases, a corticosteroid injection into the symphysis. The time frame for return to sport is unpredictable but may take several months in some cases.

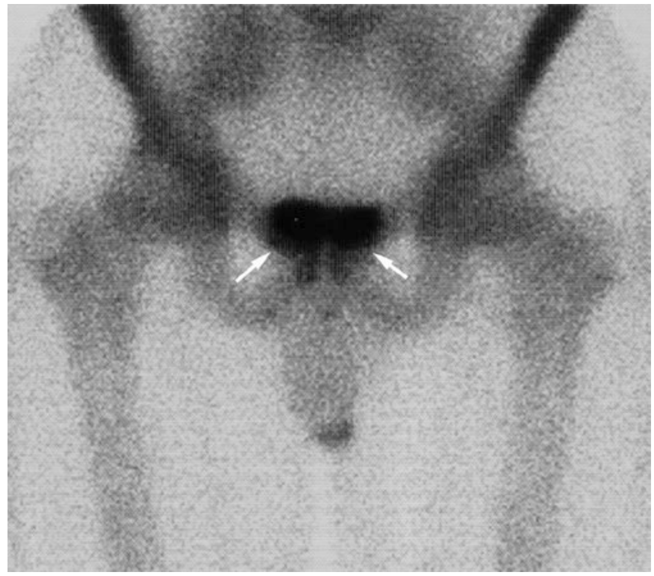

Fig. 19.1 Bone scan that shows increased uptake in both pubic rami (*arrows*) in an athlete with osteitis pubis

Adductor Muscle Group Strains: The adductor group is the most frequent site of sports groin injury and most commonly involves the adductor longus. In one series, adductor longus injuries accounted for 62% of sports groin injuries [1]. A history of a sudden injury and even a pop in the groin are not uncommon. The mechanism involves an eccentric force on the muscle (i.e., sudden stretching when the muscle is contracted). Symptoms and findings are medial thigh or groin pain with associated pain with passive or resisted adduction movements. In acute complete tears, there may be medial thigh ecchymosis and even a palpable defect. Most adductors injuries are strains and not complete tears of the tendon from its attachment to the pubis (Fig. 19.2). In chronic cases, these injuries may overlap or coexist in their clinical presentation with sports hernia and osteitis pubis. Imaging with MRI is indicated to define the extent of the injury in severe cases or those that do not resolve with conservative management. Treatment may vary according to the location and chronicity of the injury but initially should consist of rest, ice, and compression. Once symptoms subside, management should consist of progressive range of motion exercises followed by balance training/graduated strengthening and finally sports-specific functional activities. Time to return to play may vary from a few days to several weeks depending on the severity of the injury. However, some athletes have been able to return to play from even complete adductor longus tears within 5–6 weeks of injury [21].

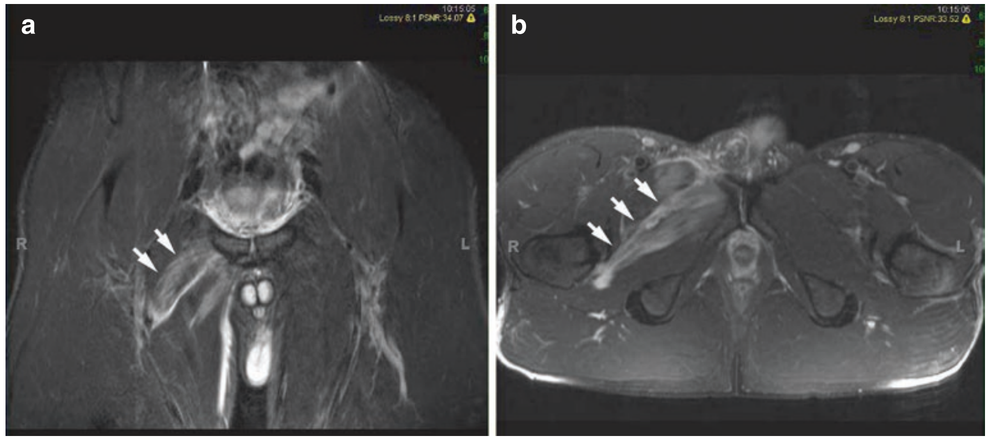

Fig. 19.2 MRI that shows extensive contusion that involves right adductor muscle group. Note the edema (bright appearance) throughout the muscle belly and feathery appearance indicating hemorrhage into the muscle planes. (**a**) STIR (short T1 inversion recovery) coronal sequences and (**b**) T2 fat-suppressed sequence

Iliopsoas Strain: Muscular strains of the iliopsoas present with deep groin or hip pain that is aggravated by hip flexion. The mechanism of injury is often from a hit the player sustains when the leg is extended, a common occurrence in soccer players. Symptoms consist of pain with resisted hip flexion [15], pain with passive hip extension, and a snapping sensation in the hip. Treatment consists of nonsteroidal anti-inflammatories, rest, stretching, and strengthening exercises. A corticosteroid injection may be considered for recalcitrant cases.

Hip Injuries: Hip injuries may also be a source of groin pain in athletes. These may include labral tears, femoral acetabular impingement, and femoral neck fractures. Symptoms may overlap or coexist with sports hernia-type pubalgia injuries. Labral tears present with pain in the hip or groin and mechanical symptoms such as a locking or catching sensation. Treatment is often arthroscopic debridement. Femoral acetabular impingement is a condition in which the femoral head and acetabulum rub abnormally and the resultant excessive friction may lead to cartilage damage, labral tears, and early hip arthritis. Stress fractures of the femoral neck should also be considered in the differential diagnosis and may lead to avascular necrosis if unrecognized. Exclusion of hip pathology first requires examination by an experienced orthopedist. Plain hip X-rays are useful, but hip MRI is necessary to identify labral tears.

Athletic groin injuries should be managed initially with standard conservative management techniques. The vast majority of these injuries resolve and do not evolve into a sports hernia or chronic pubalgia. However, injuries that persist more than 3 months without significant improvement are associated with an increased likelihood of requiring surgical intervention. Ekstrand [22] carried out a prospective, randomized trial in soccer players with chronic groin pain of more than 3 months duration. Players were randomized into four groups—controls with no treatment, two different physical therapy groups, and a surgically treated group who underwent inguinal floor repair ± inguinal and iliohypogastric neurectomy. Only the surgically treated group showed substantial and statistically significant improvement over the 6 months of the study. In another prospective trial, Paajanen and colleagues randomized 60 athletes with 3–6 months of chronic exertional groin pain to either continued physical therapy or surgical treatment using a laparoscopic mesh repair [23]. After 3 months, 90% of the surgically treated athletes had returned to sport compared to only 27% in the conservatively treated group, and by 12 months, the return to sport rate was 97% vs 50%. Moreover, seven patients in the physical therapy group crossed over to surgery after 6 months. These studies provide strong support for the rationale for surgical management in appropriately selected athletes.

Diagnostic Evaluation

Terminology

Various terms have been used to refer to athletic injuries to the lower abdominal/inguinal region that result in a syndrome of chronic exertional pain. These include “sports hernia,” athletic pubalgia [24], abdominal core injury, posterior abdominal wall deficiency [25, 26], Gilmore’s groin [27, 28], and hockey groin syndrome [29]. The term sports hernia is potentially misleading because it implies the presence of a conventional hernia which is not the case. More recently, a consensus conference meeting held by the British Hernia Society advocated the term “inguinal disruption” [30], and a second Delphi process expert consensus meeting in Doha, Qatar, recommended the following terminology, inguinal-related groin pain, adductor-related groin pain, iliopsoas-related groin pain, hip-related groin pain, and other anatomic causes of groin pain (neurologic, gynecologic, urologic, etc.,), to better describe the anatomic origins of the pain [31]. To date, these terms have not yet become ingrained in clinical usage, and, therefore, the broader term athletic pubalgia is more commonly used to describe this group of clinical entities. As will be discussed below, the pathophysiology is more complex than a simple hernia, and therefore, the term sports hernia is not a precisely accurate description of this condition. Nonetheless, "sports hernia" is firmly ingrained in the athletic community and sports media and will likely continue to be used in everyday practice.

Clinical Presentation

The classic symptoms in athletes with athletic pubalgia-type injury are pain that is localized to the lower abdominal and inguinal region that occurs during the extremes of exertion, such as with the initial propulsive movements of running, skating, and sudden stops, starts, or cutting movements. Ice hockey players may have pain when shooting the puck and soccer athletes with kicking the soccer ball. Other sports commonly associated with sports pubalgia include middle-distance running, lacrosse, football, rugby, cricket, and Australian rules football; swimming, cycling, and boxing have also associated with this condition but less commonly so [32]. The onset is often insidious without a specific precipitating event, and there may be associated adductor symptoms. One or both sides of the groin may be involved.

A challenge in evaluating and managing groin pain in athletes is that the clinical presentation may vary substantially and may not be limited to distal rectus and inguinal floor pathology. Meyers [33] has described 17 different clinical syndromes that involve non-hip soft tissue structures that can be primary causes of athletic groin pain. These most commonly include variations of injuries to the rectus abdominis, adductor muscle groups, or a combination thereof. Less common variants include severe osteitis variant, baseball pitcher/hockey goalie syndrome in which there is a tear of the adductor and adductor muscle belly, iliopsoas variant, and rectus femoris variant. Because of the potential coexistence of more than one site of injury and overlap of symptoms with hip and other pathology, it is important that such athletes undergo careful examination by a sports orthopedist prior to referral to a hernia surgeon to exclude a source of pain from the hip and other sources. In addition, an appropriate trial of conservative management and physical therapy should first be undertaken with rare exception.

Evaluation of the athlete with a chronic groin injury should include a detailed history regarding the injury. Questions that should be asked include precise location of pain, duration, onset, involvement of thigh or hip, activities that worsen the pain, presence with sneezing or coughing, and whether pain occurs only with activity or also with rest. The level of sport activity and intensity of participation should also be determined, as many groin injuries, especially in noncollegiate or professional athletes, are related to overuse. Patients should also be queried regarding what conservative management steps such as icing, anti-inflammatory medications, and physical therapy that have been undertaken before evaluation.

Physical exam findings are a critical component of the assessment and must include evaluation of the inguinal floor, pubis, rectus abdominis, adductors and hip flexors, and hip and should include muscle-specific resistance maneuvers to identify areas of pain and tenderness. In the classic sports hernia pubalgia syndrome, the most consistent findings are tenderness in the medial portion of the inguinal canal or along the distal rectus abdominis muscle. Other findings that may be present include a dilated external inguinal ring, a palpable gap or defect over the external oblique aponeurosis and inguinal floor, and pain with a resisted sit-up or resisted trunk rotation (Fig. 19.3). Pain with resisted adduction and adductor tightness may be present, especially if there is an adductor component to the injury which is frequently the case. A true inguinal hernia is rarely present, and there is typically no clinically evident hernia bulge. In our series of athletes in whom this diagnosis was made, the most common exam findings preoperatively were a weak inguinal floor (90.7%), tenderness over the medial inguinal floor/lower lateral rectus (80.2%), pain with a resisted sit-up (63.8%) or trunk rotation (73.3%), and pain with resisted adduction (56.7%) [34].

Imaging

Imaging tests are important to exclude other pathology and to help substantiate the diagnosis. Plain X-rays are usually normal but should be done if hip pathology or stress fracture is suspected. A bone scan may be ordered to rule out

Fig. 19.3 Exam for athletic pubalgia with palpation of both inguinal floors during a sit-up

osteitis pubis but is less commonly utilized than other imaging modalities. Pelvic MRI has been the most useful modality in our experience because of the details of the bony pelvis and associated muscular tears and strains it provides. Pelvic MRI was also the preferred method of imaging in patients with suspected athletic pubalgia in the British Hernia Society consensus statement released in 2014 [30]. In the athletes with a sports pubalgia seen at our center, the most common MRI findings have been edema or stress reaction and secondary cleft sign in the adjacent pubis (Fig. 19.4). Tears of the distal rectus or rectus/adductor complex may also be seen in some cases (Fig. 19.5). Adductor pathology may include tears and/or edema indicating underlying chronic tendinopathy (Fig. 19.6). Zoga and colleagues [35] recently reported results of MR imaging in 141 patients in whom athletic pubalgia was diagnosed clinically. The most common findings were rectus abdominis tendon injury, combined rectus and adductor

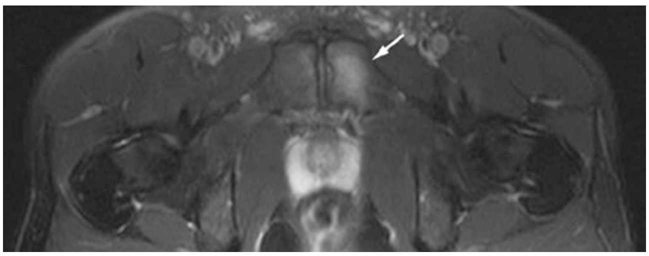

Fig. 19.4 T2 fat-suppressed MRI sequence that shows marrow edema (*arrows*) in the pubis in an athlete with sports pubalgia

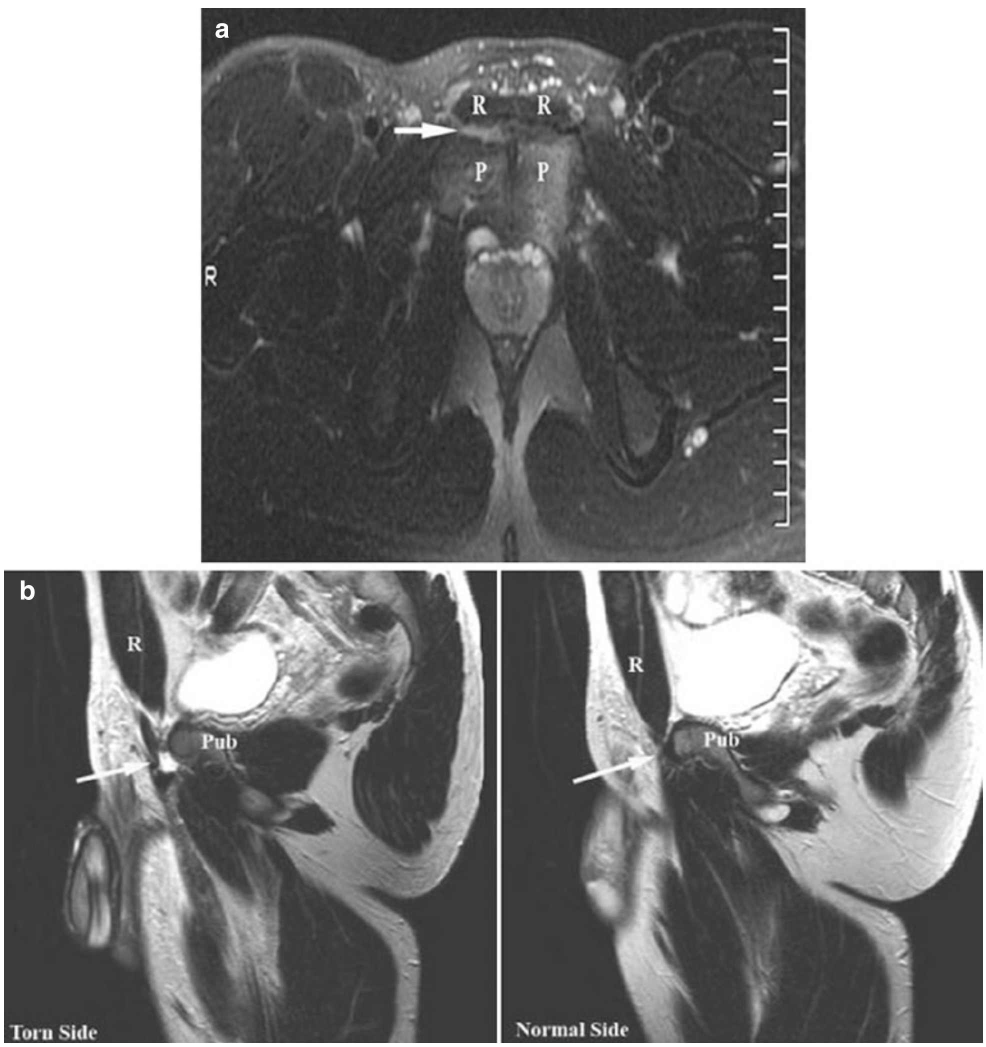

Fig. 19.5 (**a**) T2 fat-suppressed MRI of right distal rectus tear (*arrow* pointing to bright fluid in cleft where rectus is torn); *R* = rectus, *P* = pubis. (**b**) Sagittal fat-suppressed sequence that shows distal rectus tear with discontinuity (*left hand panel*) and normal contralateral side (*right hand panel*). The arrow on the left panel points to the tear (appears bright on this sequence) and to the normal rectus insertion on the right panel. *R* = rectus, *Pub* = pubis

Fig. 19.6 MRI of high-grade left adductor tendon avulsion (*arrows*)

injury, symphysis marrow edema, and a secondary cleft. The secondary cleft sign refers to an abnormal extension of the central symphyseal cleft at the anterior-inferior margin of the body of the pubis. It is thought to result from a microtear at the origin of the adductor longus and gracilis tendons [36].

Improved MRI imaging techniques have resulted in positive findings in a higher percentage of patients in recent years. Zoga [35] reported that MRI had a sensitive of 68% and specificity of 100% for rectus abdominis tendon injury and 86% and 89% sensitivity and specificity, respectively, for adductor tendon injury. MRI techniques for sports pubalgia should center the imaging volume on the pelvis which is facilitated by use of a phase array pelvic surface coil [36]. Both fat-suppressed T1-weighted and fat-suppressed fluid-sensitive imaging sequences should be included. Imaging should be carried out in three orthogonal planes (coronal, axial, and sagittal); additionally, axial/oblique sequences may be useful for better delineating adductor tendon origins [36].

Although not as commonly employed in North America, some groups have utilized ultrasound in the evaluation of athletic groin pain [37, 38]. Ultrasound has the advantage of real-time dynamic assessment of the inguinal floor and abdominal wall and can be used in conjunction with patient Valsalva maneuvers. The disadvantages are that it is operator-dependent and, therefore, requires an experienced examiner and does not readily visualize the other bony and muscular structures around the pubis and pelvis. Muschawek and Berger [38] preferentially utilize ultrasound as the primary imaging modality in athletes with groin pain. A high-frequency transducer (5–13 MHz) is used, and the motion of the inguinal canal and floor is observed with the patient supine during a stress maneuver (Valsalva). Positive findings consist of a convex anterior bulge of the posterior inguinal floor during Valsalva.

Pathophysiology

Several mechanisms have been proposed to account for the pain symptoms in athletic pubalgia syndromes. As discussed above, Meyers has proposed the concept of the "pubic joint" in which the pubis acts as the central fulcrum for the powerful abdominal and thigh muscles [39, 40]. Normally these muscles are symmetrically distributed. In athletes, especially those performing at high levels, tremendous torque is generated across the pelvis. If an imbalance in these forces is present, for example, from relative weakness of one or more muscle groups, then further weakening may develop leading to increased stress across the pubis and chronic pubalgia pain. The pain may result due to weakening of the rectus muscle at the pubic insertion site, which in turn results in unopposed action of the adductor longus [39] and increased pressure within the adductor compartment. Cadaver dissections have also shown that the anterior edge of the inferior pubis has fine, teeth-like projections that contact the adductor muscles and tendons, which may contribute to adductor compartment pain. The approach to repair as described below, therefore, is tailored to address these biomechanical considerations.

A second potential mechanism for athletic pubalgia involves weakening in the posterior floor of the inguinal canal. The weak posterior floor can result from an imbalance in forces between the relatively stronger hip musculature and the weaker lower abdominals [41, 42]. The weak posterior inguinal floor can lead to widening of the groin canal which in turn allows the rectus muscle to retract medially and superiorly [43]. The increased tension at the pubic bone that results causes pain at the symphysis or one or both sides of the pubis. Muschawek has theorized that compression or entrapment of the genital branch of the genitofemoral nerve by a discrete, localized bulge in the posterior wall of the inguinal canal during Valsalva maneuver is involved in the pain pathway in some athletes (Fig. 19.7). This concept has led to selective resection of the genital nerve in some athletes in her series.

Finally, the Montreal group [29, 44] has postulated that tears in the aponeurosis of the external oblique coupled with entrapment of branches of the ilioinguinal or iliohypogastric nerves are the central pathophysiologic mecha-

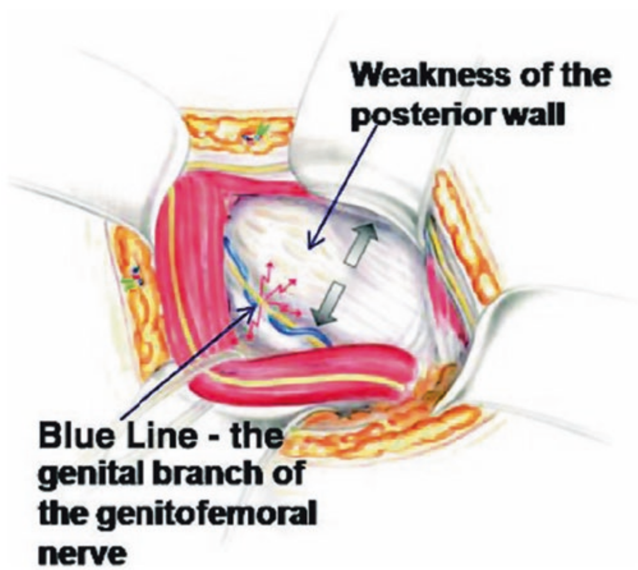

Fig. 19.7 Schematic illustration of localized bulge in posterior inguinal floor with compression of the genital branch of the genitofemoral nerve. From Muschawek U, Berger L. Sports Health (2010); 2; p. 217 (with permission)

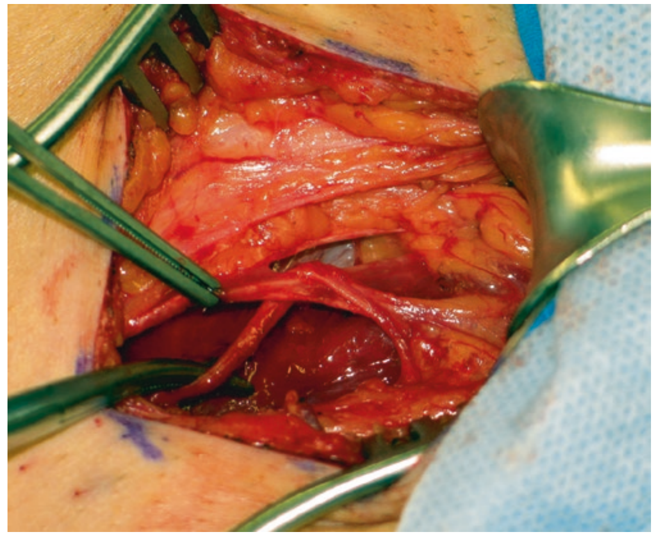

Fig. 19.8 Ilioinguinal nerve exiting through a tear in the external oblique aponeurosis medial to the external ring. Note the acute angle the nerve takes as it exits the aponeurosis, which may be a source of tension on the nerve and resultant pain

nism for athletic pubalgia pain. The external oblique tears may be central, medial, or lateral and single or multiple and may arise from increased intra-abdominal pressure during Valsalva that occur during sudden changes in movement or intense abdominal contraction such as what occurs in pushing against an opponent. A bulky internal oblique has also been a common operative finding and may limit space in the inguinal canal, thereby applying outward pressure on the external oblique that may ultimately lead to a tear. Tension on one or more of nerves as they exit the external oblique may sometimes be observed at operation (Fig. 19.8).

A number of findings have been described at operation that reflect the above mechanisms. These include an attenuated external oblique aponeurosis, disruption or weakness of the posterior inguinal floor, a thin or torn rectus insertion, and, importantly, absence of an inguinal hernia [7]. Other findings that have been reported include a torn or hypertrophied internal oblique [29], entrapment of the ilioinguinal or iliohypogastric nerves within a torn external oblique aponeurosis with a normal posterior inguinal floor [13, 29], and compression of the genital nerve by localized bulging of the posterior inguinal floor. The most common operative findings in our athletes have been an attenuated external oblique aponeurosis (96.7%) (Fig. 19.9), weakened or disrupted inguinal floor (100%) (Fig. 19.10), and lower rectus abnormality in 80.3% (lax insertion, muscular tears) [34]. There was only one indirect hernia identified (1.6%). Clinically insignificant cord lipomas were removed in 18%.

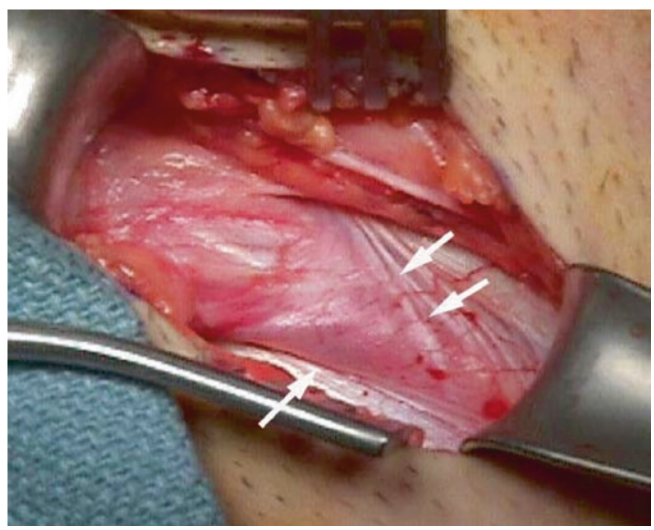

Fig. 19.9 Operative photograph showing marked attenuation in the external oblique aponeurosis

Regardless of the precise pathophysiologic mechanism of groin pain, it would appear that the central variable common to these injuries is stress across the lower abdominal wall that leads to weakening in the posterior inguinal floor or distal rectus tears or both. Whether nerve entrapment is a significant component or not is an unresolved issue, as many groups have reported successful outcomes of surgical repair without nerve resection. Factors that may contribute to the increasing incidence of these injuries include increased weight and strength training, year-round training without

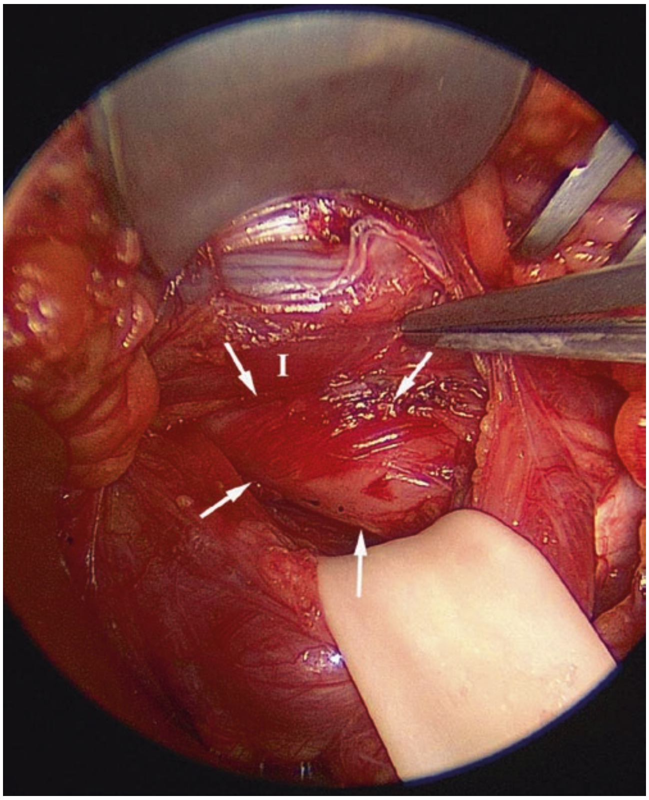

Fig. 19.10 Operative photograph showing a deficient posterior inguinal floor indicated by the *arrows*. The instrument is pointing to the internal oblique labeled I. A Penrose drain encircles the cord structures which are retracted laterally

significant time off, single-sport focus at a young age, and lack of balance in strength and flexibility between the abdomen/core and lower body.

Surgical Treatment

Surgical treatment for sports pubalgia should be reserved for patients and athletes who have the appropriate history and physical exam findings, have confirmatory evidence and/or exclusion of other significant confounding pathology with imaging (MRI or ultrasound), and have failed a trial of conservative management. In general, surgery should be considered only after 8 weeks or more of rest, physical therapy, and other local treatment measures. For recreational athletes, the period of rest and therapy is especially important since they do not often have access to experienced athletic trainers and other resources that are available in the collegiate and professional athletic setting. In our series, the average time from onset of symptoms and injury to surgical treatment has averaged over 10 months.

Consensus is lacking regarding the preferred surgical technique for repairing sports pubalgia injuries, which in part reflects disagreement about the pathomechanics of the injury. To date, in published series, no operation has generated consistently superior outcomes when compared to another operation, but no direct comparisons have been carried out in any controlled trials. In general, three broad categories of repair have been employed: open primary tissue repairs, open tension-free mesh repairs, and laparoscopic mesh repair as described in detail below. Despite differences in approaches, the common goal of each of these operations is to provide support and stability of the inguinal floor and distal rectus across the pubis.

Surgical Approaches

1. Primary pelvic floor repair: Two principal primary repair techniques have been described—primary pelvic floor repair by Meyers [24] and a minimal repair technique [38] by Muschawek. Neither of these techniques employs mesh.

Meyers Technique: The precise technical details of the Meyers approach have not been shown but broadly consist of suture plication or reattachment of the inferolateral border of the rectus abdominis fascia to the pubis and inguinal ligament [24]. This repair is somewhat analogous to a Bassini hernia repair but with differences in the way the sutures are oriented. The goal of the operation is instead to reattach or reinforce the anterior abdominal attachments to the pubis and adjacent ligaments. In order to accomplish this, the distal rectus abdominis muscle fascia is attached directly to the pubis and the inguinal ligament, using a near vertical line of sutures and by staying as close to the pubis and as anterior possible, maximizing anterior pelvic support. A second row of sutures is placed posteriorly onto the rectus fascia to add stability to the anterior row of sutures which is the primary line of support (W Meyers, personal communication).

The pelvic floor repair operation has been coupled with an adductor release in selected athletes. In the adductor component of the procedure, the anterior epimysial fibers of the adductor longus are incised 2–3 cm from their insertion into the pubis while leaving the adductor muscle intact. Conceptually, he describes a relative compartment syndrome that may exist on one or more of the adductor muscles and that the “release” allows escape of edema due to the entrapment. It is important to recognize that this is not a complete release of the adductor tendon attachment to the pubis but rather a relative loosening of the adductor compartment. It should also be noted that release of one or more adductor muscles is sometimes carried out as an isolated procedure without accompanying pelvic floor repair.

In 2003, Muschawek developed a “minimal repair” technique for athletes with chronic sports groin injuries [38]. The goal of this operation is to stabilize the posterior inguinal floor using a nearly tension-free suture method. The operation is performed under local anesthesia with sedation, and the technique is somewhat analogous to the Shouldice hernia repair but differs in that only the localized area of defect is opened and repaired and not the entire inguinal floor. In selected cases, the genital nerve is sometimes resected because of resultant pressure on the nerve from the posterior floor bulging and resultant nerve fibrosis that can result. A continuous suture is placed using a lip of iliopubic tract sutured first to itself and then over to inguinal ligament. A second row of suture is then placed to lateralize the rectus abdominis fascia which she postulates has been retracted medially and cranially by the posterior floor weakness (Fig. 19.11). These lines of suture serve to counteract the tension at the pubic bone by displacement of the rectus. Lastly, a muscular collar is placed at the deep internal ring using the lateral internal oblique in order to protect the cord structures. Conceptually, mesh is avoided in order to preserve the slide bearing function and elasticity in the inguinal floor.

2. Open tension-free mesh repair: Since primary tissue repairs of true inguinal hernia have been replaced by tension-free mesh approaches because of fewer recurrences and earlier return to activity associated with the latter, it is logical that a tension-free mesh approach could accomplish the goals described above of providing stability and support of the posterior inguinal floor and pubic joint. As a result, several groups including ours have preferentially used mesh to repair sports pubalgia injuries. The techniques used have employed lightweight polypropylene mesh or polytetrafluoroethylene (PTFE) meshes and have either been placed posteriorly and sutured to transversalis aponeurosis/rectus sheath and inguinal ligament similar to the Lichtenstein repair or more anteriorly to support the external oblique aponeurosis.

The approach used by this author is typically carried out under local anesthesia with sedation. The external oblique aponeurosis, which is often thin and attenuated, is opened along the plane of its fibers just as for standard inguinal hernia repair. A careful search is made for the ilioinguinal nerve, which is resected if it is entrapped by a slit in the external oblique or if its course is such that it is vulnerable to adhesion to the mesh or would otherwise interfere with the repair. A search is made for an indirect sac, and any cord lipoma is resected. Damaged or attenuated internal oblique fibers are debrided, and the floor is then reconstructed suturing the mesh medially to the transversus aponeurosis and medially to the inguinal ligament (Fig. 19.12). Although the internal ring is intact in these cases, the mesh is split as it is for a Lichtenstein repair, and the two limbs are sutured together to the inguinal ligament so that a flat conformity of mesh to the posterior floor is maintained. Additionally, one or two interrupted sutures are placed to anchor the mesh and distal rectus in order to further stabilize the rectus and pubis anteriorly. The intact fibers of the external oblique are then sutured together with a heavy absorbable suture (2-0 polyglactic acid) to eliminate the area of attenuation.

The Montreal group utilizes PTFE mesh in their repair and prefers to place the mesh more anteriorly to support the external oblique layer [29, 44]. The repair is carried out under general anesthesia, and the slit in the external oblique is opened generously. The patch is sutured in place to the

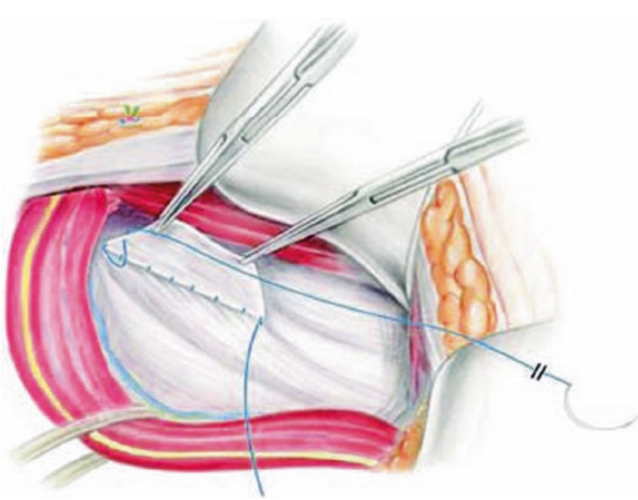

Fig. 19.11 Schematic illustration of the Muschawek minimal repair technique. Two double rows of continuous suture are placed to repair the defect. From Muschawek U, Berger L. Sports Health (2010); 2; p. 218 (with permission)

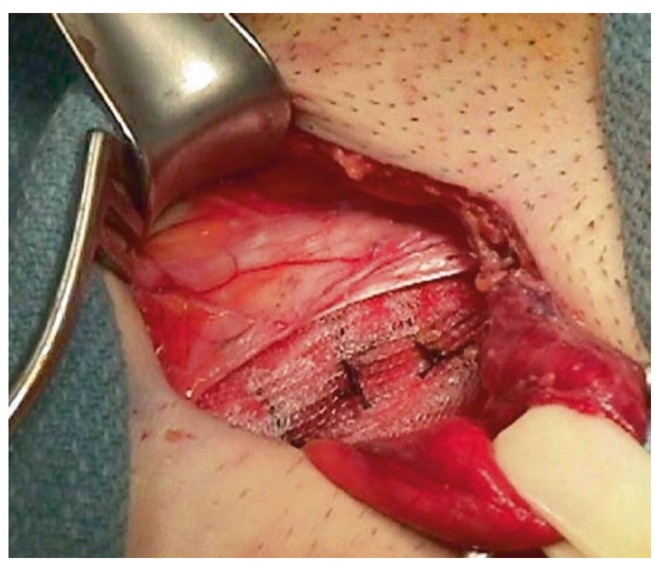

Fig. 19.12 Open tension-free mesh repair of sports pubalgia that shows mesh reinforcement of the posterior inguinal floor and distal rectus

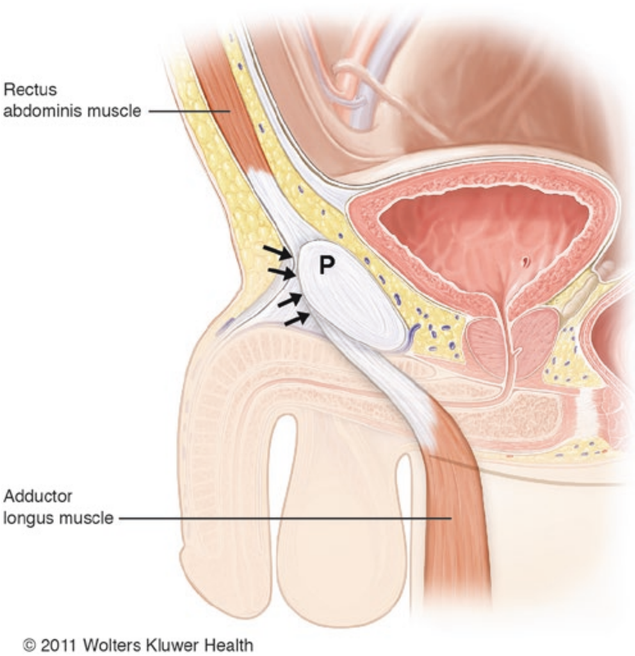

Fig. 19.13 Schematic anatomy of the rectus-pubis-adductor complex attachments from the sagittal view. *Arrows* indicate the area of potential aponeurosis tear. Modified from Brunt LM. Sports Hernia: In: Masters Techniques in Hernia Surgery. Jones DB (ed). Lippincott, Wilkins, Williams. (2013); Fig. 20.2A

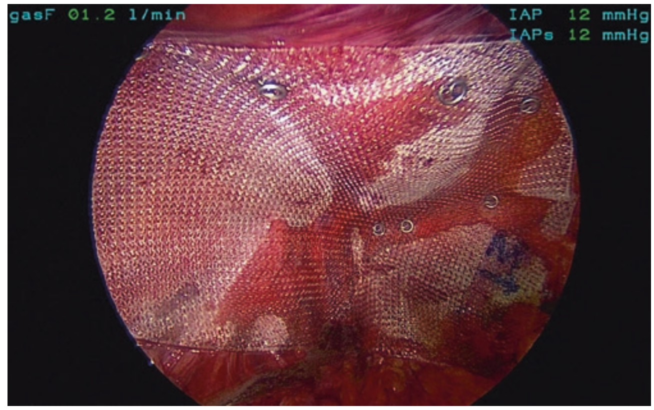

Fig. 19.14 Laparoscopic extraperitoneal mesh positioned to repair the posterior inguinal floor defect

external oblique beyond the margins of the tears using interrupted 2-0 polypropylene sutures (Fig. 19.13). The ilioinguinal and/or iliohypogastric nerves are also routinely resected.

Adductor release: In patients who have athletic pubalgia with demonstrated adductor tendinopathy with symptoms refractory to conservative management (such as physical therapy or corticosteroid injections), a partial adductor release (with or without an accompanying inguinal floor repair) may improve outcomes. The patient's hip should be flexed and externally rotated in a "frog-leg" position. The adductor longus tendon is easily palpable as a thick, strong band on the medial inner thigh. A 2-centimeter incision is made overlying the tendon, 2 centimeters distal to the inguinal crease. A #11 blade can be used to create multiple, staggered incisions in the epimysial fibers of the tendon sheath over a distance of 2–3 cm. This releases tension on the tendon and underlying muscle compartment without performing a complete release [45, 46]. It should be noted that percutaneous adductor tenotomy has also been reported for this condition [47].

3. Laparoscopic (posterior) mesh repair: Laparoscopic repair is a third potential option in athletes with groin pain that is preferred by some groups. However, its role in the repair of athletic pubalgia injuries is unclear. The total extraperitoneal (TEP) approach is generally used in this setting although transabdominal preperitoneal (TAPP) repair and exploration may be indicated in some athletes to exclude intra-abdominal sources of pain (e.g., inflammatory bowel disease, etc.) or gynecologic pathology in women. The technique is similar to that for standard TEP inguinal hernia repair (Fig. 19.14). Lloyd has employed an inguinal ligament release laparoscopically based on the concept that tension in the inguinal ligament is the primary source of pain in this condition. The inguinal floor is then reinforced with a mesh placed laparoscopically similar to a standard TAPP repair [48].

Outcomes of Surgical Treatment: A summary of reported outcomes of surgical treatment depicted by category of repair is given in Table 19.1. Reported results have in the vast majority of cases indicated a return to sport in 90% or more of cases. However, follow-up has been variable or in many cases not reported. Additionally, many studies are small, retrospective, single-center case series [32]. The interval to return to sport has ranged from 2 weeks to 4 months. In our series of over 250 cases of repair, most athletes have returned to their sports within 8 weeks of injury, with returns as early as 5–6 weeks in some cases of in-season repair. Because many of these athletes are operated on at the conclusion of their season, the time pressures for return to play are lessened, and they often extend their rehab over a period of 8–12 weeks.

Primary Repair: Meyers has reported observations from operations in 5218 athletes out of 8490 individuals (61.4%) evaluated for possible sports hernia pubalgia [33]. In the operated individuals, there were 26 different procedures and 121 combinations of procedures performed. The precise details of the procedures performed were not provided but appeared to primarily involve either pelvic floor repair with various combinations of release procedures. The most common sports involved were football, soccer, and hockey, which accounted for 70% of cases. Complications were hematomas that required reoperation in 0.3%, wound infection in 0.4%, dysesthesia in 0.3%, and penile thrombosis in

Table 19.1 Reported results of surgical treatment of sports hernia

	Center	N	Length of follow-up	Interval to return to play	Return to sport
Open primary repairs					
Polglase [56]	Australia	64	8 mo	–	63%
Gilmore [27]	UK	300	–	–	97%
Steele [26]	Australia	47	–	4 months	77%
Meyers [33]	Philadelphia	5218	24 months	Up to 3 months	95.3%
Muschawek [38]	Munich	129	–	4 weeks	
Open primary repair with adductor tenotomy					
Harr [45]	Washington D.C.	22	8 weeks	6–8 weeks	100%
Messaoudi [57]	Deurne	71	4 years	4 months	68% to the same level; 27% to a lower level
Adductor tenotomy alone					
Schilders [54]	London	43	40 months	9.2 weeks	97.6%
Maffulli [55]	London and Rome	29	36 months	–	76%
Open mesh repairs					
Joesting [58]	Minnesota	45	12 months	–	90%
Brown [44]	Montreal	98	–	–	97%
Kopelman [59]	Haifa	51	36.1 months	4.3 weeks	96%
Laparoscopic repairs					
Paajanen [49]	Helsinki	41	50 months	1 month	95%
Van Veen [50][a]	Rotterdam	55	24 weeks	3 months	91%
Ziprin [51]	London	17	–	42 days	94%
Evans [60]	UK	287	3 mos–4 years	4 weeks	90%
Genitsaris [61]	Thessaloniki	127	5 years	2–3 weeks	100%
Mann [62]	Leicester	73	–	4 weeks	99%
Laparoscopic repair with adductor tenotomy					
Rossidis	Gainesville	54	18 months	24 days	100%

[a]Four patients underwent adductor tenotomy

0.1%. Recurrent problems occurred in 16 patients, and reoperation after prior standard inguinal hernia repair (open of laparoscopic) at outside institutions was done in 241 patients. Further details regarding the type of symptomatic failure in these outside procedures were not reported.

Muschawek reported outcomes of a prospective cohort study of 129 patients treated from 2008 to 2009 [38]. At 4 weeks post-repair, 96.1% of athletes had resumed training, and full return to pre-injury sports activity had occurred in 75.8%. No recurrences were reported over the course of follow-up.

Tension-Free Mesh Repairs: Brown and colleagues [44] reported outcomes in 98 elite hockey players using the PTFE mesh approach. Overall, 97 of 98 athletes were able to return to play. Three recurrences occurred between 4 and 6 years after the original repair. All had remedial re-repair and were able to return to play.

At the Washington University Medical Center, over 250 athletes have been operated on for athletic pubalgia over the last 15 years. The majority of these repairs were performed open (87.2%) and were performed laparoscopically in 12.8%. Repairs were unilateral in 82.2% cases and bilateral in 17.8%. Of these patients, 8.9% had had a previous sports hernia repair on either side. Symptomatic outcomes assessed at intermediate (1 year) follow-up showed a successful return to athletic competition in over 90% of cases.

4. Laparoscopic repair: In soccer players with sports hernias, successful outcomes of laparoscopic mesh repairs have been reported by some groups [49–51]. In one study of 55 athletes with chronic groin pain, incipient hernias were diagnosed in 36 cases (65%) including 9 that were bilateral, and true inguinal hernias were seen in 20 athletes (36%) [50]. Laparoscopic repair was carried out in all cases, and five athletes also had an adductor tenotomy performed. At 6–8 weeks, 48 of the patients (88%) had returned to normal sports activities without pain. Five patients had residual groin pain at 12 weeks that ultimately resolved with rest and physical therapy [50]. Of note is that the high incidence of true inguinal hernias in this series differs from that reported in multiple series of open repairs. Whether this observation is due to different

selection criteria for surgery or an artifice of the laparoscopic viewpoint is unclear.

One small prospective randomized trial has been carried out that compared laparoscopic to open repair, primarily in rugby players [52]. Open repair consisted of Bassini repair in 3 athletes and Lichtenstein-type repairs in 11. Training was resumed at 4 weeks in 9 of 14 patients repaired conventionally and 13 of 14 repaired laparoscopically. Recurrent pain developed after one laparoscopic and one open repair each. Despite the apparent earlier resumption of full physical activity after laparoscopic repair, it should be noted that the role of laparoscopic repair in this setting remains controversial. Indeed, a potentially higher failure rate and need for operative reintervention in some of these athletes have been observed anecdotally by some groups [40].

Some groups have reported outcomes in patients after adductor tenotomy alone or in tandem with open or laparoscopic floor repairs. These trials have given varying results, with return to sport rates ranging from 76 to 100% [53–55].

Rehabilitation

Postoperative rehabilitation plays an important role in return to athletics after repair regardless of the surgical approach. Our group has described a stepwise series of activities and exercises (Table 19.2) to assist athletes and athletic trainers

Table 19.2 Postoperative rehabilitation protocol

Phase	Time	Therapy	Sets	Reps	Resistance	Notes
1	0–1 Weeks	Walking	1	5–60 min	3–6 MPH	When patient is able to walk 20 min. continuous begin light hamstring, quad, gastroc low back, and groin stretching
2	2–4 Weeks	Active hip ROM (leg swings), treadmill incline walking, wall sits w/ Swiss ball, quad stabilization, hamstring/gastroc/low back strengthen, begin bike workouts at 2 weeks	1	8 reps per exercise	As tolerated	At start of 3–4 weeks begin scar mobilization of surgical site—ART of surrounding muscle groups—at 4 weeks ART of affected psoas muscle. Avoid excessive trunk extension
3	3–4 Weeks	Hip flexor stretching w/ progression to resistance, light jogging, initiate exercises for transversalis and obliques, controlled rotation exercises, bridging progression, core stabilization exercises	1	8 reps per exercise	As tolerated	Continue scar mobilization
4	4–5 Weeks	Increase to speed and interval training on bike or treadmill, lunges, light sports-specific activities, single leg slideboard/ theraband, lower abdominal exercises, continue core stabilization exercises	1	8 reps per exercise	As tolerated	Continue scar mobilization
5	6–8 Weeks	Speed/function/volume and intensity to maximum, end-stage quadruped/stabilization exercises, muscle length restored/adductor strength bilateral, drills and scrimmage w/ team, MD approval and discharge				Confidence is established with timed drills/bilateral muscle strength, positive finding presurgery now negative, continues emphasis placed on maintaining muscle lengthening and symmetrical abdominal strength through adherence to stabilization program

in guiding return to elite-level athletic competition with applicability to a variety of sports [34]. A focus on both core abdominal strengthening and stabilization as well as lower body strength, flexibility, and balance with special attention to any associated adductor conditions is, we believe, essential to a successful outcome.

Other groups [29, 50] have outlined a schedule for return to sport following surgical repair but with fewer details than provided in our protocol. Muschawek [43] has utilized an accelerated path for return to sport in athletes undergoing the minimal repair technique. Patients are allowed to lift up to 20 kg for the first 14 days after surgery. Biking and running may be resumed as soon as the athlete is pain-free, and activity can be increased after the first 8 days as tolerated. This approach resulted in return to sport activity in 83% of athletes. These findings make the case for a more rapid and flexible timeline for increased activity in this population of patients that is based on symptoms and comfort level rather than a rigid time-based sequence, especially for athletes who have surgery in season, in order to minimize the number of training sessions and games missed.

Summary

In summary, groin injuries are a significant problem in athletes. A multidisciplinary team approach to evaluation and management involving the athletic trainer, orthopedist, physical therapist, and hernia surgeon is key to accurate diagnosis, treatment, and selection of patients for surgical intervention. Surgeons who evaluate athletes for "sports hernia and athletic pubalgia must develop an understanding of the clinical presentation and diagnostic evaluation of related groin injuries. Surgical repair, coupled with a structured rehabilitation program that focuses on balancing strength and flexibility in the lower abdominal and thigh muscles, should allow return to competitive play within several weeks in appropriately selected athletes.

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Femoral Hernia

20

Ursula Dahlstrand

Anatomy

A femoral hernia is a herniation through the femoral ring and into the femoral canal. The femoral canal is the smallest and most medial compartment of the femoral sheath. The intermediate and lateral compartments contain the femoral vein and femoral artery, respectively. The femoral canal contains fat, lymph vessels, a lymph node (Cloquet's gland), and loose connective tissue. The empty space of the canal allows the femoral vein to distend, due to increased venous return or increased abdominal pressure. The canal is conical in shape and about 2 cm long. The wider, cranial end of the canal is called the femoral ring. The posterior boundary of the area is the superior ramus of the pubic bone and the pectineal ligament (Cooper's ligament), the anterior is the inguinal ligament, the medial is the lacunar ligament, and the lateral is the femoral vein. The cone of the femoral canal extends down into the thigh and the tip points toward the saphenous opening (fossa ovalis) in the fascia lata where the great saphenous vein transverses fascia cribrosa and enters the femoral vein (Fig. 20.1).

There are some rare forms of femoral hernia, where the hernia protrudes into the femoral sheath, but not via the femoral canal. In the prevascular femoral hernia, the sac is positioned anterior to the femoral vein and artery, these portions of the femoral sheath with less firm boundaries allowing a possibility for the hernia orifice to grow larger than in an ordinary femoral hernia [1]. Types where the herniation occurs behind the femoral vessels, lateral to the femoral artery, through the lacunar ligament or through the pectineal fascia have also been described.

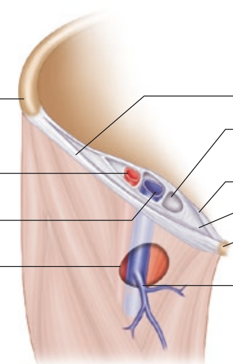

Fig. 20.1 The femoral canal and its boundaries. The femoral canal is the most medial portion of the femoral sheath, bounded by the pectineal ligament (posterior), the inguinal ligament (anterior), the lacunar ligament (medial), and the femoral vein (lateral)

Epidemiology

The true incidence is unknown since no true community-based incidence study has been performed. Incidence rates based on how many patients sought health care and were diagnosed with a hernia can be used for estimation. National morbidity surveys based on data capture in general practice in England and Wales indicate that the "demand incidence rate" for femoral hernia would be 2/10,000 person-years at risk (95% confidence interval 0.5–6.5 and 0.5–5.9 for men and women, respectively) and expected number of persons with a femoral hernia in a population 16 per 100,000. The data needs to be treated with caution due to several influencing factors though [2].

Femoral hernias are much less common than inguinal hernias. Population-based studies and a long consecutive patient series from a single center have found femoral hernias to constitute 2–4% of all groin hernias that are repaired [3–5]. An increased use of laparoscopic methods for repair of inguinal

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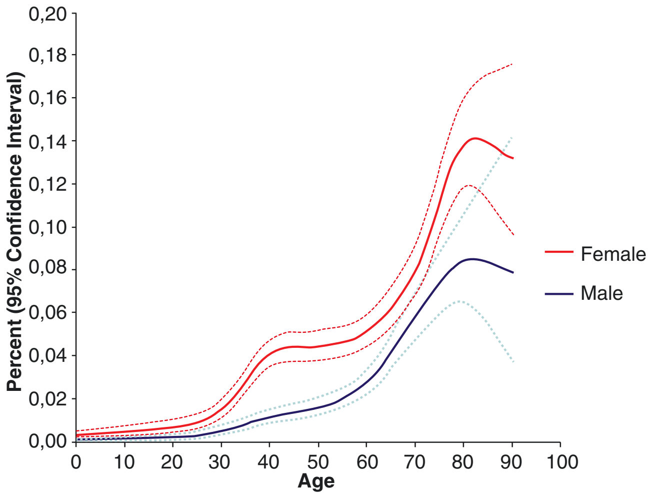

Fig. 20.2 Prevalence of femoral hernia repair stratified by age and gender. The results indicate the percentage of persons at a given age in the population who were operated for a femoral hernia during the 5-year study period. From: Burcharth J, Pedersen M, Bisgaard T, Pedersen C, Rosenberg J. Nationwide prevalence of groin hernia repair. PLoS One. (2013); 8(1):e54367. doi:https://doi.org/10.1371/journal.pone.0054367 [17]

hernias may lead to an increase in reported numbers of femoral hernias as well. In an observational study, a concomitant occult femoral hernia was found in 5% of patients with inguinal hernias who had a laparoscopic repair. The frequency of synchronous femoral hernia in the presence of a symptomatic inguinal hernia was much higher in females than males (37% vs 3%) [6]. Another study discovered occult femoral hernias in 2.4% of their patients; however, their cohort was almost entirely male (0.97% females), whereas the other cohort included 5% females [7]. Femoral hernias are more common on the right side than on the left (ratio 2:1) [3, 5].

Femoral hernias are more common in females than in males [3, 8]. 27% of repaired groin hernias in women are femoral in type; the corresponding proportion for men is 1% [9]. In males, the femoral hernia is one part of a combined hernia in about one third of the cases [3, 5]. Multiple pregnancies are a risk factor for femoral hernia, and it may even be that nulliparous women are not at much larger risk than males [10–12]. It has been suggested in several single-center studies that previous repair of an inguinal hernia is associated to an increased risk for femoral hernia [13–15]. Data from the Danish Hernia Register corroborates this, showing an occurrence of femoral hernia after inguinal hernia repair 15-fold higher than the spontaneous occurrence [16]. The reason for this may be overlooked femoral hernia at the first operation, altered anatomy predisposing for femoral hernia due to the repair, or a combination of both.

The median age at time of repair is 5 years older than for inguinal hernia (65 years vs 60 years) [3]. The age distribution for femoral hernias differs from that for inguinal hernias (Fig. 20.2). Repair for a femoral hernia is utterly uncommon before the age of 20. The risk for femoral hernias increases steadily throughout life, and the peak incidence of femoral hernia repair can be seen in octogenarians [17].

The typical patient with femoral hernia has been said to be an elderly, underweight woman. As reported, female sex and old age are undisputable risk factors. There is also data to support that low BMI is associated to femoral hernia. Among patients who have groin hernia repair, femoral hernias are at least four times more common in patients with a BMI < 20 kg/m^2 than in other patients. The finding can only in part be attributed to the fact that females are over-represented in this group [18].

Diagnosis and Clinical Presentation

The diagnosis of femoral hernia is mainly a clinical one. The classical description of a femoral hernia is a lump, often nonreducible and inferolateral to the pubic tubercle. That being said, it is not necessarily easy to make the distinction between an inguinal and a femoral hernia. The statement that femoral hernias are found below and lateral to the pubic tubercle whereas inguinal hernias are situated above and medial to the tubercle does not always hold true.

The femoral sheath fuses into the fascia of the thigh at the distal end of the femoral canal at the lower border of the saphenous opening. Therefore, the hernia sac cannot pass further down into the thigh. A larger femoral hernia turns upward and can be palpated above the inguinal ligament. It can under these circumstances be mistaken for an inguinal hernia. When studied in an elective setting in the United Kingdom, it was found that the distinction between inguinal and femoral hernia was difficult for both general practitioners (GPs) and hospital surgical staff. GPs correctly diagnosed three out of twelve femoral hernias, most often misdiagnosing the hernias as an inguinal one, whereas surgeons correctly diagnosed half of the femoral hernias [19]. The importance of distinguishing between femoral and inguinal hernia is the impact the finding should have on how expeditiously an elective repair is scheduled. A femoral hernia should be repaired with high priority due to the substantial risk of incarceration within a fairly short time frame.

Small femoral hernias can be difficult to find during clinical examination, especially in the obese patient. In cases with symptoms that may be attributed to a hernia, but without a palpable lump, imaging diagnostics such as ultrasound can be of value. Ultrasound is dynamic, is noninvasive, and does not subject the patient to ionizing radiation. Several studies have shown a high sensitivity and positive predictive value for groin hernia [20–23]. It should be noted however that the modality is highly operator dependent. The usefulness of referring for an ultrasound therefore heavily depends on whether there is access to an experienced examiner.

The misdiagnoses are not only related to the difficulty in deciding whether a lump is inguinal or femoral. A study in the United Kingdom found that in a not insignificant number of patients who were referred to the hospital, the diagnosis of a groin hernia has been missed altogether. In a sixth of the emergency cases, the preliminary diagnosis was "abdominal pain," "small bowel obstruction," or "upper GI bleeding" [24]. In that study, a correct diagnosis of femoral hernia had been made preoperatively by a surgeon in 85% of the cases. The importance of examining the groin, including all hernia sites, in patients with signs of bowel obstruction or acute abdomen cannot be stressed enough.

Examining the groin includes an assessment of the femoral canal. The best way to determine whether a reducible hernia is femoral or inguinal may be to identify the place for the femoral canal, place a finger over it, and ask the patient to strain or cough. In case of a femoral hernia, it will stay reduced, whereas an inguinal hernia will be visible again as a swelling. The femoral canal is found by palpating the femoral artery and then placing one's fingers about 1.5 cm medial to it below the inguinal ligament or by following the adductor longus tendon up to below the inguinal ligament and putting one's fingers anterolateral to the tendon [19].

Femoral hernias often present as an emergency. About 32–40% of femoral hernia repairs are carried out as emergency procedures [3, 4, 8]. Women and elderly patients are overrepresented in the group who has emergency procedures [25–28]. While no difference in risk for emergency procedure related to BMI was seen in an Austrian study, an over-risk for emergency surgery was seen for patients with BMI < 20 kg/m^2 in a Swedish population-based study [18, 29]. In a retrospective study, patients who have had femoral hernia surgery were asked about their symptoms prior to surgery. A majority of those who had emergency repair had not been aware of a hernia prior to emergency admission for surgery, and one third denied having had any symptoms from the groin more than 2 weeks prior to admission [30]. This is in accordance with other studies and suggests that, at least a subset of, femoral hernias do indeed present as emergencies [29, 31, 32].

Incarceration and Strangulation

In incarcerated hernias, the contents of the hernia are trapped within the hernia orifice. This can lead to bowel obstruction as well as strangulation, where the blood supply to the contents of the hernia is affected. The frequency with which femoral hernia incarcerate is rather much higher than that for inguinal hernia. The difference in anatomy with rigid unyielding boundaries of the femoral orifice contributes to this.

The natural course of femoral hernias that do not present as emergencies is not as well studied as that for inguinal hernias. There is a study that reports a cumulative probability for incarceration of 22% within 1 month from the hernias appearance and a cumulative probability of 45% at 21 months [33]. This speaks to the importance of an expeditious planning of an elective procedure if a femoral hernia is diagnosed out of the emergency setting.

Bowel resection is performed in 15–30% of emergency femoral hernia repairs. The corresponding figure for emergency inguinal repairs is circa 5–10% [3, 28, 34–37]. While the mortality after elective femoral hernia repair is negligible, there is a considerable increased risk after emergency femoral repair. A British study revealed a mortality of 8% in the emergency group [38]. The standardized mortality rate (i.e., the ratio between observed and expected deaths within 30 days of surgery, considering age and sex) is raised tenfold after emergency femoral hernia surgery and raised 20-fold if bowel needs to be resected [25].

In an analysis of the patients who died within 30 days of groin hernia surgery, it was noted that 64% of the patients had had emergency surgery, 70% of these had presented with signs of bowel obstruction. Even so, in 37% of these patients (with signs of bowel obstruction according to case notes), there was no record of physical examination of the groin on admittance. For patients within this study who turned out to have a femoral hernia, a record regarding groin status was missing in the majority of cases (53%). Time from admission to surgery (among these patients who eventually died after hernia surgery) exceeded 24 h in 18% of the patients where a hernia was noted upon admittance and in 70% among the patients where the hernia was not recognized initially [39]. In a Danish analysis of mortality after groin hernia surgery, substantial delays in time to admission, time to diagnosis, and time to surgery could be identified [40].

In order to improve our results regarding morbidity and mortality connected to the emergency repairs of femoral hernia, we need to become better at suspecting strangulated hernia and to assess patients accordingly when they present in the emergency situation.

Management of Femoral Hernias

Due to the high risk of incarceration, patients that present with a femoral hernia should be offered and recommended early planned surgery [41]. Watchful waiting is not advocated for these patients [42]. Surgery for femoral hernia in the elective setting is not associated with any increase in mortality, even in the elderly [25, 43, 44].

Treatment Approaches

Several different surgical techniques are described and no apparent gold standard has yet made its breakthrough. This is probably to a large extent due to the lack of large randomized studies that provide high-quality evidence regarding the outcome of the different repairs. Femoral hernias are difficult to study since they are few and they often present as emergencies outside of office hours when the infrastructure securing that patients are approached regarding ongoing research projects is less robust. Instead, the scientific body when it comes to femoral hernias is largely built upon case series from different hospitals, mostly with rather few patients in each series.

Historically an increased risk for reoperation due to recurrence compared to that seen for inguinal hernia has been noted [3, 5]. A greater diversity in methods used can be discerned; in the Swedish Hernia Register it is more common for a femoral hernia to be treated with an "unspecified" suture technique than it is for inguinal hernia. There are studies in which no difference in risk for recurrence between different surgical techniques can be seen, and the Cochrane review from 2002 regarding mesh vs tissue repair did not find sufficient data to investigate the outcome of mesh and no-mesh repairs for femoral hernia [4, 45]. At the same time, fair results are presented in smaller observational studies regarding several different techniques.

However, a distinct advantage for mesh repairs, more specifically the preperitoneal mesh repairs, was seen in a population-based study of 3980 femoral hernia repairs [3]. And in a more recent Danish study, an advantage of laparoscopic repair as compared to open repair for femoral hernia regarding risk for reoperation due to recurrence was found [8]. In a randomized smaller trial, preperitoneal mesh repair was superior to plug repair with respect to recurrence as well as sensation of foreign body and seroma formation [46].

No difference in risk for chronic pain depending on repair method has been demonstrated [47]. In a recent multicenter study, pain as well as quality of life was addressed. No difference could be seen between laparoscopic methods and open methods of repair [48]. Since no difference is seen for these parameters, we should take advice by the differences seen regarding risk for recurrence and aim to repair femoral hernias with a mesh in the preperitoneal position when possible.

Preoperative Considerations

In patients with suspected strangulation, general anesthesia should be used. In the emergency patient with symptoms of obstruction, a nasogastric tube should be secured, and fluid replacement therapy started preoperatively. The bladder should be emptied before surgery, either by catheter or by having the patient void shortly before surgery.

Patient Positioning and Theater Setup

For theater setup for laparoscopic repair, please see Chap. 15, Laparoscopic Repair.

For all the open procedures, the patient is placed in the supine position, with the operating table tilted slightly with the head down. The patient's arms are preferably extended out from the sides. In the elective setting, it can suffice that the draping provides access to the groin area. In emergency procedures, the abdomen should be prepared as well in order to allow a laparotomy without delay if needed; the abdomen may be covered with a sterile drape that can easily be removed if need be.

Laparoscopic Approach

Femoral hernias are very well suited for laparoscopic repair. The dissection allows full view of all three hernia orifices in the groin. If there are multiple hernias in the same groin, they can all be addressed with the same repair. The entire myopectineal orifice can, and should, be covered by the mesh with an adequate overlap.

Transabdominal preperitoneal repair, TAPP, and the totally extraperitoneal repair, TEP, are described in Chap. 16. The patient positioning, the theater setup, and the surgical steps do not differ from the case with an inguinal hernia.

When the dissection area is prepared, care must be taken to ascertain that the entire sac is reduced. In cases where it is difficult to reduce the sac, it can be helpful to cut the lacunar ligament medial to the femoral ring. In case of any uncertainty as to the viability of the sac content, i.e., in the case of incarcerated hernia, the sac content must be examined. In the case of TAPP, this is of course already taken care of before the peritoneum is taken down, but in TEP technique, this must not be overlooked.

The repair and the positioning of the mesh do not differ from cases with inguinal hernia, with the key to a successful repair being an adequate positioning with a sufficient overlap of the mesh in regard to the entire myopectineal opening.

Regarding postoperative care and patient information, the patient with femoral hernia should be treated the same way as patients with inguinal hernia.

Open Preperitoneal Approach

The open, just like the laparoscopic, preperitoneal approach provides a good access to the area to be operated in. After dissection the entire myopectineal orifice is visible; thus, concomitant ipsilateral inguinal hernias are detected. This approach is well suited for the emergency operations when strangulation is suspected, since the peritoneum easily can be opened for inspection of the hernia contents. It is also possible to, when needed, access both groins with a single incision.

The use of mesh is recommended due to the decreased risk for recurrence, but the approach was first described for tissue repair.

Incision and Access

Several incisions have been described and can be used for this approach. A lower abdominal transverse incision two fingerbreadths above the inguinal ligament on the side of the hernia followed by a transverse incision in the rectus sheath, at the level of the skin incision, was advocated by Nyhus [49]. The rectus sheath is opened laterally with the opening extending out into the aponeurosis of the three lateral abdominal wall muscles. The rectus muscle is retracted medially, and the inferior epigastric vessels are protected. It is possible to extend the incision across the midline in a patient with bilateral hernia (although it is obvious that in the bilateral case, the laparoscopic approach is much less invasive).

Other alternatives are the vertical para-rectal incision exposing both the inguinal region and the femoral region, described by McEvedy, and the midline incision described by Henry [12, 50].

For surgeons not used to the preperitoneal approach, it may feel more familiar to gain access through the midline. An incision is made in the midline from the symphysis and approximately 8 cm in cephalad direction. The anterior rectus sheath is exposed and the linea alba incised, taking care not to enter the abdomen but to leave the peritoneum intact. This is the same incision described by Smith et al. in the technique of preperitoneal packing in hemodynamically unstable patients with pelvic fractures [51], a technique now taught as part of the damage control concept in the Definitive Surgical Trauma Care (DSTC™) course and may thus be an approach with which even the inexperienced hernia surgeon may feel at least theoretically comfortable.

Operative Steps

When access to the preperitoneal space has been gained, it is prepared by blunt dissection. The peritoneum is separated from the abdominal wall of the inguinal region and the pelvic floor. Herniation into inguinal or femoral defects (Fig. 20.3) can now be seen. If the hernia sac is not easily reduced, an incision in the medial part of the ring, the lacunar ligament, can be made.

If strangulation is suspected, the peritoneum should be opened when the sac has been reduced (or if needed before reduction) to allow inspection of the contents. The neck of the sac is ligated and the sac excised.

For mesh repairs, a flat mesh of polypropylene, 15 × 15 cm, can be used. It is placed between the peritoneum and the transversalis fascia, with the inferior epigastric vessels superficial to it, covering the entrance to the femoral canal and the entire posterior wall of the inguinal canal. The mesh is placed with one third of the mesh extending caudally from the inguinal ligament. Care is taken that the upper edge of the mesh will extend more cranially than the incision into the abdominal wall, thus minimizing the risk for an abdominal incisional hernia (Fig. 20.4). The mesh is secured with a pair of nonabsorbable sutures to the pectineal ligament.

In case of a suture repair, the femoral ring is closed using nonabsorbable suture. Two or three interrupted sutures between the iliopubic tract and ligament are placed with direct vision and protection of the external iliac vein (Fig. 20.5).

Closure

After placement of the mesh, or performing the suture repair, hemostasis is ensured. The transversalis fascia and the anterior rectus sheath are closed using slowly absorbable sutures. Scarpa's fascia is sutured with absorbable sutures, and the skin is closed with a running intracutaneous suture.

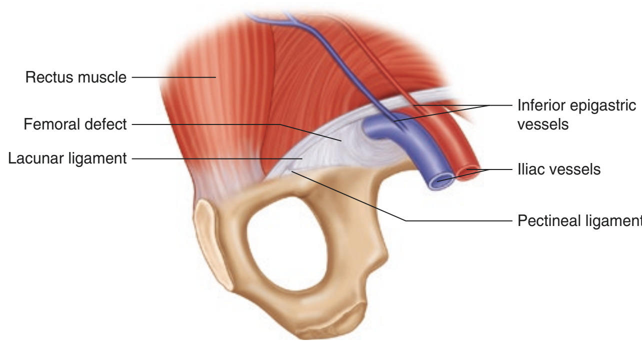

Fig. 20.3 Preperitoneal view of femoral hernia defect, right groin

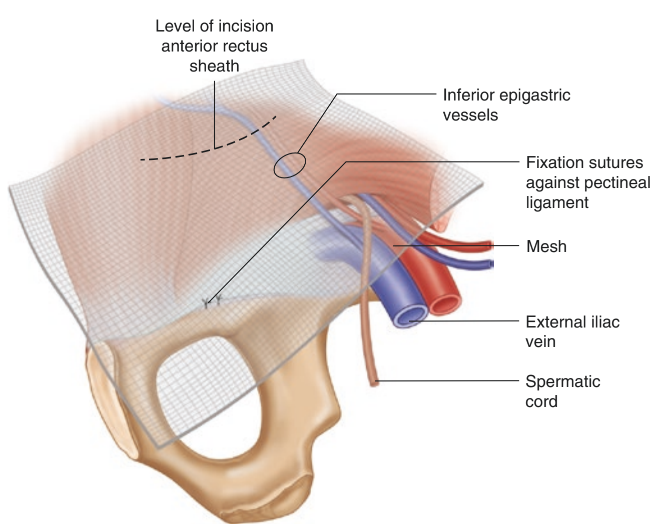

Fig. 20.4 Placement of mesh in preperitoneal repair, right groin. The *dashed line* represents position of incision into the anterior rectus sheath. The mesh is placed between the peritoneum and the inguinal floor/pelvic floor, deep to the inferior epigastric vessels. The mesh is fixed by two sutures to the pectineal ligament

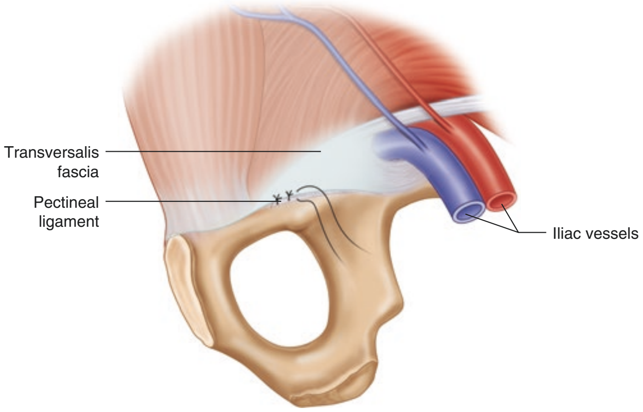

Fig. 20.5 Suture repair femoral hernia preperitoneal approach, right groin. The transversalis fascia is sutured to the pectineal ligament

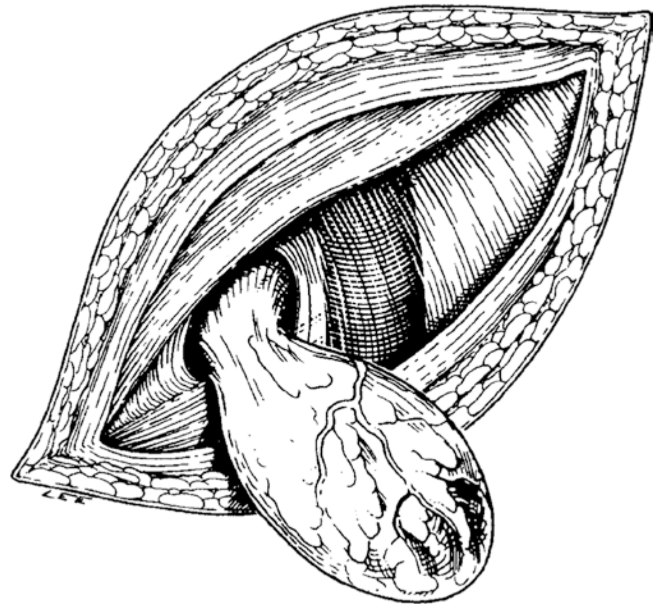

Fig. 20.6 Mobilized sac in femoral approach, left groin

Tips and Pitfalls

It is of great importance that a full dissection of the space is carried out. The entire myopectineal orifice should be fully visualized and the dissected space large enough to allow for a sufficient overlap of the mesh. The peritoneum needs to be mobilized especially in the lower aspect where incomplete mobilization may lead to a part of the peritoneum finding its way in between the mesh and the pelvic floor, leading to a recurrence.

It is also important to pay close attention to the repair of the abdominal wall to prevent the occurrence of an incisional hernia; suturing of the incision in the fascia needs to be thorough, and in mesh repair, the mesh should cover the incision.

When the hernia is not easily reduced, care must be taken not to try to widen the hernia defect in the lateral direction, due to the risk for injury to the femoral vein.

Femoral Approach

The infra-inguinal approach may allow for less tissue dissection since it is a fairly direct approach, leading the surgeon straight to the hernia sac. It is not appropriate for the emergency hernia since it provides limited access to hernia content and site of strangulation.

The repair can either be performed using only suturing of the femoral ring or using a plug to fill the femoral canal. The suture repair has been associated with high recurrence rates. Due to the relative simplicity of the approach, there are quite a few smaller studies where single centers have used the infra-inguinal plug method for femoral hernias and show fair results, thus advocating use of the method [52–56].

Incision and Access

A transverse infra-inguinal incision is made and the subcutis dissected to reveal the hernia sac. Sharp dissection is used and electrocautery ensures hemostasis.

Operative Steps

First, the hernia sac needs to be mobilized. The hernia pushes the transversalis fascia and preperitoneal fat in front of it. As the hernia meets the cribriform fascia of the saphenous opening and the point where the femoral sheath fuses into the fascia of the thigh, it often turns upward. When the sac is to be mobilized, it is important to consider this.

Using sharp dissection, the fascial layers are to be completely dissected from the hernia sac, and the femoral ring must be defined. The boundaries constituted by the inguinal ligament (anterior) and the lacunar ligament (medial) should first be identified and separated from the sac. Once this is done, the sac can be lifted, allowing exposure of the pectineus muscle and its origin on the superior ramus of the pubic bone as well as the pectineal ligament. On the medial side, electrocautery may be used; on the lateral side, which is yet to be dissected, cold dissection is advisable. The femoral vein is covered by a fascial sheath that can make it difficult to easily identify. Dissection should be kept close to the hernia sac with fine dissecting scissors. The sac neck should be isolated all the way up to the femoral ring (Fig. 20.6).

The sac should be opened to inspect its content. If the hernia content shows signs of ischemia, a change in approach should be considered. The femoral approach does not provide good access. If the content is reduced, it is difficult to observe if normal blood supply seems to be restituted. One should definitely refrain from attempts to perform bowel resection through the femoral opening.

Due to the often small defect, reduction of the hernia can be difficult. An incision medially into the lacunar ligament

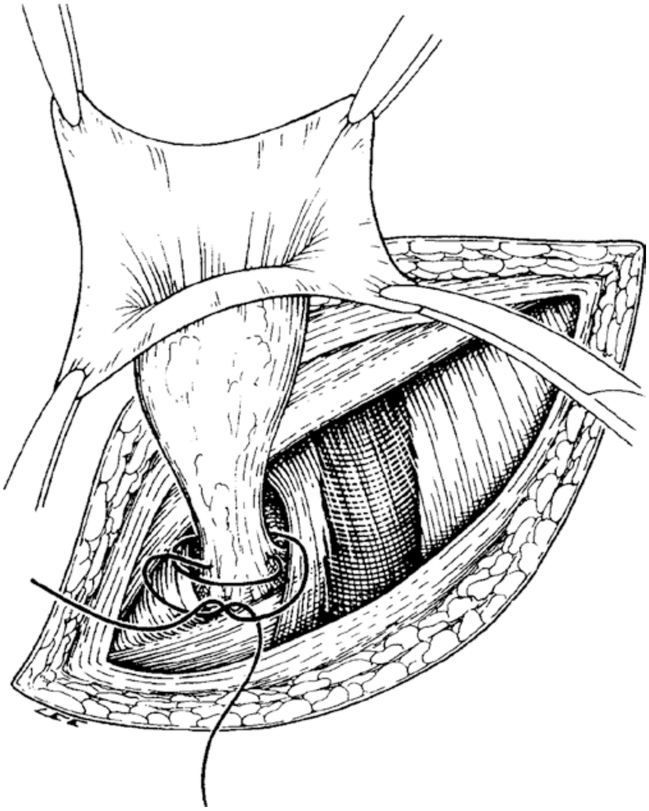

Fig. 20.7 Closure of the sac at the neck, left groin

can be made in such instances. When the, non-strangulated, hernia contents have been reduced successfully, the hernia sac can be closed and excised (Fig. 20.7).

If a plug is used, it should be tailored to an appropriate size. The plug can either be of the rolled type described by Lichtenstein [57] or of the “umbrella” type (one constructed from a circular flat mesh or a preformed one) [58]. The point of using a prosthetic plug is to obliterate the opening of the canal without causing tension. When the plug has been put into place within the femoral canal, it is sutured to the medial, posterior, and anterior aspects. It is not to be fixated laterally, in order to not risk injury to the iliofemoral vein.

In a suture repair, the femoral ring is shut by means of a suture. The femoral vein should be protected and retracted laterally. The suture starts at the medial margin of the femoral vein (where it would be, were it not retracted) first going through the pectineal ligament and then the inguinal ligament. If the suture is performed as a figure of eight, a knot adjacent to the femoral vein can be avoided (Fig. 20.8).

Closure

After ensuring hemostasis, one or two absorbable interrupted sutures are used to close the subcutis. The skin is closed with a running intracutaneous suture.

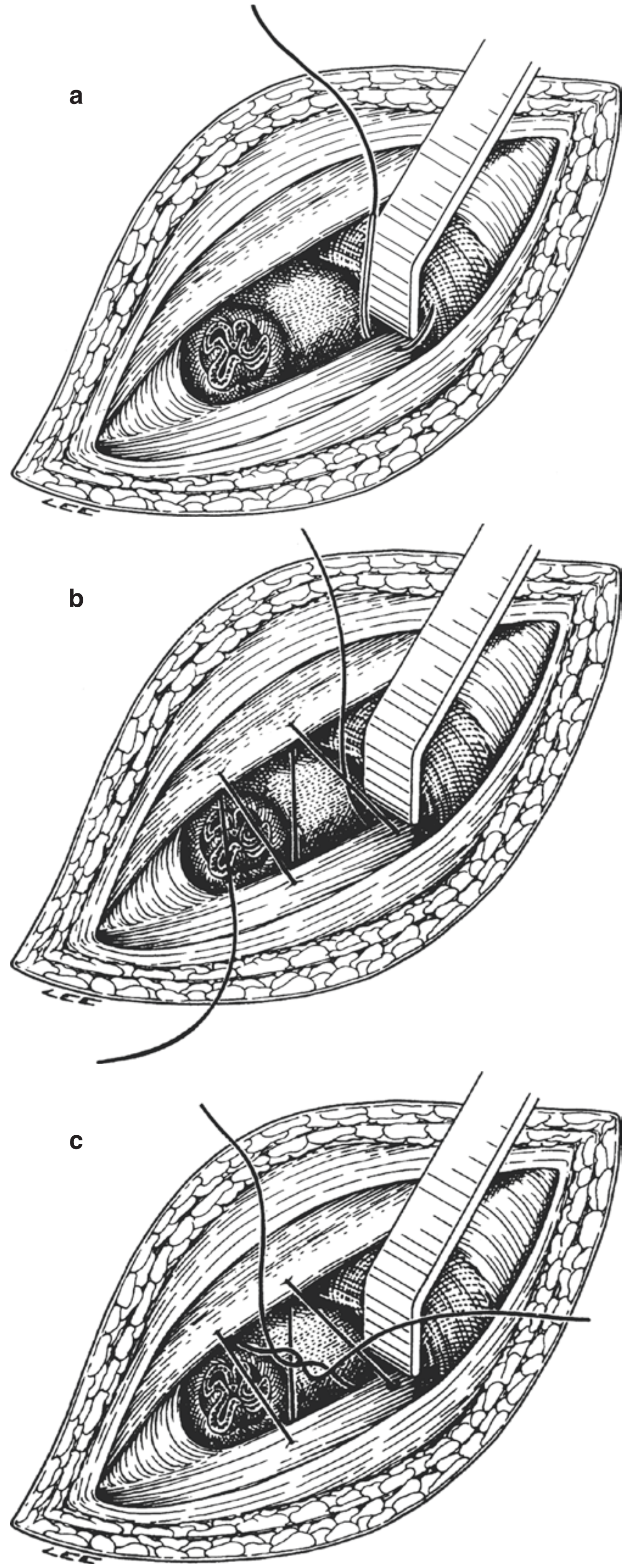

Fig. 20.8 (**a**–**c**) Suture repair of a left-sided femoral hernia from the femoral approach. The femoral vein is retracted laterally. The first suture bite goes through the pectineal ligament. A figure-of-eight suture between the pectineal ligament and the inguinal ligament is performed. The knot is secured medially

Tips and Pitfalls

The method is not suited for patients where obstruction or strangulation is suspected. It is difficult to ensure that you are able to adequately assess hernia content.

While the approach leaves the inguinal area intact, it also stops the surgeon from identifying an ipsilateral concomitant inguinal hernia that could be repaired in the same session. Combined hernias including a femoral component are not uncommon, especially not in males with femoral herniation.

If a too large plug is used, it may obstruct the femoral vein.

If the suture of the femoral ring is too tight upon the femoral vein, it may cause venous obstruction, while a suture started too far from the vein may provide inadequate closure and make the patient prone to recurrence.

Inguinal Approach

This open route provides a view that may be more familiar to surgeons who are accustomed to repair of inguinal hernia. The access to incarcerated hernia content is not as pronounced as with the preperitoneal approach, and the approach is technically more demanding than the femoral approach.

Incision and Access

An incision is made parallel to the inguinal ligament, just as for an inguinal repair. The subcutaneous tissue is dissected, the external aponeurosis opened, and the transversalis fascia is identified.

Operative Steps

The transversalis fascia is incised and the posterior wall of the inguinal canal opened. The femoral hernia is identified. After preparation of the neck, the hernia is reduced. If needed, the lacunar ligament can be incised to make the reduction easier. The neck of the sac is ligated and the sac excised.

The repair can be performed with a flat preperitoneal mesh, a mesh plug or by suture.

In the transinguinal preperitoneal technique, a flat mesh is placed preperitoneally. The access is seldom as good as in the preperitoneal techniques (open or laparoscopic). The mesh should cover the entire myopectineal orifice though. After placement of the mesh, the transversalis fascia and the aponeurosis of the external oblique are closed using running sutures.

In a plug repair, the plug is placed just like the plug in the femoral approach, only from the cranial side of the inguinal ligament. The plug is secured with multiple sutures. In order to address the fact that the posterior wall of the inguinal canal was opened up, a flat mesh can be placed between the transversalis fascia and the external oblique, as it would have been if there was an inguinal hernia, as a preventive measure.

If a suture repair is performed, a nonabsorbable figure-of-eight suture is applied between the inguinal ligament and the pectineal ligament.

Tips and Pitfalls

This approach engages the inguinal area, even if there is no hernia there. The repair needs to take that into account and minimize the risk for an (incisional) inguinal hernia. Placing a flat mesh can be a solution, but it could also be argued that several dissection planes are used without benefit and that the method introduces larger amounts of foreign material than actually needed.

In the suture technique, there is a risk for tissue tension, and relaxing incision may be needed.

Conclusion

Femoral hernia is a rather uncommon but clinically important entity. Its relative infrequency combined with its tendency to present as an emergency makes it more difficult to gather high-quality evidence regarding best practice.

Femoral hernias should be repaired electively when at all possible. The largest studies available indicate that preperitoneal mesh repairs render the best results with regard to risk for recurrence.

It is paramount that strangulated femoral hernias are identified as soon as possible. In patients who present with abdominal pain and signs of intestinal obstruction or strangulation, femoral hernia should always be suspected. The physical examination of these patients should accordingly always include an assessment of the groin.

Acknowledgment This is an updated version of the chapter authored by Patrick J. O'Dwyer. Patrick J. O'Dwyer has not participated in the revision of this chapter for the fifth edition.

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Inguinal Hernias in Babies and Children

21

R. Miller and S. Clarke

Introduction

A Brief History of Paediatric Inguinal Hernia Repair

A congenital inguinal hernia can be defined as a protrusion of intra-abdominal contents through the deep inguinal ring. The underlying abnormality leading to its development is a patent processus vaginalis (PPV). This was described by Galen in 176 AD as a 'small off-shoot of the great peritoneal sac in the lower abdomen' which may result in a congenital (indirect) inguinal hernia or hydrocele [1].

Initially the management of hernias was compression strapping. However, the surgical management of inguinal hernias has been documented as far back as the Roman Celsus, where removal of the hernial sac and testis through a scrotal incision was recommended [1]. Testicle amputation was an essential part of the surgical management of inguinal hernias until it was rejected by William de Salicet (1210–1277).

The foundation of herniology was set during the Renaissance. The greatest contributor was Pierre Franco, a Swiss barber-surgeon, who in 1556 devised a technique to allow division of the constricting facial ring without damage to the bowel [2]. Ligation of the hernial sac at the external inguinal ring was practised by Stromayr, who distinguished between direct and indirect hernias and allowed removal of the testis in the latter type, and by Purmann (1649–1711) who spared the testicle [3, 4].

While Bassini, Halsted and Shouldice were describing methods of repair and reinforcement in adult hernias, Turner, in 1912, reported that in the majority of children, no repair was required for the treatment of inguinal hernia and that only high ligation of the sac was necessary [3].

Soon after the advent of laparoscopy for adult inguinal hernias, laparoscopic repair in children gained popularity. Shouldice and Lichtenstein repairs are still the most favoured approaches for the treatment of groin hernias in adults [2], but techniques for inguinal hernia repair in children continue to evolve.

Embryology

The sex of an embryo is determined genetically and therefore present from the time of fertilisation. However, for the first 6 weeks, the sex of the foetus is indeterminable. It is not until approximately the seventh week that germ cells appear at the urogenital ridge and the indifferent gonads develop the morphological features of male or female. Both the urinary and genital systems develop from mesoderm [5].

Towards the end of the second month, a cord of condensed mesenchymal cells forms extending from the caudal pole of the male gonad. This is known as the gubernaculum. As testicular descent starts, an extra-abdominal portion of gubernaculum forms, growing towards the scrotal swellings. The inguinal canal forms around this gubernaculum as the muscles of the abdominal wall begin to differentiate. As the testis moves through the inguinal ring, the gubernaculum contracts and the testes will normally reach the scrotum by 33 weeks [5]. In tandem but independent to this process is the bilateral evagination of peritoneum either side of the midline. This evagination forms the processus vaginalis (PV) and follows the gubernaculum into the scrotum (Fig. 21.1). The PV accompanies the muscular and fascial layers of the abdominal wall, which form the inguinal canal. Some researchers have suggested that formation of the PV is a result of intra-abdominal pressure, whereas others believe that it is an active process [6].

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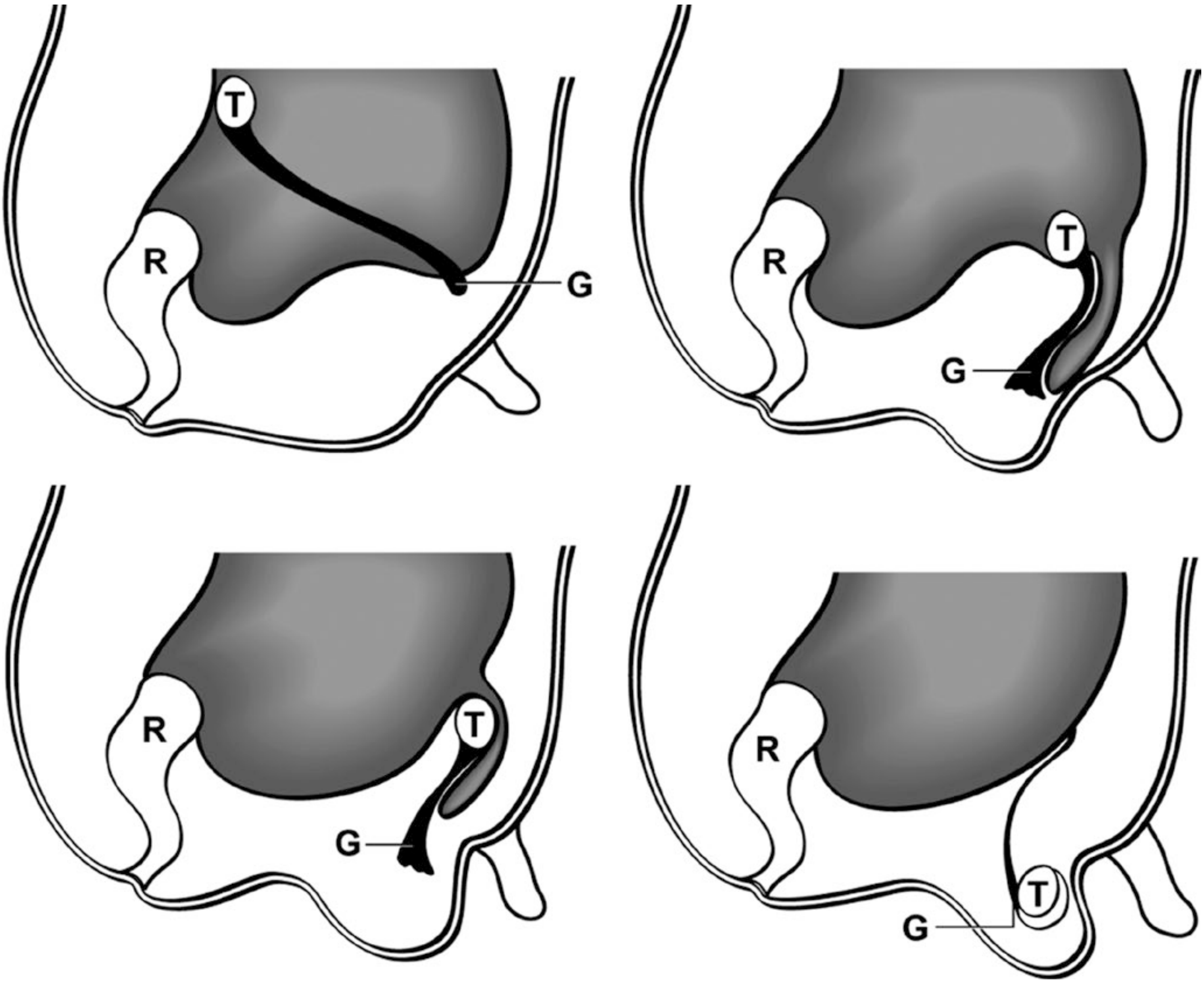

Fig. 21.1 Embryology of the processus vaginalis. *T* testicle, *G* gubernaculum, *R* rectum

It is important to note that the testis projects into the reflected *fold* of the PV. It is not within the PV. In males, the distal end of the PV, into which the testis projects, forms the *tunica vaginalis*, and the proximal part, adjacent to the spermatic cord, becomes obliterated leaving a fibrous remnant. This normally closes in the first year of life. If this proximal part of the PV does not close, a congenital inguinal hernia may form. If the tract partially obliterates, a hydrocele may form at the spermatic cord, testis or both [5]. Within females, the same parietal peritoneal evagination occurs, accompanying the round ligament. This forms the *processus vaginalis* within the inguinal canal, sometimes termed the *canal of Nuck.* This normally undergoes complete obliteration. However, rarely, failure or incomplete obliteration can occur, causing an indirect hernia or hydrocele in females [7].

It is unknown *where* the processus starts its closure: proximal, middle or distal parts [6], and the mechanisms governing PV obliteration are not fully understood. Some authors believe that apoptosis of smooth muscle is pivotal for PV closure and that the interplay of androgens and catecholaminergic activity governs this process [8, 9]. The importance of smooth muscle cells has also been highlighted in indirect inguinal hernias in adult patients [10]. Other factors thought to be important include hepatocyte growth factor (HGF) and *calcitonin gene-related peptide* (CGRP). Studies have shown that exogenous CGRP in cultured PV epithelial cells causes fusion of a patent PV by epithelial mesenchymal transformation, possible via HGF [11, 12].

The exact timing of closure is also uncertain. Studies suggest that most infants are born with a patent processus vaginalis [6] and that closure is most likely within the first year of life [5]. After that, patency rates fall more gradually and stabilise around 3–5 years of age. However, one study reports that 22% of patients under the age of 20 years had a PPV, dropping to 6% of those between 20 and 30 years [13].

Anatomy

The basic anatomy of the inguinal canal is the same in children as in adults. However, there are some differences. In infants and children, the inguinal canal is shorter in relation to body size than in adults. In infants it is 1–1.5 cm long. The internal and the external rings are nearly superimposed in cases of pubic diastasis (bladder and cloacal exstrophy) or in infants with very large inguinal hernias where the external inguinal ring is very stretched. Finally, Scarpa's fascia is often more prominent in infants, so much so that the surgeon may mistake it for the aponeurosis of the external oblique muscle.

Aetiology

Failure of obliteration of the PV may result in a variety of inguinoscrotal anomalies (Fig. 21.2).

These will include:

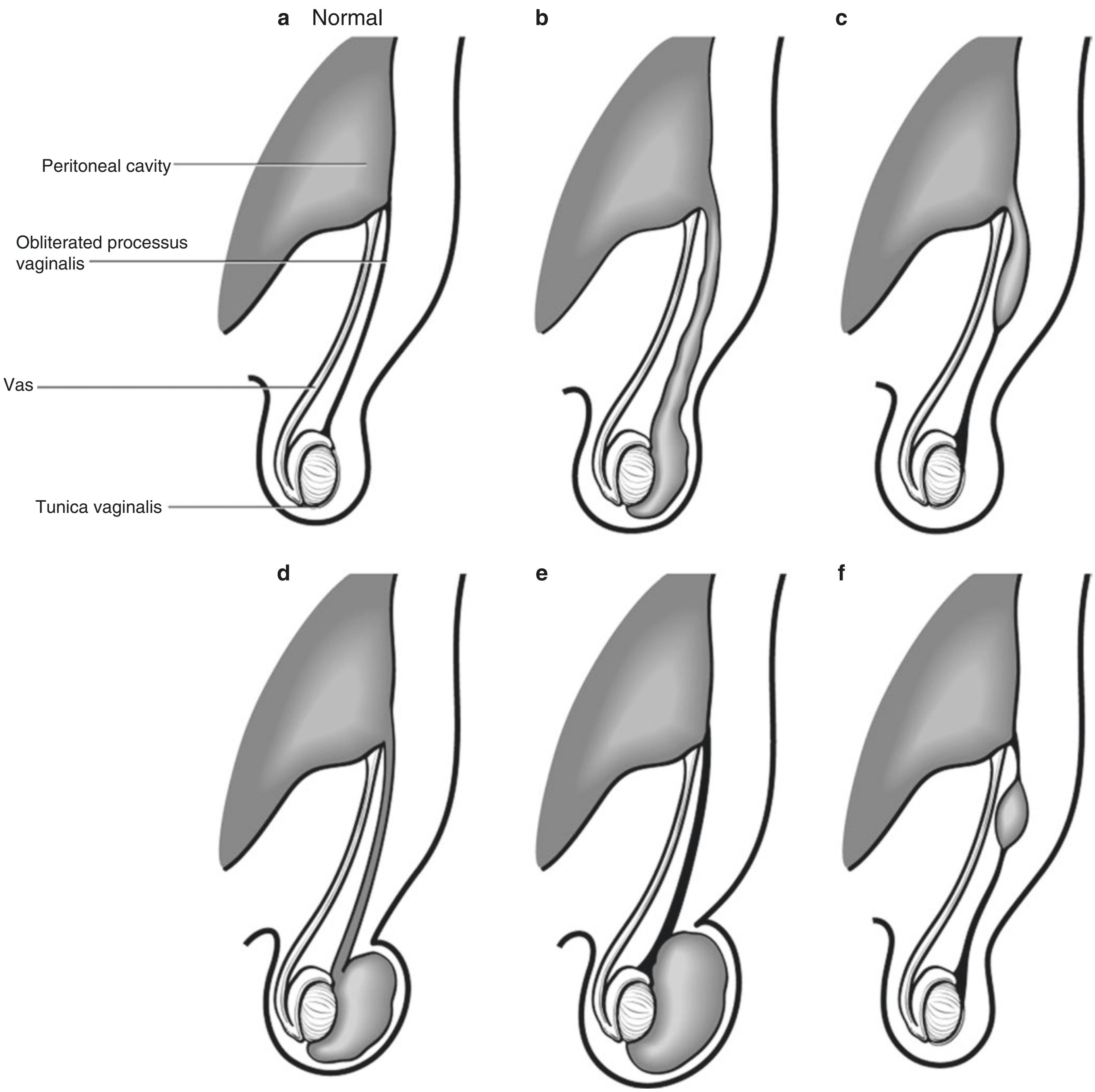

Fig. 21.2 Inguinoscrotal variations of the processus vaginalis. Normally obliterated (**a**), indirect inguinoscrotal hernia (**b**), inguinal hernia (**c**), communicating hydrocele (**d**), hydrocele of the tunica vaginalis (**e**), hydrocele of the cord (**f**)

- Complete persistence resulting in an *indirect inguinoscrotal hernia* (Fig. 21.2b).
- Complete patency with a narrow opening at the internal ring referred to as a *communicating hydrocele* (Fig. 21.2d).
- Distal processus obliteration and proximal hernia patency resulting in an indirect *inguinal hernia* (Fig. 21.2c).
- Proximal obliteration with distal patency resulting in *hydrocele of the tunica vaginalis* (noncommunicating hydrocele). Its counterparts in girls are called *a hydrocele of the canal of Nuck* (Fig. 21.2e).
- Proximal and distal obliteration with central patency referred to as a *hydrocele of the cord* (Fig. 21.2f).

A patent processus vaginalis (PPV) is a prerequisite for developing an indirect inguinal hernia but its patency alone does not mean an *inevitable* hernia. Prematurity is one situation where the normal physiological processes of testicular descent and PV closure are not complete, hence the high incidence of inguinal hernia. A positive family history and other factors (Table 21.1) have also been shown to be associated with inguinal hernia in children. A link between inguinal hernia and some genetic diseases (viz. connective tissue disorders) is also documented [14].

Incidence

The percentage of children with inguinal hernia is reported to be around 5% [1]. This incidence rises in premature infants, and reported ranges vary from 11% [3] to 25% [1].

Table 21.1 Predisposing factors to inguinal hernia in children

Age (prematurity)
Family history
Urogenital
Undescended testis
Pubic diastasis
Increased intra-abdominal pressure
Repair of exomphalos or gastroschisis
Ascites
Ventriculo-peritoneal shunt
Peritoneal dialysis
Meconium peritonitis
Chronic respiratory disease
Cystic fibrosis
Connective tissue disorders
Congenital hip dislocation
Ehlers–Danlos syndrome
Hunter–Hurler syndrome
Marfan's syndrome
Mucopolysaccharidosis

Boys are three to ten times more commonly affected than girls [1, 6]. In a recent study of 79, 794 Taiwanese children under 15 years of age, the cumulative incidence of inguinal hernias in boys was 6.62% vs. 0.74% in girls [15]. In addition, age at presentation is significantly younger in males [16]. 85–90% of hernias are reportedly unilateral [4, 16, 17] or 5.54:1, bilateral/unilateral [15]. Consistently, approximately 60% of inguinal hernias are right sided [4, 16]. However, less consistently is the distribution of left and bilateral hernias. Approximately 18–30% of inguinal hernias occur on the left side and the remaining 10–24% are bilateral at presentation [4, 16]. This weighting to right-sided hernias is attributed to later testicular descent and delayed obliteration of the processus vaginalis on the right [1, 4, 18]. In girls, this observation cannot be explained by the same mechanism of testicular descent, and the cause remains obscure. An inguinal hernia in a girl should not be taken at face value, and the surgeon should always have a suspicion of complete androgen insensitivity syndrome (CAIS) [19] and take the appropriate measures for preoperative and intraoperative investigations. The incidence of inguinal hernias is higher in both preterm and low birth weight infants. The incidence in low birth weight infants is reported to be around 16% [20, 21]. Within this group, bilateral hernias appear to be more common than unilateral, with up to 60% being bilateral [17, 21]. There is a positive family history in 11.5% of patients [22], with an increased incidence in twins (10.6% in male twins and 4.1% in female twins) [6].

Presentation, Diagnosis and Differentials

The typical presenting history of an inguinal hernia is intermittent swelling in the groin in the region of the external inguinal ring, scrotum or labia. As with many childhood conditions, this is usually first noticed by the carer. Parents might notice it during bathing or when the child is crying and will often reliably point to this area when prompted. Alternatively, a paediatrician or general practitioner may find it on routine examination.

Although physical examination will often be unremarkable, signs can be observed to support the diagnosis. To complete an examination, the child or infant should be placed supine and undressed on an examining table in a warm room with a chaperone present. After inspection of the groin for any visible mass or asymmetry, the testis should be localised in the scrotum to account for both testes and distinguish true inguinal swellings from retractile or undescended testes. If a mass is still not apparent, the 'silk scarf/glove sign' may be used to determine patency of the PV. This is performed by laying two fingers over the spermatic cord slightly above the level of the pubic tubercle. The fingers are lightly rolled over the cord from side to side. A positive sign is when the fingers 'slide' as the two surfaces of the PPV roll against each other indicating patency. It should be compared with the 'normal' non-presenting side, bearing in mind that the child may have bilateral inguinal hernias. This remains a somewhat subjective sign although accuracy of up to 91% from repeated examination is reported [23]. In addition to this, increasing the intra-abdominal pressure, through the child coughing, laughing or crying, may be helpful to demonstrate the bulge of a hernia.

It is important to remember that the first presentation may be acutely with a complication. The child may present with incarceration, strangulation or bowel obstruction. As in adults, it is important to remember that any child presenting with intestinal obstruction should have a thorough examination of the hernial orifices.

In most cases, the diagnosis of an inguinal hernia is a clinical one and is sufficient for a paediatric surgeon to operate. Historically, investigations have not been necessary. They can be employed in rare cases where diagnostic doubt exists, in the assessment of the contralateral side or where there is suspicion of hernia recurrence. For this, ultrasound scanning (USS) has gained popularity over the past decade (Fig. 21.3). It has the advantage of being rapid, non-invasive and complication-free. Studies reported by Chen et al. [24] and Erez et al. [25] concluded that ultrasound is a reliable tool and may even be used for preoperative evaluation of the contralateral groin in cases of unilateral hernia on clinical examination. On USS, a normal inguinal canal was found with an inguinal canal width of 3.6 ± 0.8 mm. Measurements of 4.9 ± 1.1 mm were associated with a PPV, whereas measurements of 7.2 ± 2.0 mm or greater were associated with a true hernia [25]. An accuracy of up to 91.7% has been reported in the use of USS for preoperative detection of a patient processus vaginalis on the contralateral side of a clinically diagnosed inguinal hernia [26]. In turn, the development rate of contralateral inguinal hernias after unilateral herniorrhaphy was reduced from 10.2 to 1.5% with the use of contralateral USS ± fixation [27, 28].

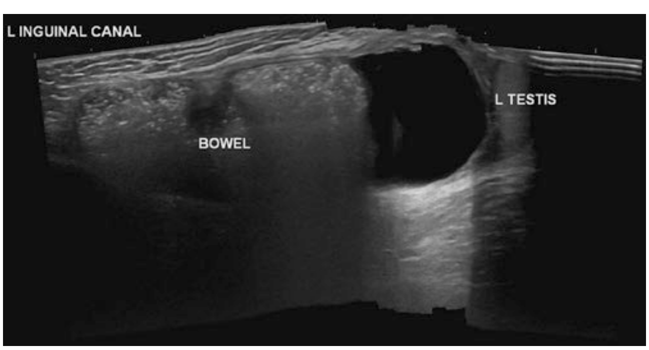

Fig. 21.3 Ultrasound scan of inguinal canal with herniated bowel loop in a child

In the hands of an experienced sonographer, ultrasound is equally useful in girls with unilateral or bilateral inguinal hernias, in order to exclude CAIS [19], and in the assessment and diagnosis of uterus and ovarian herniation [29].

If there is uncertainty regarding the diagnosis, differentials to consider in infants and children include a hydrocele, hydrocele of the cord, an undescended testicle (cryptorchidism) or a lymph node (Table 21.2).

While the underlying cause for an inguinal hernia and hydrocele is the same, differentiating the two is important because it affects subsequent management. The history of a hydrocele can be similar to an inguinal hernia. However, they should be differentiated on physical examination with transillumination being the pathognomonic sign for a hydrocele. A hydrocele usually masks the testis and therefore it is difficult to palpate the testicle separately (remember that the testicle is not within a hydrocele but projected into the tunica vaginalis, which contains the fluid of a hydrocele). In contrast, the testis is usually palpable separately from a hernia. However, a large hydrocele in an infant may be difficult to distinguish from an incarcerated hernia. Remember that, although rare, hydroceles can occur in females within the canal of Nuck [7].

For infants with a congenital hydrocele, the processus vaginalis usually closes with resolution of the hydrocele during the first year of life. The recommended management is therefore to avoid surgery during that period, unless a hernia cannot be excluded. As discussed above, USS may be helpful if this is the case. After 2 years of age, a hydrocele is unlikely to resolve and should be operated upon. The recommended operation is high ligation of the processus vaginalis, as for inguinal hernia, with drainage of the distal sac. Splitting, everting and removal of the distal sac are not only unnecessary but may even cause a post-operative haematoma. Fluid rarely reaccumulates, and if it does, it usually resolves spontaneously. Although theoretically possible due to incomplete obliteration of the processus vaginalis, there is no evidence that a hydrocele progresses to form a hernia. Occasionally, a previously unapparent hydrocele may present in an older child as a scrotal swelling. This often presents during a viral illness.

Retractile or undescended testis may again have a similar history of intermittent swelling in the scrotal region. However, this should be easily differentiated on physical examination whereupon there would be failure to localise the testicle within the hemi-scrotum and the scrotal sack may be underdeveloped.

Table 21.2 Differential diagnoses for a mass in the groin in children and infants

Inguinal hernia ± incarceration/strangulation
Hydrocele
Hydrocele of the cord (hydrocele of the canal of Nuck)
Undescended/retractile testes
Lymph nodes

Palpable inguinal lymphadenopathy is a possible differential diagnosis; however both the history and examination are different. With a lymph node, there is unlikely to be fluctuations in size, and examination will reveal a discrete rubbery swelling that is noncompressible, non-reducible and anatomically distant from the external ring. It may be tender in the context of an acute infection but is unlikely to be persistent. However, palpable inguinal lymphadenopathy is not common, and a local source of infection might be sought, or the examiner should proceed to palpate the other lymph nodes to detect generalised lymphadenopathy.

Specific Considerations and Complications

Although in infants and children the majority of inguinal hernias are indirect, they can rarely have direct inguinal hernias. These occur due to defects in the transversalis fascia and presents as a bulge more medially in the groin (medial to the inferior epigastric vessels). They are often misdiagnosed as indirect hernias. A direct hernia may not be obvious while the patient is anaesthetised; however it should be suspected if a typical patent PV couldn't be found. If not spotted intraoperatively, patients may return with what appears to be a recurrent indirect inguinal hernia [30]. If this is the case, it is repaired using interrupted non-absorbable sutures between the inguinal ligament and conjoined tendon. Occasionally a mesh repair is required in the older child.

The predominant complication of inguinal hernias is incarceration (Fig. 21.4) and, depending on the structures involved, the potential relevant sequelae. A number of structures can be involved and may 'slide' in and out of the hernial sac without becoming incarcerated. In infants, the bladder may be pulled with the hernial sac, or a bladder diverticulum may become incarcerated [43]. Alternatively the caecum or appendix [44] may share a wall with a right-sided hernial sac and bowel can become incarcerated. In girls, a fallopian tube, uterus, mesosalpinx and ovary may share a wall with the sac [45].

Fig. 21.4 Incarcerated inguinal hernia

As stated previously, incarceration may be the first presentation of an inguinal hernia, or it may develop in a child awaiting elective hernia repair. The incidence of incarceration ranges widely from 3.4 to 31% (Table 21.3). Within this variability, incarceration is more common at younger ages, with the majority in children around 1 year of age and younger [3]. However, premature infants have a relatively lower rate of incarceration rate, possibly due to a stretched inguinal canal [1]. Interestingly, as illustrated in Table 21.2, the incidence of incarceration appears to be decreasing over time with a dramatic difference between studies prior to 1991. This may be due to advances in medical practice and the ability to operate at younger ages, preventing incarceration occurring.

Incarcerated hernias present as a clearly defined, tense mass in the inguinal region that may extend into the scrotum. They are tender and do not spontaneously reduce. Occasionally, it will transilluminate and must then be distinguished from a tense hydrocele of the cord. Ultrasound may help to make this distinction. Incarceration of the bowel can result in strangulation and intestinal obstruction. Bowel obstruction may occur in up to 9% of non-reducible incarcerated hernias [33]. This will manifest with vomiting, abdominal distension and absolute constipation. Abdominal X-ray will show evidence of intestinal obstruction, and gas may be seen within the incarcerated bowel loops in the scrotum. The overlying skin and the testis may be swollen and tender. Ischaemia of strangulated incarcerated contents may insure with prolonged incarceration, manifesting with intensified pain and significant systemic upset.

It is often possible to safely reduce an incarcerated inguinal hernia in infants and convert a surgical emergency, to a condition requiring a semi-elective procedure. The success rate in reducing infant hernias is over 70% [1, 3, 4, 35, 46]. Indeed, Karabulut reports all incarcerated hernias were manually reducible with none requiring emergency surgery [40]. Therefore, the initial management of incarcerated inguinal hernia without strangulation and ischaemia should be nonoperative.

In order to achieve reduction, the basic requirements are a stable environment, adequate monitoring, adequate resuscitation and analgesia. The latter is achieved with morphine. 0.1 mg/kg is given intravenously to infants and 0.2 mg/kg as an oral preparation for children over 6 months of age. The dose should be reduced to 0.025 mg/kg for the premature infant. Midazolam 0.1 mg/kg may be added for the older child. Sedation should only be conducted by those trained to do so with monitoring of respiratory rate and pulse throughout. After allowing adequate time for the infant to settle, spontaneous reduction may occur. If not, gentle bimanual compression with gentle and sustained pressure should be

Table 21.3 Overview of incarceration rates in published studies

Age	Sample size	Incarceration (%)	Year published	Reference
0–17 years	2100	18.1	1957	[30][a]
0–16 years	2764	12.7	1971	[17][a]
<1 years	511	31.0	1984	[43][a]
<2 months	100	31.0	1984	[44][a]
<2 months	384	24	1991	[45]
4 years (mean)	1582	9.7	2003	[31]
<18 years (mean, 3.3)	6361	12	2006	[32]
<2 years	1065	11.9	2008	[33]
Short-wait group, 25.52 days	Short-wait group: 25	12 ($n = 3$)	2010	[34][b]
Long-wait group, 55.0 days	Long-wait group: 16	56.2 ($n = 9$)		
Total cohort, 46.6 (postconceptional age—weeks) Repair before NICU discharge, 27.8 weeks Elective repair, 31.7 weeks	172 45 127	4.6 11 2	2011	[35][c]
20 days to 16 years	402	8.7	2011	[36]
32 months (mean)	3776	3.4	2012	[15]
Boys, 2.71 years (mean) Girls, 3.70 years (mean)	92,308 (3881 operations)	None reported	2013	[37]
<15 years	79,794	4.19	2016	[14]
3.5 years (mean)	6826	6.10	2017	[38]

[a]Referenced in Groseld 1989 analysis of incarceration rates in different ages [6]
[b]Study of premature infants (28–35 weeks gestation) comparing short and long waits for operative intervention
[c]Retrospective review of premature infants with a mean birth weight of 1428 g

used. Flexing the ipsilateral hip with external rotation can aid reduction. A gurgling sensation will indicate emptying of the bowel and subsequent reduction. Preferably an elective repair should then be scheduled within approximately 24–48 h [1, 35, 46]. This time allows some resolution of the oedema, minimising the difficulty of the dissection and decreasing the risk of complications.

Failure to reduce the hernia is an indication for an immediate operation. The operative approach is that for the elective procedure but the external inguinal ring must be opened to allow reduction of the contents of the hernia. Further operative management is determined by the viability of the intestine. If the incarcerated contents are viable, it is reduced into the abdominal cavity and a high ligation of the sac is performed. However, if the content is no longer viable, it should be resected, either though the sac or through a separate entry into the peritoneal cavity via the same skin incision. Prolonged incarceration can lead to intestinal resection in 3–7% of cases [33]. Some authors report testicular ischemia in almost one-third of boys with incarcerated hernia, while other authors suggest that the problem has been much overemphasized [35]. Gonadal infarction secondary to incarceration was found to be more common in infants younger than 3 months [47] compared to similar cases in older age groups [3]. However, an incarcerated hernia in an infant is technically more difficult since the hernial sac is typically oedematous and fragile and so also has a higher complication rate [16]. The testicular vessels and the vas deferens are particularly susceptible to injury because of the oedema and an often-challenging dissection. These procedures are safest in the hands of experienced surgeons.

The overall complication rate in patients with incarcerated hernia has been reported to range from 11 up to 33% [35]. Reducible incarcerated hernias have a complication rate of 4.5%, compared to 33% for those that were irreducible and required an emergency operation [3]. Rescorla and Grosfeld noted a slightly higher complication rate in very low birth weight infants younger than 2 months of age at the time of their operation [33].

A specific complication to consider in females is ovarian incarceration. The management of an asymptomatic irreducible incarcerated ovary is unclear. In a survey of the variability of technique in inguinal hernia management and repair, Levitt et al. found that management of an incarcerated nontender ovary still varied from repair at the first available elective time (50%), repair that week (28%) or repair that day as an emergency (10%) [48]. The herniated ovary and fallopian tube are at a risk of vascular compromise either due to incarceration or, more likely, torsion. The reported incidence of strangulated irreducible ovaries is as high as 32% [6]. It is therefore our opinion that the risk to the ovary is indeed significant and should be managed as an emergency.

Management Options

From an understanding of the anatomical causes of inguinal hernias in infants and children, it is clear that they will not spontaneously resolve. Surgical management is therefore the gold standard, and long-term conservative management is never indicated, due to the high rate of associated complications [49, 50]. Ideally surgery should be carried out in an elective/semi-elective setting. However, complicated hernias presenting acutely should be managed urgently, as discussed above.

Regarding elective surgical management, there are some specific considerations for infants and children. This includes the timing of the operation, which is particularly pertinent for premature or low birth weight infants. Secondly, what should be done about metachronous hernias and finally the operative approach: open vs. minimally invasive.

Timing of Surgery

As stated above, even without incarceration, elective repair should occur promptly after diagnosis, taking into consideration the age of the child and associated anaesthetic risks. Some reports suggest that the great majority of complications can be avoided if repair is done early with an increased incarceration risk with time from diagnosis. After diagnosis, a wait time over 14 days was associated with a doubling of incarceration risk [37].

Furthermore, the premature and low birth weight infant presents a unique challenge. Premature infants show an increased risk of post-operative life-threatening apnoea after inguinal hernia repair [51, 52], although the risk is still thought to be low [39]. Unlike older children who may be treated on a day-case basis, monitoring of these high-risk infants for 12–24 h after operation is *strongly* recommended [52, 53]. It has been suggested that prematurity, rather than age at operation, or even incarceration, has the greatest impact on inguinal hernia repair complication rates [54], and low birth weight is an independent risk factor for emergency inguinal hernia repair surgery [55]. The optimal timing of surgical repair in these neonates is controversial [46]. In a small premature infant, the operation is technically more challenging and associated with a higher morbidity. Furthermore, the anaesthetic risk is higher. For those already admitted to a neonatal intensive care unit, it has been suggested that they should have their hernia repaired prior to discharge [1], but this is a simplistic proposal and on review of 172 premature infants undergoing inguinal hernia repair Lee et al. found that repair prior to neonatal intensive care unit discharge was associated with prolonged hospital admission [39]. This is echoed by Vaos et al., who advocate an early elective herniotomy in premature infants [38]. However, although the risk of incarceration is still relatively low in premature infants [39], there is a significant financial burden associated with emergency repair in this group, with a difference in cost of €1,183 in favour of elective repair [56].

Many factors such as gestational age, birth weight, actual weight, comorbidities, pulmonary status and history of incarceration are all factors that should be taken into consideration in order to formulate an individualised approach to determine the optimal time for surgical repair [53]. However, in general terms, *early* elective inguinal hernia repair, with appropriate precautions, is recommended for premature infants [46]. For infants diagnosed after discharge and who are expected to require ventilatory support or experience episodes of apnoea and/or bradycardia, elective repair has been recommended to be delayed for up to 44–60 weeks of corrected conceptional age [33]. Locally determined guidelines and resources will ultimately influence this.

Metachronous Contralateral Inguinal Hernia (MCIH)

If patients are observed after ipsilateral hernia repair, a metachronous hernia will appear on the contralateral side in 1–31% of the time [57]. In a recent 17-year analysis of 31,100 unilateral inguinal hernia repairs in Taiwan, the overall MCIH rate was 12.3%, with 91.7% requiring repair within 5 years [58]. This is a higher figure than a meta-analysis of six studies (1669 children) in 2015, which gave a MCIH rate of 6% [59]. This risk appears to be greater when the original hernia is on the left side [57, 59].

Exploration of the asymptomatic side can be used to detect a patent processus vaginalis or non-evident clinical hernia. The goals of identifying these two entities are to avoid a second anaesthesia, minimise parental and patient inconvenience, avoid the chance of incarceration and reduce costs. However, there is no current support for contralateral exploration in any child with a unilateral inguinal hernia and a clinically normal, asymptomatic contralateral groin [60–62].

In 2007, a systematic review on the risk of developing a MCIH acknowledged that ‘the success of contralateral exploration cannot be measured by how many PPVs are closed, but by how many MCIHs are prevented’ [62]. The results of the review stated that the risk of MCIH for all children having open hernia repair is 7.2%. Overall, 14–17% contralateral explorations are required to prevent one MCIH [59, 62] and the complication risk of contralateral exploration is still 2–16% [63].

However, laparoscopy offers a significant advantage regarding the assessment of contralateral hernias, as the contralateral deep ring can be examined with no increase in morbidity or mortality. If a patent PV is found, the decision can then be made to close it.

Although not routinely offered, another process, which may be beneficial in unilateral inguinal hernias, as discussed previously, is the use of ultrasound. In one study, the development rate of contralateral inguinal hernias after unilateral herniorrhaphy was reduced from 10.2 to 1.5% with the use of contralateral USS ± repair [27].

Preoperative Considerations

As discussed above, preoperative considerations will change if the hernia is incarcerated or not on presentation. This will then dictate whether preoperative reduction is warranted or not.

Consent

Consent will require the use of a parental consent form but with involvement of the child if they are of a suitable age. The parents should be fully informed regarding the procedure including the incision, the nature of the repair (open vs. minimally invasive), potential complications (discussed later) and post-operative management. It is important to consider consenting for the exploration ± repair of the contralateral side, if this is intended.

Complications may be intraoperative or post-operative and all should be discussed. In general terms, the consent process is the same for incarcerated and non-incarcerated hernias. However, the risk of complications is increased with incarceration, as is the necessity to perform the procedure sooner. One series quotes a complication rate of 3.6% in elective repairs compared to 14.4% in incarcerated hernias [16]. This may be in part due to operative difficulty but also possible systemic upset in incarcerations.

Important intraoperative complications include damage to the vas deferens (1–2%) and damage to testicular vessels (1.6%) [16]. Damage to these structures may result in subsequent testicular atrophy and should therefore always be mentioned during the consent process. Atrophy occurs more commonly in *incarcerated* hernias with an incidence reported to be up to 20% [49]; however in elective repair, it is rare at around 4% [64]. Given that most injuries to the vas result from crushing or vascular impairment [1, 65], they might go unnoticed intraoperatively. However, if the vas deferens is divided, it should be repaired with interrupted 7/0 or 8/0 monofilament sutures. An experienced practitioner utilising adequate magnification will make the repair more precise.

Regarding incarcerated hernias, it is important to mention the possibility of damage to the hernia contents. Structures include the intestine, omentum, appendix and ovaries.

Although rare, deaths have been reported in association with inguinal hernias. In 1978 the quoted mortality rate of elective inguinal hernia was 0.1% rising to 3.0% with incarcerated inguinal hernias [66]. However, in more recent series, almost no deaths have been recorded, and mortality appears to be associated with coexisting risk factors such as cardiac disease and prematurity [64, 67], rather than the inguinal hernia per se.

Post-operative complications include wound infections, hydrocele formation, iatrogenic undescended testes, recurrence and altered fertility. These will be addressed later.

It is important to mention that all operative sites should also be marked. Correct site surgery relies on adequate preoperative marking on the abdomen with parental agreement as to the affected side. This is important even if laparoscopic repair is planned, in case pneumoperitoneum is not possible.

Anaesthesia for Inguinal Hernia

General anaesthesia is usually required. In addition local anaesthesia using 0.25% bupivacaine (0.8 ml/kg) within the fascia or a pararectal block is recommended. Some evidence exists for reduced post-operative pain requirement with a preoperative caudal anaesthetic [68].

The World Health Organization (WHO) Checklist

The WHO checklist should be completed with a sign-in, time-out and sign-out.

Regarding the time-out, in a straightforward inguinal herniotomy, there are no critical steps, minimal anticipated blood loss and an estimated duration of 30–40 min. There is no essential imaging and little evidence for the use of antibiotic prophylaxis. We would recommend the use of prophylactic antibiotics only for acute incarcerated hernias requiring emergency surgery.

If a minimally invasive approach is being used, it is important to discuss the necessary equipment and set-up required, depending on the technique being used and surgeons' preference.

Operative Options

Hernias can be fixed via an open approach or using minimally invasive techniques. Laparoscopy was first applied to paediatric inguinal hernias to evaluate the contralateral side for the presence of a patent processus vaginalis (PPV) and to confirm the diagnosis of an inguinal hernia [69–71]. However, there has been a recent emphasis on minimally invasive techniques for the fixation of inguinal hernias.

It is important to mention that the chosen option of course depends on the competencies of the surgeon performing the operation and the resources available at the given centre.

The International Pediatric Endosurgery Group (IPEG) Evidence-Based Review Committee recently chose to review minimally invasive approaches to inguinal hernia repair providing the most up-to-date assessment of the literature both in terms of evidence availability and also evidence quality for the use of minimally invasive techniques [72].

As identified by the IPEG review, to date there are four meta-analyses [73–75] but only one meta-analysis providing level 1a evidence [63] for the use of laparoscopic vs. open hernia repair [72].

Several advantages were identified for the use of laparoscopic repair of inguinal hernias from the IPEG review. Operative time for bilateral hernia repair is reduced and post-op complication rates are lower. As mentioned previously, it offers the advantage of facilitating easy inspection of the contralateral side for identification of metachronous hernias. However, the recurrence rate is comparable with open hernia repair. A disadvantage for consideration is that peritoneal thickening from chronic irritation may hinder the identification of cord structures and put them at risk of damage. Nerve entrapment is also a possibility [76]. There are also the added risks of intra-abdominal organ damage associated with laparoscopic port insertion. Laparoscopy has been reported to be equally advantageous in cases of recurrent inguinal hernias after open surgery [46] allowing the surgeon to avoid previously operated tissue planes and potentially lowering the risks of injury to the vas and/or vessels. In addition, the pneumoperitoneum may widen the internal ring and help in reduction of incarcerated hernias [77], the viability of which can be easily assessed and addressed if needed.

Within minimally invasive inguinal hernia repair, there are several options. The IPEG committee classifies these according to suture placement [72]. This may be either intracorporeal or extracorporeal and both may have single of multiple suture sites. Examples of intracorporeal suture placement include purse-string or 'z' sutures, flip-flap peritoneal coverage or inversion with ligation in females. Examples of extracorporeal suture placement include subcutaneous endoscopically assisted ligation (SEAL) and the use of various instruments to pass a suture around the internal ring, for example, a Reverdin needle or Endoneedle. Intracorporeal suturing is purely laparoscopic and may include dissection of the hernial sac. Extracorporeal suturing uses a groin incision and the suture insertion into the preperitoneal plane with laparoscopic visualisation. Several additional steps or variations on these methods have been described to ease the passage of the suture in this plane and improve hernia closure, such as hydrodissection or traumatisation of the peritoneum.

There is a variety of evidence assessing these techniques from level 4 case series to 1b randomised control trials, but the IPEG committee conclude that there is insufficient evidence to support one method over another [72]. One randomised control trial did specifically compare intra- vs. extracorporeal suture placement and found that extracorporeal suture placement was a significantly faster technique but had no statistically significant improvement in outcomes [78].

In summary, in the right hands, minimally invasive surgery for inguinal hernia repair can be very effective, but open repair should not be abandoned.

Operative Steps: Open Repair (Figs. 21.5 and 21.6)

Patient Position and Theatre Set-Up

The child is placed supine on the operating table. Preparation with a careful aseptic technique combined with betadine or chlorhexidine will suffice. Drapes are applied so that the inguinal area is exposed throughout the operation. The surgical site mark must be visible after draping.

Incision and Access

An incision is made in the lowest inguinal crease along Langer's lines. The Scarpa's fascia is incised and spread. The rounded edge of the external oblique and external inguinal ring should then be identified. The external oblique can then be incised and spread in the line of the fibres. Alternatively the spermatic cord can be accessed from the external ring. However, it is not essential to open the external inguinal ring when opening the external oblique aponeurosis. The ilioinguinal nerve should always be identified on the inner surface of the external oblique aponeurosis in order to avoid its entrapment. The cremasteric fascia is then opened to expose the cord structures.

Key Steps

Care is taken not to grasp either the vas deferens or the vessels. Only loose connective tissue may be handled until the hernial sac is identified. At this point, the latter is grasped with a pair of non-toothed forceps and the remaining cord

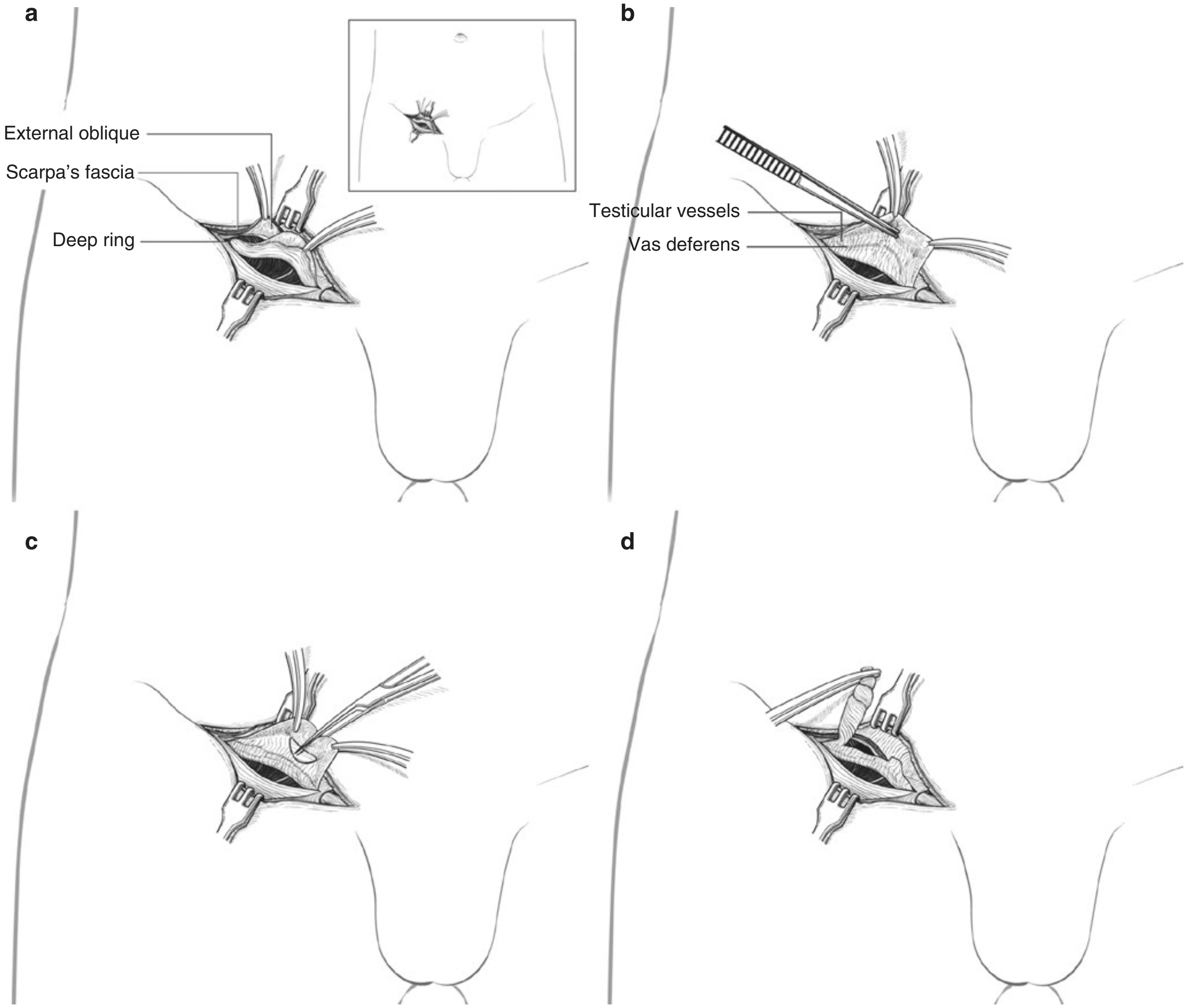

Fig. 21.5 (**a–d**) Open inguinal herniotomy. (**a**) The cremasteric fascia is opened to expose the cord structures. (**b**) The sac is grasped with a pair of non-toothed forceps and the remaining cord structures pushed away bluntly separating them from the hernial sac. This creates a 'window' between the sac and cord structures. This is illustrated far better in children than adults. (**c**) The sac is divided between clamps and the proximal end dissected superiorly to the level of the internal inguinal ring. (**d**) The contents of the sac are reduced and the sac twisted and transfixed

structures pushed away bluntly. In boys, delivery of the testicle into the wound is usually unnecessary.

Once free from the vas and vessels, the sac can be divided between clamps and the proximal end dissected superiorly to the level of the internal inguinal ring. This is identified by appearance of the preperitoneal fat. If necessary, the contents of the sac are reduced; the sac is twisted and then transfixed using a braided absorbable suture. The distal end of the sac is left open. Further dissection of this distal sac is discouraged. Some authors prior to ligation check for a contralateral hernia via hernioscopy. This can be done by insertion of a 30° or 70° scope via the hernial sac following insufflation via a nasogastric tube through the hernial sac [79].

In boys, the testicle should be confirmed to be in a normal intrascrotal position at the end of the procedure. It is equally important to document this on the operation note. In girls, the absence of vital cord structures makes repair simpler. The surgical approach to the sac is the same. However, it is important to routinely open the sac in girls because as many as 21% [80] have a sliding component and to exclude complete androgen insensitivity syndrome (CAIS) where an ovotestis may be present.

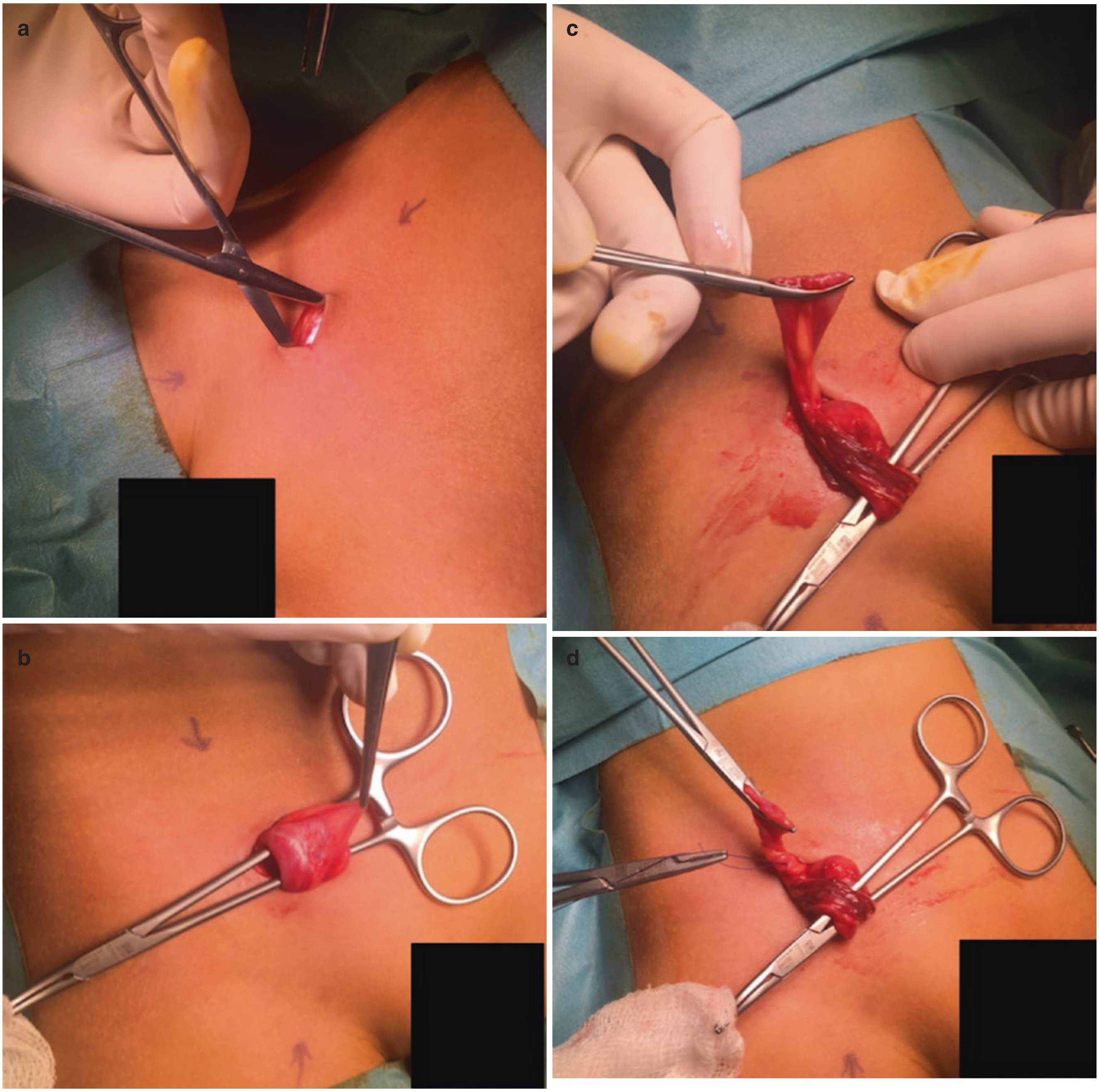

Fig. 21.6 (**a**–**d**) Open inguinal herniotomy. (**a**) Skin incision with dissection through the Scarpa's fascia and external oblique. (**b**) The sac is identified (held in the non-toothed forceps) wrapping around the cord structures. This is bluntly dissected away creating a window between the sac and cord structure—see '**b**' in Fig. 21.5. (**c**) The sac is divided and the proximal end dissected superiorly to the level of the internal inguinal ring. (**d**) The contents of the sac are reduced and the sac twisted and transfixed

Closure

Unlike in adults, the infantile inguinal hernia does not need reinforcement. Exception is made for children with an underlying collagen disease [14]. The external oblique (if opened) should be closed with a continuous suture. Scarpa's fascia can then be closed with interrupted absorbable sutures. Finally, the skin is closed with a subcuticular absorbable suture.

Alternative Open Approach: The High Scrotal 'Bianchi' Approach

In 1989, Bianchi and Squire hailed the use of their scrotal approach for a palpable undescended testis as an acceptable alternative to the groin incision. A high scrotal crease incision exposes the cord structures. The hernial sac is dissected in the usual manner. Upward traction allows access to the neck of the hernial sac for transfixation. Age may be a limiting factor to this approach. The older the child, the bigger retraction necessary to reach the neck of the hernial sac. Some published reports support this approach [81, 82].

Operative Steps: Laparoscopic

Patient Position and Theatre Set-Up

The child is placed supine on the operating table, either inline or across the table depending on size of the child. Careful preparation with an aseptic technique combined and betadine or chlorhexidine will suffice. Drapes are applied so that both inguinal and umbilical areas are exposed as well as the marked side.

For a minimally invasive repair, the theatre must be set up appropriately. This will depend on both the surgeons' preferences but also the technique being used. The senior authors' preference for laparoscopy in neonates and infants is to stand at the patient's head. Therefore, positioning the patient across the table, with or without an extension, is preferable. Care must be taken not to insufflate the stomach too much during anaesthesia or at least provide tubal decompression as distal intestinal distension decreases working space.

Incision and Access

Three incisions are needed. Firstly, an open Hassan technique should be used to insert the umbilical port. A purse-string suture is used to secure the 5 mm port and maintain a pneumoperitoneum. A short 5 mm 30° telescope is inserted and the deep internal rings assessed. Two further 3–4 mm incisions are made in the right and left lower quadrants. Ports are not essential at these points and instruments can be inserted directly in to the abdominal cavity.

The internal ring can then be closed using a purse-string suture avoiding vas and vessels. This suture does not seem to affect testicular viability [83]. The choice of suture material (absorbable vs. non-absorbable, monofilament vs. braided) differs according to the surgeon. However, we recommend a non-absorbable monofilament suture, such as 4-0 prolene (Fig. 21.7). Some authors incise the peritoneum laterally to reduce mechanical tension, although the benefit of this step has been questioned [69, 70]. In addition to the purse-string suture, a 'Z' suture can also be placed over the purse string to re-enforce the repair. Other groups have reported a needlescopic technique, using one or two lateral ports to assist with percutaneous, extraperitoneal ligation of the internal ring [71, 84].

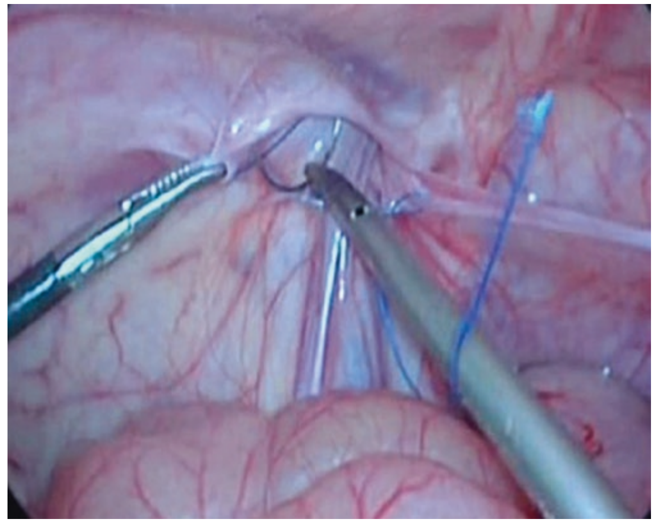

Fig. 21.7 Laparoscopic closure of inguinal hernia using 4-0 prolene

Closure

The right and left iliac fossa openings if no larger than 3–4 mm (size of the needle driver shaft) can be closed with glue alone. Hernia formation is unlikely if left open [70]. The umbilical port site is closed with the purse-string suture placed at the beginning and further suture to close any fascial defect if needed. A braided suture such as Polysorb (Ethicon) 2-0 or 3-0 can be used. It is important to make a sound closure to prevent subsequent umbilical hernia formation. Similarly, if an umbilical hernia is present, this should be closed concurrently with a formal umbilical herniotomy technique (see previous chapter).

Alternative Minimally Invasive Techniques

Flip-Flap Closure

A flap of peritoneum is dissected laterally, flipped and anchored to cover the hernial opening [88]. Initial reports on this technique are unsatisfactory due to intraoperative complications (vas injury and flap avulsion) and high rate of recurrence.

The Reverdin* Needle (RN)

RN is a surgical needle with an eye that can be opened and closed with a slide. It essentially modifies the delivery of the suture material, creating extracorporeal knot-tying. It markedly reduces both operative time and technical difficulty [78, 85] (Fig. 21.8).

*Jaques L. Reverdin, Swiss surgeon, 1842–1929

Laparoscopic Inversion Ligation (LIL)

The hernial sac is inverted into the peritoneal cavity and the base tied with an endo-loop. It is only applicable in girls, as the vas and vessels cannot be excluded from the tie. A series of 30 females reported no recurrences [89]. Similarly, a larger series of 241 hernia repairs reported no intraoperative or wound complications and a recurrence rate of 0.83% [86] (Fig. 21.9).

Laparoscopic Extraperitoneal Closure (LPC)

An *Endoneedle* [90] devised by the department of Paediatric Surgery of Saitama Municipal Hospital in Japan is a special instrument that has a wire loop to hold the suture material at the top and can be used for purse-string suturing around the internal inguinal ring, with extracorporeal knot tying [87]. On analysis of 1257 hernias repaired with laparoscopic extraperitoneal closure, there was a recurrence rate of 0.2% [91]. In addition, in conjunction with umbilical ligament reinforcement, this has been shown to achieve near-zero recurrence rates [92] (Fig. 21.10).

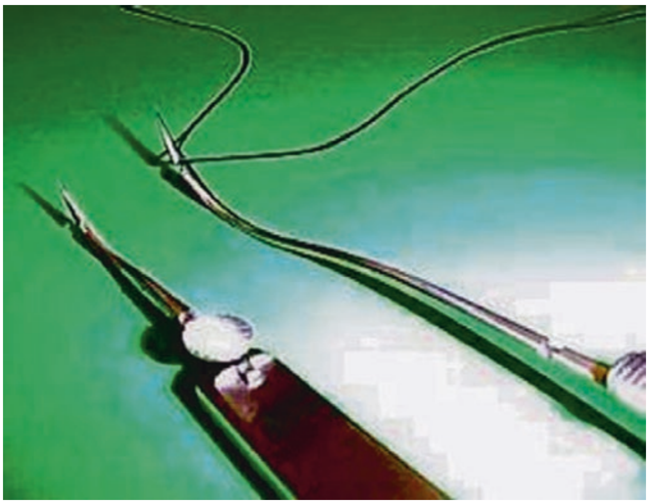

Fig. 21.8 Both components of the Reverdin needle, seen here with mounted suture. Reprinted with permission from [85]

Percutaneous Internal Ring Suturing (PIRS)

A hollow needle with suture material inside is passed percutaneously under the peritoneum of each half of the internal ring. It allows extracorporeal knot tying by catching a loop of the suture material and pulling it to the surface. Patkowski et al. report some intraoperative and post-operative complications, the most serious of which was bowel strangulation that required resection and anastomosis. Recurrence occurred in 3 cases out of 106 children (2.8%) [93]. Another series of 250 patients demonstrated a recurrence of 1.4% and a complication rate of 2.8% in children over 10 kg [94] and a further series of 205 hernia repairs had no recurrences, with a mean follow-up of 3.6 years [95].

Subcutaneously Endoscopically Assisted Ligation (SEAL)

A swaged-on needle is inserted percutaneously and passed in the extraperitoneal space over half of the internal ring. A hollow needle is also inserted percutaneously over the opposite

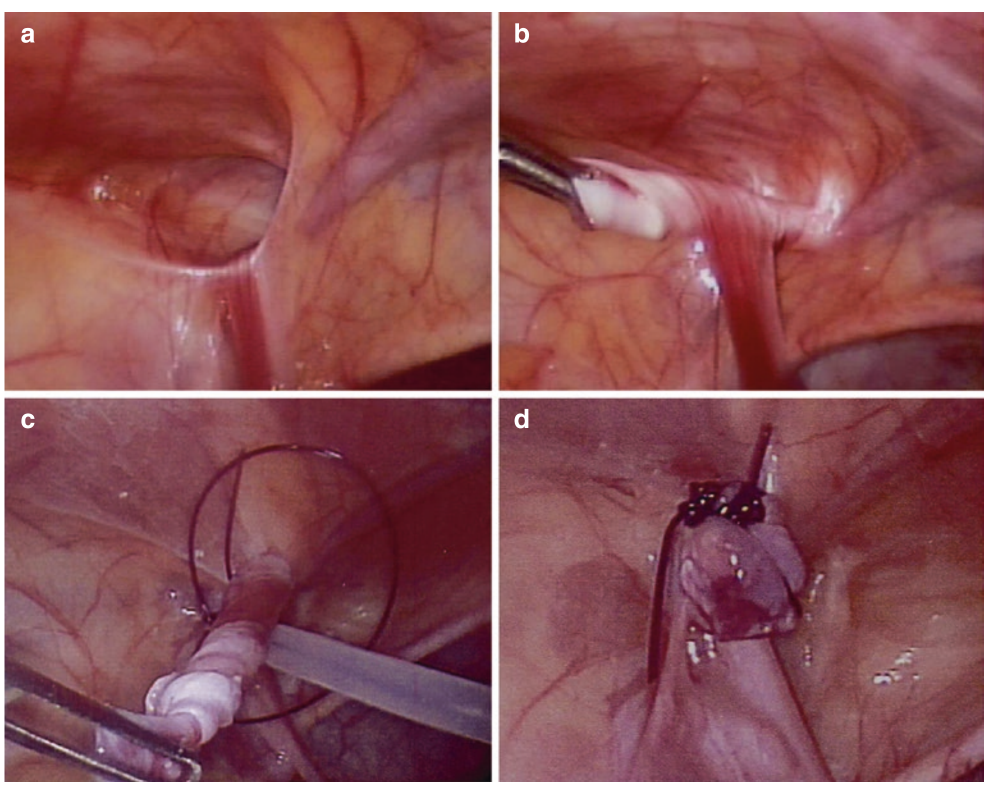

Fig. 21.9 Laparoscopic inversion ligation (LIL). Hernia is identified (**a**), peritoneum inverted (**b**), twisted and double ligated (**c**) and then excised (**d**). Reprinted with permission from [86]

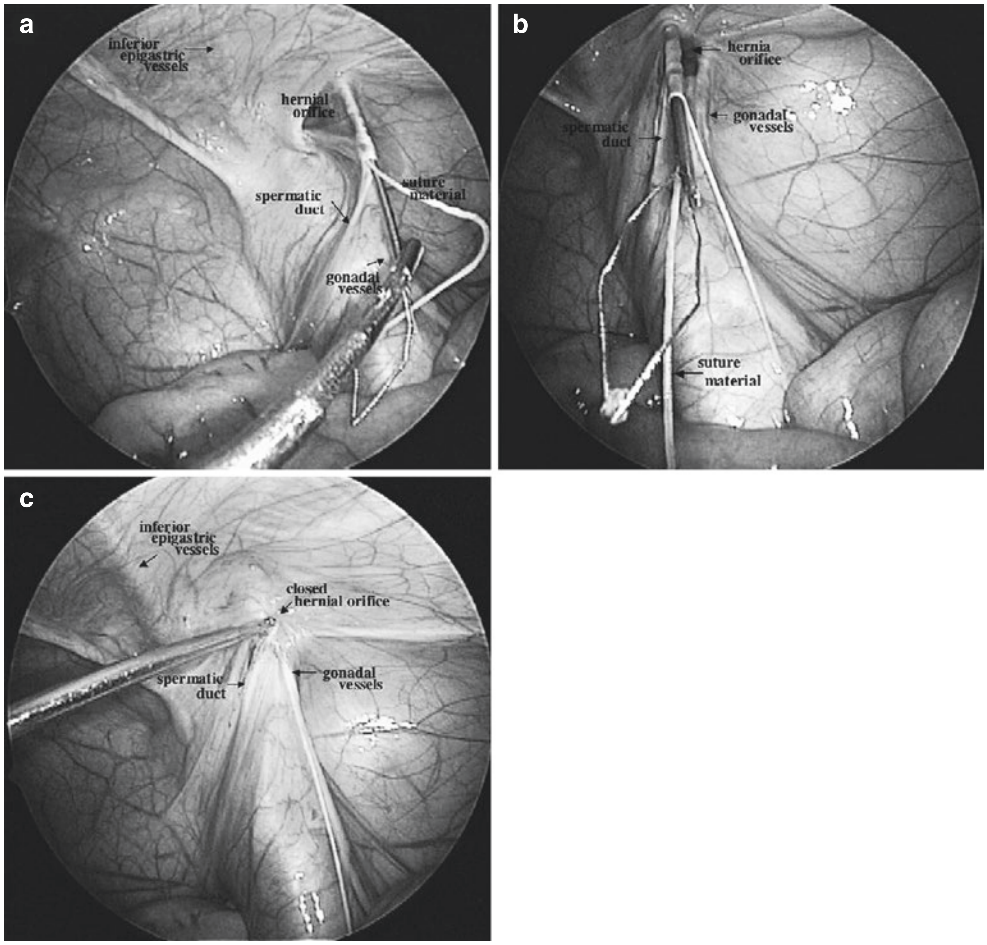

Fig. 21.10 (**a–c**) Laparoscopic percutaneous extraperitoneal closure (LPEC) of the internal ring. (**a**) Half of the purse-string suturing is started extraperitoneally, beginning at the anterior edge and proceeding to the posterior edge on the lateral side of the internal inguinal ring using the LPEC needle. (**b**) Suturing of the medial side of the internal ring is placed extraperitoneally using the same technique, and the suture material is held in the wire loop inside the LPEC needle. (**c**) The LPEC needle is then removed from the abdomen together with the suture material. The purse string is tied extracorporeally. Reprinted with permission from [87]

half of the internal ring. Mating of the two allows the suture material to jump over the vas and vessels and encompass most of the circumference of the internal ring. The swaged needle is then backed subcutaneously (completing the circumference), retrieved through its entry point and tied extracorporeally [96]. This technique was used in 43 hernia repairs and no intra- or post-operative complications were reported [97].

Tissue Adhesives

The use of tissue adhesives as an adjunct to closing paediatric inguinal hernias remains at an experimental level. Sealants mentioned in the literature include electrocautery and talc and glue [71, 98]. In a preliminary study on the usefulness of tissue adhesives in repair of inguinal hernias, Kato et al. reported that only the laparoscopic injection of octylcyanoacrylate (Dermabond®) is effective and scarless. Interestingly it also did not affect fertility [99].

Post-operative Management

With the exception of infants who require extended observation, most patients are discharged on the day of surgery.

Premature infants at risk of apnoea may require prolonged observation or overnight stay based on local protocols [52]. Similarly, an extensive laparoscopic procedure may require hospital admission. Oral intake may be resumed when the effects of anaesthesia wear off. The reader is referred to 'Good practice in post-operative and procedural pain' for advice on best practice with regard to post-operative pain management [100]. Baths can then be resumed on the third post-operative day. Older children should refrain from bicycle riding, swimming or other vigorous physical activities for approximately 1 month [4].

Post-operative Complications

Possible post-operative complications are outlined below. As mentioned previously, these should be considered when consenting patients. However, exact rates will vary depending on the technique used.

Wound Infection

The wound infection rate at most major paediatric centres is low, approximately <2% [4]. An increased incidence of infection would be expected in incarcerated hernias.

Hydrocele

This may be attributed to incomplete excision of the distal sac and may be avoided by partial resection of the latter, although this is not usually recommended. The post-operative hydrocele often resolves spontaneously, rarely requiring aspiration. Occasionally, long-term persistence of the hydrocele may require a formal hydrocelectomy [64].

Iatrogenic Undescended Testis

Otherwise known as a ‘trapped testicle’, it is a possible sequel to inguinal hernia repair. It may be attributed to improper replacement of the testicle in the scrotum at the end of the operation or secondary to subsequent retraction. If this occurs, orchidopexy is necessary. It has a low reported incidence. In a series of 3776 repairs using a modified Marcy approach, only one case was described (0.03%) [16]. However, rates of 2% have been reported [64].

Recurrent Inguinal Hernia

This is a relatively uncommon complication in children. The rate following repair on an uncomplicated inguinal hernia is up to 0.8%, rising up to 15% in premature infants and 20% in incarcerated hernias [1, 6, 30, 46] Of these, 80% are noted within the first post-operative year [46], although there is a suggestion that recurrence rates are under-reported due to lack of long-term follow-up in the studies [6].

Interestingly, the surgeon’s level of experience was not found to be statistically associated with recurrence [6], although a technical error will certainly contribute to recurrence.

Testicular Atrophy

Testicular atrophy after elective inguinal hernia repair is rare [1, 64]. In two recent series, a rate of 0.03% has been reported [16, 42]. Atrophy occurs more commonly in *incarcerated* hernias with an incidence reported to be up to 20% [49]. Erdogan et al. report two cases of atrophy in incarcerated repairs (0.5%). Intraoperative or early post-operative assessment of the testicle is unhelpful [101]. An intraoperative cyanotic testicle may frequently improve; therefore an orchidectomy is discouraged unless obvious necrosis is seen [6]. Similarly, testicular atrophy may not declare itself until after puberty [101].

Fertility

Documented intraoperative vasal injuries are quoted at 0.13% [102], while post-operative examination of excised hernial sacs claims it to be 0.23% [103]. As the hernial sac is not routinely sent for histopathological examination and as the vas may also be damaged by crushing, stretch or mere grasping [1], the true incidence of vasal injury is probably under-reported. Subfertility [104], obstructive azoospermia [105] and subsequent circulating spermatic autoagglutinating antibodies [106, 107] have been associated with inguinal hernia repair in childhood. However, unless the injury is bilateral, the ultimate effect on fertility may not be evident, and this is not routinely discussed during consent.

Major causes of recurrent inguinal hernia in children [1, 46, 6]

1. Incarceration
2. Missed hernial sac or unrecognized peritoneal tear
3. Broken suture ligature at the neck of the sac
4. Failure to repair a large internal inguinal ring
5. Injury to the floor of the inguinal canal, resulting in a direct inguinal hernia
6. Severe wound infection
7. Increased intra-abdominal pressure
8. Connective tissue disorders
9. Conditions with pubic diastasis

Summary

All inguinal hernias in infants and children should be managed operatively and there is no role for conservative management. Incarceration is the predominant complication. These hernias require urgent reduction and, if achieved, expedited surgical management. If reduction is not possible, they require emergency surgical intervention. There are a variety of techniques for surgical repair, both open and minimally invasive. Open approaches are well established but minimally invasive approaches continue to develop. The approach used depends on the competencies of the surgeon performing the procedure.

Tips and Pitfalls

- Ensure correct site marking at the beginning of all hernia procedures.
- If sac is opened during open inguinal herniotomy, care must be taken to ensure sac is controlled and separated from vas and vessels before ligating.
- Leave at least 48 h if cord is oedematous before proceeding to open inguinal herniotomy.
- Careful inspection of the neck of the hernial sac before transfixation avoids injuring structures that may be inside the sack, either from sliding or incarceration. If there is any doubt of safety, the sac should be opened and inspected from the inside and subsequently closed with a purse-string suture.
- It is important to remember that Scarpa’s fascia is often more prominent in infants. So much so that the surgeon may mistake it for the aponeurosis of the external oblique muscle. However, there may be a layer of fat between the fascia and the aponeurosis. As long as fat is encountered, the external oblique aponeurosis has not been reached.
- If a concomitant umbilical hernia is present when using the site for optical port in laparoscopy, ensure an adequate umbilical herniotomy is carried out. Simple port closure will result in recurrence.

- It is important to make sure that both testicles are present in the scrotum at the end of the operation and that this is clearly documented on the operative note.

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22 Management of Adverse Events After Inguinal Hernia Repair

Gina L. Adrales and Sepehr Lalezari

Introduction

Inguinal hernia repair is a commonly performed operation. In the United States, it is estimated that 770,000 repairs are performed annually [1]. While this is generally a safe operation, adverse events may occur. This can range from relatively benign problems such as a seroma to more significant complications that may require intervention such as intestinal injury. The majority of surgical complications reported in association with inguinal hernia repair fall in the category of Grade I complications under Clavien's proposed system [2]. Vascular and visceral injuries are rare, particularly in association with laparoscopic inguinal hernia repair [3]. In a recent large meta-analysis of randomized trials comparing laparoscopic and open unilateral inguinal hernia repair, the recurrence risk was equivalent between transabdominal preperitoneal repair and open inguinal hernia repair [4]. The totally extraperitoneal laparoscopic approach had an increased risk of hernia recurrence compared to open repair (RR = 3.72, 95% CI = 1.66–8.35). In this meta-analysis, the transabdominal repair, but not the totally extraperitoneal approach, had a greater perioperative complication risk compared to open repair (RR = 1.47, 95% CI = 1.18–1.84). However, laparoscopic repair was associated with a decreased risk of chronic pain and numbness compared to open repair. A 2003 Cochrane Review noted fewer hematomas in the laparoscopic group but a higher incidence of seromas compared to open repair [5]. There were only three reported cases of deep surgical site infection or mesh infection in the entire review, highlighting the relative benign nature of inguinal hernia repair compared to ventral herniorrhaphy.

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While management of selected intraoperative complications is discussed, the focus of this chapter is the management of adverse events after inguinal hernia repair with the exception of chronic pain.

Postoperative Nausea and Vomiting (PONV)

Approximately 50% of patients undergoing anesthesia will develop postoperative nausea and 30% will have emesis [6]. Postoperative retching may place undue stress on an early repair. Risk factors for PONV are younger age (<50 yo), female gender, history of prior PONV, nonsmoking status, history of motion sickness, use of volatile anesthetics, duration of anesthesia, postoperative opioid use, general vs. regional anesthesia, and nitrous oxide [6].

The best approach is prevention of postoperative nausea. Prophylaxis against PONV includes antiemetics, antihistamines, anticholinergics, propofol, steroids, neurokinin-1 receptor antagonists, and physiologic volume replacement. The 5-HT3 receptor antagonist ondansetron is the "gold standard" antiemetic [6]. The proper dosage is 4 mg IV which is equivalent to the 8 mg oral disintegrating tablet. The optimal timing for administration of ondansetron for PONV prophylaxis is at the end of the surgical procedure [7]. Transdermal scopolamine is an anticholinergic that can be used as an adjunct for prevention of PONV. It is usually applied the night before surgery or 2–4 h before anesthesia start time. Side effects include visual disturbances, dry mouth, and dizziness. Dexamethasone has been shown to prevent PONV in various studies [8]. The dosage varies between 2–5 mg and 8–16 mg. A study by Karanicolas et al. showed superiority of the 8–16 mg dose, but in another meta-analysis by De Oliveria et al., the outcome difference was not significant but favored utilization of the 4–5 mg dose [8, 9]. Elhakim et al. showed that a combination of 8 mg dexamethasone and an antiemetic was the optimal dosage

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for prevention of PONV [10]. Administration of dexamethasone at induction is likely the optimal time [6, 11].

Urinary Retention

Postoperative urinary retention, or the inability to void despite a full bladder, may manifest as pelvic discomfort or pain requiring catheterization. The morbidity of postoperative urinary retention includes temporary bladder atony which may become permanent [12]. Normal adult bladder capacity varies between 400 and 600 cc. The first urge to void is felt at a bladder volume of 150 cc while fullness is felt at 300 cc [13]. Diagnosing urinary retention may be done by physical examination, bladder catheterization, or ultrasound [14]. Bladder catheterization, although invasive, is a means to both diagnose and treat the urinary retention.

Urinary retention after inguinal hernia repair has been reported over a range from 1 to 22%, and these rates are lower for laparoscopic repair as opposed to open repair [12, 15–21]. Risk factors include increasing age (especially if greater than 50 years), male gender, and benign prostatic hypertrophy (BPH) [19, 21, 22]. Prevention of this complication includes preoperative voiding prior to induction, limitation of fluid infusion to less than 500–1200 cc, medical treatment for BPH, avoidance of general anesthesia, and reduction in opioids [16, 17, 19, 20, 22]. General anesthesia is associated with a higher incidence of postoperative urinary retention [20]. Anesthetic choice should be considered carefully for those patients at increased risk for postoperative urinary retention. Limitation of intravenous fluids is controversial. In a prospective randomized study by Kozol, the difference in perioperative fluid restriction did not reach significance although the authors did recommend intraoperative intravenous fluid restriction [22].

According to Choi and Awad, management of postoperative urinary retention includes assessment by ultrasound at 4 h post-op or 4 h post catheter removal [23]. If bladder volume measurement is >500 cc, a single catheterization should be performed. Post-void residual (PVR) volume should be checked once the patient voids spontaneously [12]. If the PVR is >300 cc, the patient should be scanned again in 2 h. If at the 2 h mark the bladder volume is >500 cc and the patient is unable to void spontaneously, then a second catheterization should be performed. The process should be repeated if the patient does not spontaneously void, but the next step is to place an indwelling catheter with a plan to discharge home with the catheter. If the PVR is <100 cc, monitoring can be discontinued. If PVR is between 100 and 300 cc, another PVR should be checked at the next spontaneous void.

Bleeding

The management of intraoperative bleeding first starts in the preoperative phase with preventative measures to reduce the risk of hemorrhage. Specific attention must be paid to patient use of prescribed and over-the-counter anticoagulation medications. Approximately one-third to one-half of surgical patients in the United States are on herbal supplements [24]. As outlined by Levy et al., only 50% of patients on herbal supplements disclose their use to their healthcare providers, and only about 50% discontinue them as directed. There are many common supplements that increase the risk of bleeding [24, 25] (Table 22.1). The Omega-3 fish oil supplement is commonly consumed for its cardiac benefits and management of dry eyes. It has moderate antiplatelet activity. Other common supplements such as green tea, magnesium, rosemary, and flax seed have high antiplatelet activity. Ginger is consumed for a variety of reasons including digestive symptoms, which might occur in the setting of a hernia. Ginger is a strong antithrombotic inhibitor. In light of the nonessential nature of these herbal supplements, they should be discontinued at least 1 week prior to surgery.

The management of prescribed anticoagulation medications should be determined based on the indications for use, cardiac status, and hernia factors. It is advisable to be more conservative regarding anticoagulation medication use in the patient with a recurrent or incarcerated hernia where more significant adhesiolysis might be expected. Warfarin has a half-life of 36–42 h, and its effects may last several days after cessation of drug therapy. The American College of Chest Physicians recommends cessation of warfarin 5 days prior to surgery with resumption of warfarin 12–24 h after surgery assuming adequate hemostasis was achieved intraoperatively [26, 27]. The administration of bridging therapy with low molecular weight heparin is based on the risk of thromboembolism. No bridging therapy is indicated for those patients at low risk, such as patients with atrial

Table 22.1 Common herbs and herbal supplements that may be associated with postoperative bleeding

Supplement	Action
Chamomile	Cytochrome p450 inhibition
Flaxseed	Antiplatelet
Garlic	Inhibits platelet aggregation
Ginger	Inhibits platelet aggregation
Gingko	Antiplatelet, antithrombotic
Green tea	Antiplatelet
Omega-3 fish oil	Antiplatelet
Rosemary	Antiplatelet
Sage	Cytochrome p450 inhibition
Vitamin E	Inhibits platelet aggregation

Sources: [24, 25]

fibrillation in sinus rhythm and low risk of thromboembolism [26, 27]. The newer direct oral anticoagulants, such as apixaban, should be held a minimum of 48 h prior to surgery and resumed 48–72 h after surgery assuming that hemostasis was achieved [28]. In general, the risk for perioperative hemorrhage is greater than the risk of thromboembolism [26]. General recommendations regarding discontinuation of anticoagulation medications are summarized in Table 22.2; however, management of anticoagulation should be individualized according to the patient's comorbidities, risk for bleeding and thromboembolism, and cardiac status.

Meticulous tissue handling can reduce the risk of bleeding. The use of electrocautery should be judicious to avoid visceral, spermatic cord, or nerve injury. Clips are helpful in this regard during endoscopic repair with care taken to avoid compression nerve injury particularly in the lateral space. Bleeding may occur during preperitoneal balloon dissection in totally extraperitoneal preperitoneal (TEP) repair. Minor bleeding seen during balloon expansion may stop with the tamponade of the balloon. A few minutes of balloon inflation thus may provide at least temporary relief and allow placement of the additional trocars after balloon release to achieve more deliberate hemostatic control with cautery or clips. Management of bleeding epigastric vessels is fairly straightforward with clip placement though the bleeding may obscure visualization. If the injury is cephalad, one must be cognizant of the location of a lateral epigastric branch. While visualization of the internal iliac vein is important to ensure there is no femoral hernia, the vein wall is thin and traction injury or direct injury may occur. Direct pressure should be applied immediately with a grasper or dissector, and this will allow time for definitive repair. Conversion to an open preperitoneal or transabdominal approach or laparoscopic vascular repair will be conducted based on surgeon experience and degree of bleeding control.

Immediate postoperative bleeding manifested by a rapidly enlarging hematoma or hemodynamic instability is best addressed surgically. If this occurs after an open repair, it should be approached via an open approach with reopening of the incision, evacuation of the clot, and identification of the bleeding source with particular attention to the epigastric vessels and muscle bed. In many cases, the definitive bleeding source eludes identification, but exploration in the immediate recovery period may be beneficial in evacuation of the clot which otherwise could later predispose the patient to surgical site infection and chronic mesh infection. Postoperative hemorrhage after laparoscopic repair, though rare, can be more challenging as the blood can spread into the wider retroperitoneal space with limited tamponade. For the hemodynamically unstable patient, an open approach to the preperitoneal space is likely most expedient. Removal of the mesh may be required to expose the bleeding source. The area of the corona mortis and epigastric vessels and the area of dissection in proximity to the external iliac vessels should be explored. The choice of mesh reimplantation or conversion to primary tissue repair after postoperative bleeding is left to the surgeon's judgement with consideration of the risk of infection or recurrent bleeding.

Table 22.2 General recommendations for preoperative cessation of anticoagulation medication

Medication	Class	Preoperative stop date
Warfarin	Vitamin K antagonist	5 days
Apixaban	Direct factor Xa inhibitor	48 h
Edoxaban	Direct factor Xa inhibitor	48 h
Clopidogrel	Antiplatelet agent	7 days
Rivaroxaban	Direct factor Xa inhibitor	48 h
Dabigatran	Direct thrombin inhibitor	48 h

Hematoma

The hematoma that develops beyond the acute recovery is less worrisome. Postoperative hematomas occur approximately 0.3–6% of the time [29–32]. It appears that these rates do not change significantly by procedural approach (open or laparoscopic), laterality, or usage of antiplatelet agents [31, 32]. In a study by Zeb and colleagues, cardiac valvular disease had the highest risk for hematoma formation followed by incarcerated hernia, bridging with heparin, previous bleeding, recurrent hernia, warfarin, atrial fibrillation, coronary artery disease, and hypertension [32]. Most hematomas were found to be superficial to the external oblique aponeurosis; thus special care should be taken to identify subcutaneous vessels in patients at higher risk for hematoma formation. Hematomas and seromas are best identified by a CT scan. Although an ultrasound may be used, differentiation of seroma from hematoma is difficult unless a bleeding vessel is identified on Doppler ultrasound. Management options for an early hematoma and seroma include reoperation for hemostasis and washout, needle aspiration, or embolization of an identifiable vessel by interventional radiology. As noted previously, most often an identifiable vessel will not be evident. In some patients there will be slight but diffuse bleeding suggestive of a coagulopathy, and in others, no source may be identified [30].

Seroma

Seroma is a common occurrence after inguinal hernia repair. Supportive undergarments may provide comfort, but there is no evidence to support their use in terms of prevention or reduction of seroma. Closure of the direct inguinal hernia defect during endoscopic repair may decrease the rate of seroma. Patients with scrotal hernias or large direct defects are at increased risk for postoperative seroma (Fig. 22.1).

Fig. 22.1 Ultrasound of a large seroma after laparoscopic transabdominal preperitoneal repair of an incarcerated scrotal inguinal hernia

Ligation of the sac and suturing the sac to the posterior inguinal wall may decrease the seroma formation after endoscopic repair of a large scrotal hernia [33].

Management of postoperative seroma is largely expectant. Many are asymptomatic though can be disturbing to patients if they are not prepared for this possibility during the preoperative informed consent discussion. For the symptomatic or large seroma, needle aspiration is performed under sterile technique and may be done by the surgeon with or without ultrasound guidance or by interventional radiology depending on the comfort of the surgeon and the complexity of the seroma.

Testicular Complications

Testicular complications include pain, ischemic orchitis, and testicular atrophy. Orchitis is the likely cause of pain, and it may progress to testicular atrophy. Orchitis usually manifests within 24–72 h from surgery. It is associated with painful swelling of the testicle which is firm and unyielding, and it may be associated with a low-grade fever [34]. Pain is usually severe and may last for up to 6 weeks after surgery. Ischemia is usually due to thrombosis of the spermatic cord venous plexus from vigorous dissection of the hernia sac, although placement of mesh is also associated with inflammation and scarring which may compromise vascular flow to and from the testicle [35]. There is no true role for surgical intervention if this problem arises. Anti-inflammatory agents and/or narcotic administration will afford symptomatic relief only. Ultimately, the affected testis will atrophy.

Infertility

The incidence of infertility is 0.3–5% after inguinal hernia surgery [35, 36]. Both males and females may experience infertility after inguinal hernia repair. Infertility is defined as a failure to conceive a child after 1 year of unprotected intercourse. Overall, 65% of the time, failure to conceive is a result of female infertility [37]. Although female infertility is a rare occurrence after inguinal hernia repair, there is an incidence of 4.7% among males [38]. Infertility as a result of inguinal hernia repair usually occurs from damage to the reproductive organs at the time of the repair [38, 39]. One must be aware that the ovary and fallopian tube may reside in the hernia sac and care must be taken to avoid injury. A systematic review assessed the rate of obstructive azoospermia at 0.03% for open repair and 2.5% for bilateral laparoscopic transabdominal inguinal hernia repair [40]. In this study, male infertility was detected in 0.8% of the open inguinal mesh repair patients, and interestingly, there was no correlation to the type of mesh (lightweight versus heavyweight). Thus, it may be conjectured that male infertility after inguinal repair may have more to do with tissue handling during the dissection rather than postoperative inflammation and scarring. However, open primary tissue repair had no effect on male fertility and obstructive azoospermia.

Because of the limited surgical treatment options for male infertility, detailed informed consent about the possibility of infertility after inguinal hernia repair should be conducted and the necessary care taken to protect the vas deferens during surgery. This is particularly pertinent to discussion about repair of the asymptomatic or incidentally found contralateral inguinal hernia.

Bowel Complications

Intraoperative Bowel Injury

Inadvertent bowel injury is a worrisome intraoperative complication. A serosal tear need not change management, but any contamination from a full-thickness intestinal injury should be addressed. A full enterotomy converts the clean hernia repair to a clean/contaminated (Class II) or contaminated (Class III) with an associated increased risk for surgical site infection and required change in operative management. While deciding upon mesh implantation in this scenario, one must weigh the long-term risk of hernia recurrence with the short- to long-term risk of mesh infection and subsequent reoperation or chronic wound. The approach should be selected based on surgeon experience, patient risk factors for perioperative complications, and reoperation as well as hernia recurrence. If the injury occurs during the course of an endoscopic repair and the surgeon is facile in intracorporeal suturing and laparoscopic bowel surgery, then the bowel should be repaired, and the decision to place permanent prosthetic for a lower hernia recurrence must be balanced against the risk of mesh infection. This will largely depend on the degree of contamination. While there is published data regarding ventral hernia repair with polypropylene mesh in contaminated fields [41], mesh-related complications have been shown to temper the advantage of decreased hernia recurrence risk of incisional hernia mesh repair over sutured repair with both rates approximately 5% at 5 years [42]. Moreover, it is not advisable to extend these findings for an off-label use of the prosthetic mesh to inguinal repair particularly in the setting of colon injury. Given that there are acceptable tissue repair options for elective inguinal hernia repair, conversion from laparoscopic or open mesh repair to open tissue repair appears to be the safest management though the volume and quality of evidence to support this recommendation are low.

Missed Enterotomy

A missed bowel injury is a rare complication after inguinal hernia repair but one with potentially grave consequences. This should be suspected for any postoperative patient who does not fit the pattern of the usual quick recovery. Presenting findings may include peritoneal signs and tachycardia but may be more subtle with pain that is not well controlled and mild fever. Suspected missed enterotomy after endoscopic transabdominal or totally extraperitoneal inguinal repair may be approached laparoscopically depending on the experience of the surgeon with laparoscopic bowel surgery. The colon near the repair site and the small intestine should be inspected in their entirety. Should bilious fluid be seen but no bowel injury found or if the suspicion remains high for a bowel injury based on details of the index surgery (e.g., herniated and adherent bowel), then conversion to laparotomy is recommended. Removal of the exposed mesh in the case of bowel injury with spillage is the most conservative option to reduce the risk of reoperation and chronic mesh infection. If the initial repair was performed via open technique, laparotomy should be performed as the most expedient method to evaluate and repair the bowel. The mesh exposure to intestinal spillage in this situation may be minimal. If this is the case, the mesh need not be removed but should be monitored closely.

Bowel Obstruction

Postoperative bowel obstruction is an unusual complication after inguinal hernia repair. In the early days of laparoscopic repair, this was reported with relative frequency after the laparoscopic transabdominal preperitoneal (TAPP) inguinal hernia repair [43, 44]. There is notably more exposure to the intestine with the transabdominal technique compared to TEP or open repair. Postoperative bowel obstructions following TAPP have been attributed primarily to incomplete closure of the peritoneal flap. Care must to be taken during closure not to leave any gaping openings between staples and tacks. Sutured repair is preferred by the author during TAPP. However, this technique is not immune to bowel obstruction as bowel adhesions to the edge of the peritoneal flap have also been reported. Bowel adhesions to self-anchoring barbed suture have been reported after TAPP [45]. This mechanism for bowel obstruction may also be a concern for robotic TAPP repair.

Factors to consider in the management of the postoperative bowel obstruction include the degree of obstruction (partial versus complete), the presence of a transition point on imaging, and the timing of presentation after inguinal hernia repair. Bowel obstruction after open inguinal hernia repair is such a rare occurrence that there is no reported guidance in management. Unless there was direct manipulation of the intestine during open inguinal hernia repair or there is concern that the intestine was not entirely reduced during repair, postoperative bowel obstruction after open repair can be managed as one would for any presentation of bowel obstruction guided by the severity of the clinical presentation and imaging. Particularly in the case of the patient with a prior history of other abdominal surgery, obstructive symptoms without peritonitis and no clear transition on computed tomography imaging may be amenable to nonoperative therapy with nasogastric tube decompression as indicated, bowel rest, and supportive care. For early postoperative bowel obstruction after endoscopic repair, one must be suspicious of a breach in the peritoneum or tethering of the intestine during fascial closure, and a lower threshold for return to the operating room is recommended.

Bladder Injury

Bladder complications after open inguinal hernia repair may appear with variable latency after repair, ranging up to 20 years after repair [46]. Though infrequent after open repair, these have been reported with greatest frequency after plug repair with mesh migration and erosion. These can be associated with urinary infection and urinary irritating symptoms such as frequent voiding but may be asymptomatic. Mesh plugs have been associated with migration into the peritoneal cavity and bowel obstruction, bladder erosion, and scrotal migration with mass effect [46–50]. Bladder erosion has also been reported after open preperitoneal Stoppa repair requiring laparotomy, but this appears to be a rare event [51].

Bladder injury occurs infrequently during the course of balloon dissection with TEP repair. Bladder injury after TEP repair is very rare with reported incidence in large TEP series less than 0.05% [52, 53]. A large registry series of over 9300 patients who underwent TEP repair reported a higher rate of bladder injury with bilateral inguinal hernia repair (0.28%) than unilateral repair (0.04%) [54]. Balloon inflation is the mechanism by which bladder rupture occurs during TEP. Patients with prior abdominal surgery, trauma, and suprapubic catheters are at highest risk [55–58].

Other bladder complications after laparoscopic inguinal hernia repair have been reported in the form of single case reports. This includes bladder injury and stone formation after laparoscopic transabdominal inguinal hernia repair due to permanent tack fixation involving the bladder. In a report by Colegate-Stone et al., this was managed laparoscopically with opening of the bladder to retrieve the tack and bladder primary closure [59]. Painless hematuria in a patient with prior history of laparoscopic inguinal hernia repair may represent mesh migration into the bladder. Mesh erosion after laparoscopic repair is extremely rare [47, 60, 61]. Other presenting symptoms include urinary frequency and urgency as well as urinary tract infection. In addition, colovesicular fistula after laparoscopic transabdominal inguinal hernia repair has been reported [62]. Distinguishing mesh erosion from bladder malignancy by imaging alone is insufficient, and cystoscopy is indicated where there is diagnostic uncertainty in patients with history of inguinal repair [63].

In summary, there are no established guidelines in addressing these rare bladder complications after open or laparoscopic inguinal hernia repair. Open rather than laparoscopic urologic surgery is likely needed for complex erosions involving the bladder wall though a robotic approach may be feasible. A laparoscopic approach to bladder and bowel erosion after TEP and simple cystoscopy with mesh removal after open inguinal hernia repair have both been reported [47, 64]. Given the rarity of mesh erosion into the bladder and the variability in severity and timing of presentation, an individualized approach with urology involvement is recommended.

Immediate Neuropathic Pain

The recovery after endoscopic or open inguinal hernia repair tends to follow a pattern of pain that is well controlled with anti-inflammatory medication and usual narcotic dosing. One should be concerned about the patient who complains of sharp, uncontrolled pain in the recovery area or who is unable to ambulate due to pain. In addition to immediate evaluation for peritonitis, a careful neurologic exam of the groin and thigh is mandated. Should nerve injury be suspected, immediate return to the operating room with inspection for nerve impingement or direct nerve injury represents the best opportunity to alleviate the pain and reduce the risk of chronic inguinodynia. Any offending tacks or sutures should be removed. One may consider involving a peripheral nerve specialist. In terms of transection of the involved nerve, there is no data regarding this situation of nerve injury in the immediate postoperative setting. The results of preemptive nerve transection during open inguinal hernia repair are mixed with improvement in short- and midterm pain but not long term [65]. These results cannot be extrapolated reliably to the immediate postoperative setting.

Infection

Inguinal hernia repair is considered a clean procedure, and the incidence of surgical site infection after repair should be low. The European Hernia Society guidelines do not recommend antibiotic prophylaxis for inguinal herniorrhaphy at hospitals where the rate of surgical site infection is low (<5%) unless there are patient factors such as immunosuppression that would increase the risk for infection [66, 67]. Outcomes associated with the Swedish Hernia Registry indicate that the risk of postoperative wound infection after open inguinal hernia repair is increased by the presence of cirrhosis, chronic kidney disease, BMI >25, and male gender with an increased risk for reoperation due to superficial infection or bleeding in older patients or those with peripheral vascular disease [68]. The recommendation against broad spectrum antibiotic prophylaxis for inguinal hernia repair is based on the results of randomized trials which do not provide unequivocal support for its use [69]. However, many hospital guidelines and quality metrics may necessitate the use of antibiotics.

Superficial infection after inguinal hernia repair typically occurs within the first 30 days after surgery and often can be treated with simple drainage and antibiotic therapy [70]. Deep surgical site infection involving the fascia and the implant may present late [71]. There are no definitive evidence-based guidelines to direct surgical management of this complication. Treatment is thus individualized based on patient factors and surgical judgement and may include antibiotic therapy, exploration and removal of the mesh with primary tissue repair as needed, limited exploration with excision of sinus tract and partial mesh or suture removal, and percutaneous drainage. Surgical site infection after inguinal herniorrhaphy can be costly in terms of patient morbidity and patient care, estimated to be an additional $600 dollars by conservative and dated analysis [72] with the expectation that this cost is even higher today.

Hernia Recurrence

The surgical approach to the recurrent hernia will depend on the type of the initial repair, with a general recommendation that the recurrent repair be conducted in a different plane than the index operation. Endoscopic inguinal hernia repair after open inguinal repair is associated with a lower recurrence rate compared to other open techniques (1.3% compared to a rate of 7–19% for open recurrent repair) [73]. There does not appear to be conclusive support for open inguinal hernia repair after failed endoscopic repair with reports of both open and transabdominal preperitoneal approaches. Decision-making for care of the patient with a recurrent inguinal hernia should include consideration of the risk of general anesthesia, bleeding, chronic pain and infection, and surgeon experience.

Conclusion

Inguinal hernia repair is a common general surgery ambulatory procedure with a low complication rate. Many adverse events after inguinal hernia repair are potentially preventable with patient preparation and education and sound operative technique and judgement.

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Chronic Pain After Inguinal Repair

23

Nicholas H. Carter and David C. Chen

Introduction

Chronic postherniorrhaphy inguinal pain (CPIP) is the most common severe complication following modern inguinal hernia repair. CPIP is defined as pain that develops following inguinal hernia repair and lasts more than 3 months with other causes of pain excluded [1]. The risk of developing moderate to severe chronic pain following inguinal hernia repair is 10–12% [2]. Over 20 million inguinal herniorrhaphies are performed annually, with nearly 800,000 procedures in the United States alone [1, 3]. As widespread adoption of tension-free mesh repairs and refinements in open and laparoscopic surgical techniques have reduced hernia recurrence rates, chronic pain has emerged as the single most problematic consequence of inguinal hernia repair.

The precise mechanisms that drive chronic pain following inguinal surgery are not fully understood. Processes that have been implicated include early-postoperative ectopic activity from injured nerves, collateral sprouting from intact adjacent nociceptive Aδ afferent nerves, excitotoxic destruction of antinociceptive inhibitory interneurons in the spinal dorsal horn, neuroimmune alterations, maladaptive neuronal plasticity, and high-frequency injury firing from damaged nerves [4–6]. Although the specific pathophysiology behind CPIP is incompletely known, the devastating effects of CPIP are all too familiar. In addition to pain, patients with CPIP suffer negative psychological and physical consequences with an overall reduced quality of life [7]. Costs associated with CPIP have not been precisely evaluated, but total direct and indirect annual costs associated with severe postoperative neuropathic pain have been estimated to be as high as US $40,000 per patient [8].

Prevention of chronic pain is far easier than treatment. In this chapter, we will describe the evidence-based recommendations for pre-, intra-, and postoperative practices for reducing risk of chronic pain associated with primary hernia repair. We will then describe the decision-making and technical steps for treating a patient who has developed chronic pain after inguinal hernia repair.

Preoperative Considerations

Prevention

Prior to recommending an elective inguinal herniorrhaphy, the surgeon should consider the individual patient's risk factors for chronic pain. A list of associated risk factors is found in Table 23.1 [4]. CPIP is also modulated by cognitive, emotional, and social factors that are only beginning to be elucidated. Several newer studies suggest that genetics may drive susceptibility to postoperative pain and response to analgesics, although no specific genetic tests to determine an individual's risk have yet been validated [9–11]. The patient's risk for chronic pain should be reviewed in the preoperative discussion with the surgeon and documented in the consent.

Treatment

The decision to operate on a patient for chronic pain should never be taken lightly. Attention to risk factors, underlying etiology, and options for non-operative interventions is mandatory. A primary concern is considering the likely etiology of a particular patient's pain. Iatrogenic injury to inguinal nerves is widely believed to be the single most important cause of CPIP. This pain is often distributed in the sensory

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regions of the affected nerve. The principal nerves at risk of injury during open inguinal repair are the ilioinguinal nerve (IIN), the iliohypogastric nerve (IHN), and the genital branch of the genitofemoral nerve (GFN). The femoral branch of the GFN or lateral femoral cutaneous nerve may additionally be implicated in laparoscopic inguinal hernia repair. Mechanisms of intraoperative injury vary widely and may include complete or partial transection, stretching, crushing, thermal injury associated with electrocautery, entrapment by suture, or direct injury or fixation from laparoscopic tacks. In the postoperative period, nerves may become involved within a meshoma, inflammation, or fibrosis.

Evaluation of the patient with chronic inguinodynia requires close attention to symptoms and physical exam to try to discern the likely source of their pain. Many patients present with mixed symptomatology which clouds the clinical picture. Neuropathic, nociceptive (inflammatory non-neuropathic), somatic, and visceral pain are all commonly seen in postherniorrhaphy patients. Neuropathic pain is characterized by dysesthesia, allodynia, hyperalgesia, or negative sensory phenomena that may radiate to the scrotum, labium, or upper leg. Neuropathic pain may sometimes be reproduced by a trigger point or worsened by ambulation, hyperextension of the hip, or sexual intercourse. In contrast, non-neuropathic nociceptive pain is usually constant, dull pain that involves the groin area without an isolated trigger point. Somatic pain is characterized by localized tenderness at the pubic tubercle secondary to periosteal anchoring of mesh [12]. Visceral pain may be associated with adherence of non-nerve structures to mesh or with hernia recurrence or incarceration. Visceral pain may be associated with sexual dysfunction including ejaculatory pain at the superficial ring or scrotum.

Imaging of the groin in CPIP is used to detect hernia recurrence or meshoma and to rule out a variety of less common anatomic pathologies. Because of the overlap with musculoskeletal pathologies, MRI is currently favored as the best modality for investigating causes of chronic inguinal pain [13, 14]. Ultrasonography and cross-sectional computed tomography have also been employed [15]. Peripheral nerve blocks may be helpful in distinguishing neuropathic from non-neuropathic pain, and needle electromyogram or magnetic resonance neurography may help identify nerve injury or compression [16, 17].

Non-operative Therapies

CPIP may be managed with a variety of non-operative modalities that may make discomfort tolerable and obviate the need for subsequent surgery. High-level evidence to guide clinical decisions in selecting among these therapies is lacking, and the surgeon should pursue treatments that match the suspected etiology of pain and minimize side effect burden for the individual patient [18]. In addition to nonsteroidal anti-inflammatory drugs and acetaminophen, pharmacologic therapy may include calcium channel α2-δ ligands (gabapentin or pregabalin) or antidepressants with norepinephrine reuptake inhibition (duloxetine or venlafaxine). Guidelines for treatment of neuropathic pain based on randomized trial are available and may be appropriately applied for CPIP patients [19, 20]. Lidocaine or capsaicin patches may be used as adjuncts [21, 22].

If a patient has severe, persistent pain despite appropriate pharmacologic therapy, interventional approaches should be considered. Some authors have reported success in reducing pain severity using peripheral nerve infiltrations and nerve stimulation [23]. Overall, however, evidence for efficacy of interventional management of CPIP is lacking. The only randomized trial to investigate ultrasound-guided nerve blocks for CPIP failed to demonstrate sustained analgesic effect [24]. A variety of ablative and stimulative interventions have been applied with mixed results [4].

Operative Therapies

Surgical management of CPIP should not be offered for at least 3 months following the patient's most recent inguinal operation. This recommended duration is often extended to 6 months if the pathology is felt to be mesh or scar related as tissue remodeling with mesh repairs extends to this time point. Even after this time has elapsed, not all patients with persistent, severe pain are reasonable candidates for reoperation. All patients should be evaluated by a pain specialist. If surgery is being considered, patients should undergo diagnostic (and potentially therapeutic) nerve blocks of the ilioinguinal, iliohypogastric, and genitofemoral nerves. Sensory mapping may also be helpful in reaching an accurate neuropathic assessment [25]. Our practice focuses on identifying patients with neuropathic pain that is restricted to the inguinal region and improved at least temporarily with nerve blocks.

Preoperative Counseling

Patients are counseled extensively on the complexity of pain, likely mechanisms involved in their presentation, interventions that would be most appropriate for them (mesh removal, neurectomy, repair of resultant defect, possible subsequent use of mesh), the likely potential for improvement, and the inherent risks to these procedures. The primary intraoperative risks that must be considered are vascular injury and loss of cord structures or the testicle. Chronic considerations include infection, testicular atrophy, permanent (anticipated) numbness, motor weakness/atrophy, and the persistence of pain. It is paramount to establish realistic expectations so that patients can make an educated decision. Patients with low-intensity pain are counseled to avoid operative intervention as the anticipated outcome may not be significantly different than their baseline. Those with high-intensity pain and significant impact on daily quality of life are most likely to realize a benefit. Failure to respond may be due to several factors including ongoing nociceptive pain, deafferentation hypersensitivity, and alternative overlapping pathologies and is defined by subjective measures of pain scores, quality of life assessment, and satisfaction with intervention. Often, the surgical targeted intervention will be successful (desired numbness from neurectomy, correction of recurrence, removal of meshoma), but success is defined by benefit to the patient and may not be directly correlated with surgical success. This reality underscores the importance of experience, patient selection, and shared decision-making regarding remedial surgery for inguinodynia.

The preferred operation for most patients with neuropathic CPIP who require surgical intervention is triple neurectomy, which may be performed by either the open or laparoscopic approaches. A wide variety of operations have historically been offered to patients with CPIP, including selective IIN, IHN, or GFN neurectomy or neurolysis, mesh and suture or tack removal, or revision of the previous herniorrhaphy. Selective neurectomy has been shown to have lower efficacy rates compared to triple neurectomy, likely secondary to the challenge of determining which nerve(s) is driving the pain symptoms [26–29]. In addition, the notable variation and cross innervation of nerves within the inguinal canal make selective neurectomy less reliable [30]. If selective neurectomy fails, the surgeon faces the unpalatable option of reoperating on a surgical field that has already undergone several procedures.

In contrast to the limitations of selective neurectomy, triple neurectomy provides sustained relief in the majority of patients with neuropathic CPIP refractory to analgesics and other non-operative interventions. Introduced at our institution in the 1990s, single-stage triple neurectomy is now a widely accepted surgical intervention for refractory CPIP [31]. We have performed more than 700 open triple neurectomies with greater than 85% success rate. Our selected subpopulation of CPIP patients who undergo laparoscopic retroperitoneal triple neurectomy experience a slightly higher rate of success in addressing the neuropathic component of their pain [32]. This technique is typically reserved for patients that had an initial open or laparoscopic preperitoneal repair, prior failed open or laparoscopic preperitoneal neurectomy, multiple prior anterior repairs, or extensive scarring from infection or inflammation as proximal neurectomy results in greater numbness and the potential for laxity of the oblique muscles. The open triple neurectomy approach for CPIP allows for simultaneous repair of hernia recurrence or meshoma and is favored for prior anterior or bilayer repairs. The laparoscopic retroperitoneal approach allows the surgeon to safely identify and resect nerves in fresh tissue planes. Recurrence or preperitoneal mesh removal may also be addressed laparoscopically or with a hybrid open technique. Operative tailoring based upon prior operations, neuropathology, meshoma, and recurrence is essential for optimal outcomes.

Patient Positioning and Theater Setup

Prevention

For both open and laparoscopic inguinal repairs, patients are typically placed in supine position. No studies have clearly identified the optimal modality of anesthesia to prevent chronic pain following inguinal operations, but severe pre- and early-postoperative pain is frequently associated with CPIP [2, 5, 7]. For open hernia repairs, local anesthesia has been shown to provide improved early pain relief and discharge with few complications [33, 34]. Regional anesthesia is not recommended due to increased risk of urinary retention and other rare complications [35]. Laparoscopic repair has been thought to result in lower rates of chronic pain, but pain secondary to mesh positioning or proximal nerve injury during laparoscopic repair can be severe and difficult to treat [1, 36].

Treatment

In open triple neurectomy, patients are placed in supine position similar to primary hernia repair. For laparoscopic retroperitoneal triple neurectomy, the patient is placed in lateral decubitus position with the affected side elevated. To open the region between the costal margin and iliac crest, the table should be flexed.

Incision and Access

Prevention

Prevention of CPIP during hernia repair hinges upon avoiding injury to nerve structures. Routinely identifying all three inguinal nerves is feasible and associated with diminished risk of CPIP [37, 38]. This practice is supported by a variety of meta-analyses and international guidelines [1, 39]. Routine division of nerves, “prophylactic neurectomy,” is associated with increased risk of persistent postoperative numbness without diminished CPIP and is not recommended [40].

Table 23.1 Risk factors for chronic postherniorrhaphy inguinal pain (reproduced from [4])

Preoperative factors
Young age
Female sex
High pain intensity level
Lower preoperative optimism
Impairment of everyday activities
Operation for a recurrent hernia
Genetic predisposition
Experimentally induced pain
High pain intensity to tonic heat stimulation
Perioperative factors
Less experience surgeon/not designated hernia center
Open repair technique
Mesh type: heavyweight (open or laparoscopic)
Mesh fixation: suture (open), staple (laparoscopic)
IIN neurolysis in Lichtenstein repair
Postoperative factors
Postoperative complications (hematoma, infection)
High early-postoperative pain intensity
Lower perceived control over pain
Sensory dysfunction in the groin

Treatment

Open triple neurectomy is typically performed using the same incision as the patient's prior open herniorrhaphy. In this reoperative field, the surgeon must anticipate scar tissue and distortion of anatomy. The skin incision and dissection may be extended cephalad and lateral to enter an unscarred field allowing proximal exposure of the IIN and IHN. The IIN may be identified lateral to the deep inguinal ring and dissected out in the proximal direction. The distal IHN is found along the conjoined tendon between the internal and external oblique aponeuroses and should be dissected back to its origin. Approximately 10–15% of the time, the inguinal segment of the IHN is obscured by an intramuscular segment that runs below the internal oblique aponeurosis. This can be traced from its distal exit to its origin penetrating the floor of the inguinal canal medial to the IIN. The genital branch of the GFN is found within the cremasteric fibers adjacent to the external spermatic vein on the posterior side of the spermatic cord (see Fig. 23.1).

In laparoscopic retroperitoneal triple neurectomy, a 12-mm transverse incision is made 3–4 cm above the iliac crest in the midaxillary line and extended down through oblique muscles to access the retroperitoneum. A dissecting balloon may be inserted into this space and inflated under direct visualization to mobilize the peritoneum medially and open the retroperitoneal space. The dissecting balloon is removed and a 12-mm balloon trocar is inserted. Carbon dioxide insufflation should be used to achieve a pressure of 15 mmHg. An additional 5-mm port is then inserted 2 cm medial to allow dissection of the retroperitoneal fat pad to expose the psoas and quadratus lumborum muscles.

Operative Steps

Prevention

Mesh selection and methods for securing mesh are both important factors in reducing risk for CPIP. Several systematic reviews have found diminished rates of CPIP using lightweight mesh for both open and laparoscopic hernia repairs [41, 42]. To reduce the risk of direct nerve injury or entrapment associated with sutures and tacks, numerous alternative fixation products have been studied. Overall, the results are mixed. One meta-analysis found that glue fixation in open repair reduced chronic pain and several other key outcome measures [43]. Two other large reviews concluded that more data is still required in order to make a recommendation regarding glue fixation [44, 45]. Self-gripping mesh seems to be associated with similar rates of CPIP as sutured mesh based on available data [46]. These techniques of atraumatic fixation avoid entrapment from suture and may diminish the risk of direct nerve injury from this mechanism.

Treatment

In open triple neurectomy, the IIN and IHN are divided as proximally as possible. The genital branch of the GFN is divided at the internal ring or proximally over the psoas. Our practice is to ligate the nerves to close the neurilemma and diminish risk of neuroma formation. We then bury the proximal nerve stump within adjacent muscle to limit inflammation and perineural scarring.

In laparoscopic retroperitoneal triple neurectomy, the lumbar plexus is identified as well as the T12 subcostal nerve. The iliohypogastric and ilioinguinal nerves can then be located overlying the quadratus muscle at L1 (see Fig. 23.2). These major nerves frequently share a common trunk at this proximal position. Dissection toward the groin will then expose the genitofemoral nerve along the psoas muscle (see Fig. 23.3). The genital branch of the genitofemoral nerve should be identified and clipped proximally and distally. During the course of the operation, the lateral femoral cutaneous nerve, ureter, and iliac vessels should all be identified and protected. The ilioinguinal and iliohypogastric nerves can then be safely clipped proximally and distally.

Nociceptive pain caused by meshoma should be addressed simultaneously at the time of operative intervention. Isolated nociceptive pain caused by mesh folding, migration, contraction, and extrusion is best remediated by judicious mesh removal. This procedure carries the highest operative morbidity with risks of vascular or visceral injury and testicular compromise, atrophy, or loss. Accordingly, the bulk of mesh can be removed while leaving a small rim of mesh adjacent to critical structures to minimize these risks (see Fig. 23.4).

Hernia recurrence may cause nociceptive, somatic, or visceral pain. Recurrence without neuropathic or meshoma pain is best addressed by repair using a separate untouched field (i.e., open after prior lap). If recurrence is accompanied by CPIP, the prior scarred operative field must often be addressed. If anterior mesh is removed with an open groin exploration and neurectomy, repair may be performed as an open remedial anterior repair with lightweight mesh, a laparoscopic mesh repair in the unscarred field, or a tissue repair depending on patient factors and preference. If posterior mesh is removed with a laparoscopic or hybrid operation, recurrence can be addressed with a remedial laparoscopic repair if the peritoneal flap is adequate or an open anterior mesh or tissue-based inguinal hernia repair.

Orchialgia is not typically resolved by inguinal neurectomy as the etiology is not inguinal nerve mediated. Neurectomy of the autonomic paravasal nerves at the time of open or laparoscopic surgery may ameliorate neuropathic orchialgia [47]. Nociceptive orchialgia may result from ischemia or tissue damage and is more challenging to ameliorate. Spermatic cord blocks, denervation, and orchiectomy are employed with variable outcomes (see Fig. 23.5).

Closure

For both primary hernia repairs and subsequent neurectomy procedures, closure is performed in layers with absorbable suture with attention to avoiding entrapment of nerves. Since complications such as hematoma or infection are known risk factors for CPIP, close attention to hemostasis and layered protection of any mesh from the bowel, bladder, and skin is mandatory.

Postoperative Management

Prevention

One of the defined risk factors for chronic pain is severe acute postoperative pain. Within the treatment algorithm of inguinal pain, expectant management with conservative measures is uniformly advocated in the acute postoperative period. However, the circumstance of severe immediate

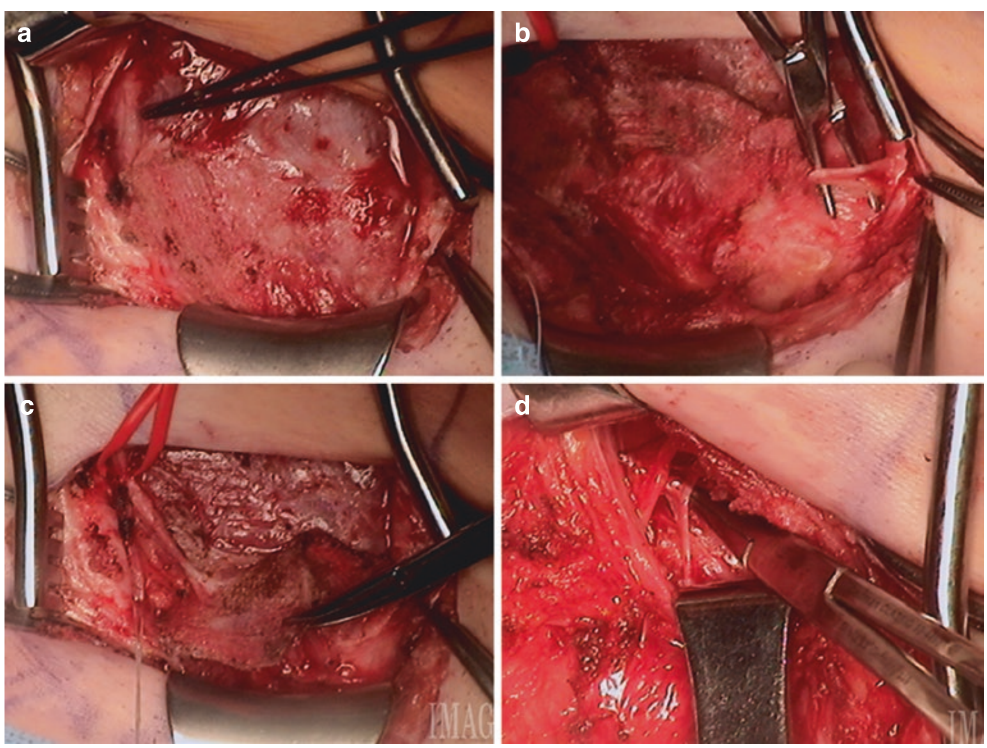

Fig. 23.1 Open triple neurectomy (**a**) ilioinguinal nerve cephalad of mesh (**b**) iliohypogastric nerve isolation at conjoint tendon (**c**) mesh dissection to internal ring (**d**) preperitoneal genital nerve through opened floor at internal ring

acute postoperative pain deserves special consideration. High-intensity severe inguinal pain out of the expected range or any motor abnormality encountered immediately after surgery should be interrogated with consideration to return to the operating room for evaluation. This rare circumstance requires clinical judgment regarding individual patient factors, pain tolerance, and operative/anesthetic considerations regarding possible mechanism of injury. A misplaced tack or suture, early mesh disruption or displacement, recurrence, or cord ischemia may be correctable with early intervention potentially saving the patient conversion to chronic pain.

Treatment

Postoperative treatment following laparoscopic triple neurectomy involves standard monitoring for bleeding or infection as well as encouraging early resumption of physical activities and weaning from narcotics. Numbness is to be anticipated in the distribution of the neurectomy. In a prospective series of 42 patients, all patients reported numbness [32]. One-third of patients complained of transient hypersensitivity although only four patients had persistent symptoms lasting greater than 3 months. Improvements in mechanical, thermal, and pressure pain thresholds have also been demonstrated [48].

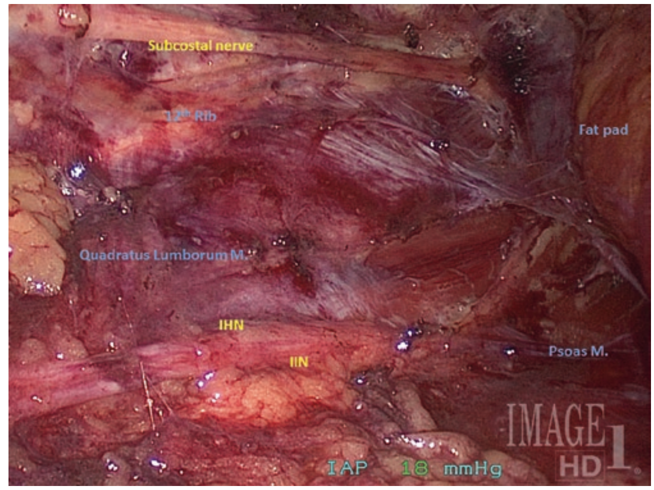

Fig. 23.2 Laparoscopic Retroperitoneal Access and Neurectomy (cephalad view) Ilioinguinal and Iliohypogastric Nerves over the Quadratus Muscle

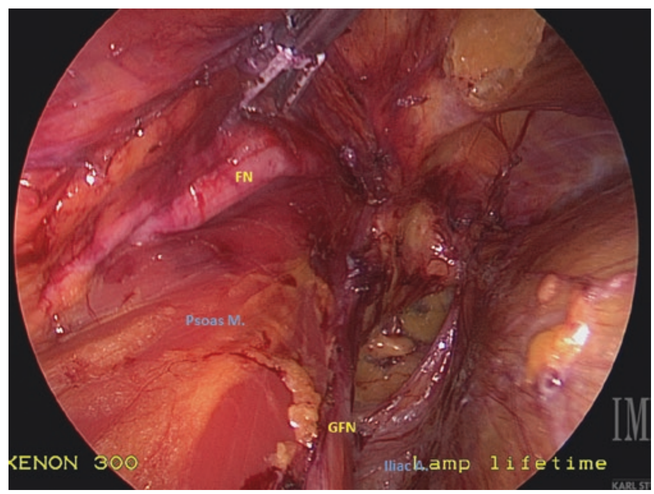

Fig. 23.3 Laparoscopic Retroperitoneal Access and Neurectomy (caudad view) Genitofemoral Nerve over the Psoas Muscle, Femoral Nerve Lateral to Psoas Muscle

Tips and Pitfalls

- Both prevention and surgical treatment of CPIP depend on attention to the highly variable neuroanatomy of the groin. Anterior to the transversalis fascia, the IIN, IHN, and genital branch of the GFN may all be injured or entrapped during open repairs or with penetrating laparoscopic mesh fixation. In the preperitoneal space, the genitofemoral nerve is vulnerable to injury secondary to open preperitoneal approaches such as plug, bilayer, and preperitoneal mesh or during laparoscopic TEP/TAPP repairs. In the retroperitoneal space, the main trunk of the GFN along the psoas muscle and lateral femoral cutaneous nerve may be injured particularly with lateral overdissection with laparoscopic repair.
- The proven efficacy of the triple neurectomy challenges an oft-repeated surgical axiom: "If you operate for pain you will get…more pain." Even in experienced hands, however, definitive identification of inguinal nerves within a reoperative field can be difficult. Appropriate selection of patients for surgical intervention requires close partnership with pain specialists with expertise in chronic inguinal pain. This selection based upon history, prior operative technique, presentation, dermatosensory testing, response to blocks and intervention, and appropriate patient counseling is essential and dictates the success of any remedial operation. While the initial steps in diagnosis and treatment of CPIP should be practiced by all, there are many complexities and subtleties to the management of CPIP affecting the likelihood of a successful outcome. There is no shame in surgeons referring patients with CPIP to specialty centers for evaluation and possible surgical treatment.

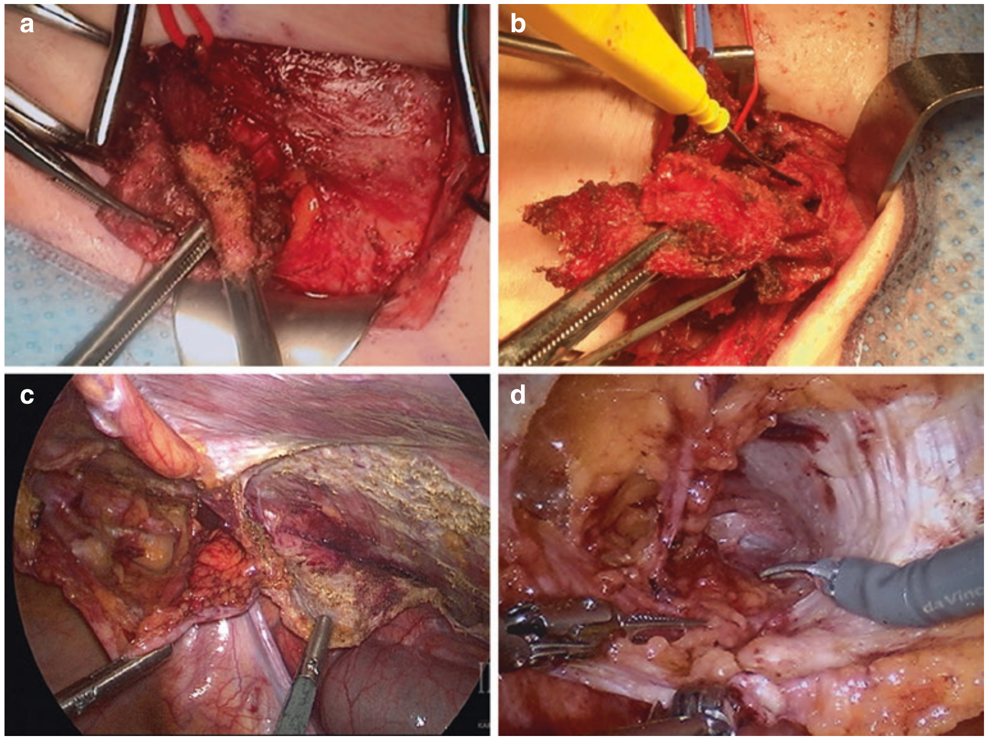

Fig. 23.4 Mesh Removal (**a**) open anterior- plug (**b**) open anterior- bilayer (**c**) laparoscopic preperitoneal (**d**) robotic preperitoneal

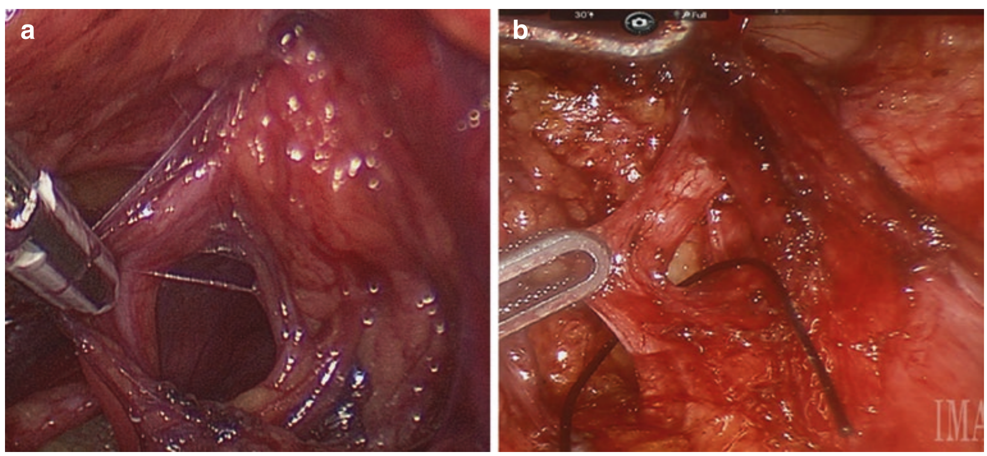

Fig. 23.5 Paravasal Neurectomy for Orchialgia (**a**) laparoscopic (**b**) robotic

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Part III

Incisional and Ventral Hernia

24 The Open Abdomen: Indications and Management

Helen J. Thomson and Alastair Windsor

Introduction

In 1897, McCosh [1] noticed that after surgery for sepsis, it could be difficult to fit all the bowel back into the abdominal cavity. He described leaving the original incision partly open to allow time for the bowel to settle. The outcomes were not good by modern standards, but this partially open abdomen did show benefits in some patients.

Ogilvie's paper of 1940 [2] described complications of abdominal war wounds including burst abdomen, hernias, residual abscesses and fistulae. He suggested that if at the end of surgery the midline defect was more than 3 inches wide, no attempt should be made to close it, as this would cause too much tension. He suggested inlaying a shaped piece of canvas covered in Vaseline, secured with sutures, to 'close' the abdomen without tension. This achieved control of abdominal contents and allowed healing, whilst protecting the bowel.

Indications for the Open Abdomen

Over the last 20 years, the therapeutic 'open abdomen' (OA) has become more widely used. It can be a useful tool in the treatment of the abdominal catastrophe. New techniques for its management have been developed, and outcomes are improving.

Many indications for open abdomen have been described: severe abdominal sepsis, severe acute pancreatitis, damage control laparotomy, surgery for major haemorrhage, bowel ischaemia or where a relook laparotomy is planned. Other indications include prevention of or treatment of intra-abdominal hypertension (IAH) or abdominal compartment syndrome (ACS).

OA should not be seen as a panacea but a very useful therapeutic measure to be used in certain specific conditions. Wherever possible, primary closure of the abdomen should be carried out, even if further laparotomy may be needed [3–6]. The indications cited in the literature come down to the same two true indications for OA—prevention of IAH/ACS and treating it once it is established. OA should not be used as an easy way to re-enter the abdominal cavity for planned relook laparotomy.

Abdominal Compartment Syndrome

IAH and ACS were defined by the international conference of experts on intra-abdominal hypertension and abdominal compartment syndrome and published in 2006 [3].

IAH is defined as sustained or repeated pathological elevation of IAP ≥12 mmHg. Abdominal compartment syndrome (ACS) is defined as a sustained IAP >20 mmHg that is associated with new organ dysfunction/failure. It may be primary, secondary or recurrent. Primary ACS is associated with injury or disease in the abdomino-pelvic region, whilst secondary ACS refers to conditions that do not originate from the abdomino-pelvic region. Recurrent ACS refers to the condition in which ACS redevelops following previous surgical or medical treatment of primary or secondary ACS [3].

Causes of IAH/ACS

IAH/ACS may be caused by factors arising within (primary) or outwith (secondary) the abdomen. The risk factors for the development of ACS are any condition that increases the volume of the abdominal contents or decreases the compliance of any of the anatomical walls that confine that space or a combination of both as well as more general patient factors

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[7–9]. Whatever the causes, they have to be of a relatively acute onset in order to overcome the body's natural compensatory ability.

Intra-luminal volume of the gut may be increased by gastric dilatation, ileus, pseudo-obstruction, toxic megacolon or any volvulus. We should also consider massive abdominal hernia repair in this group. If a significant amount of abdominal contents are returned into the abdominal cavity without addressing any preoperative domain loss, the intra-abdominal pressure will increase. Increased extra-luminal volume may be solid as in rapidly growing tumours or more often fluid such as peritoneal dialysis, ascites, intra-abdominal infection or collections, haemoperitoneum or pneumoperitoneum, which may be iatrogenic as in laparoscopic surgery. In any critically ill patient, fluid shifts can follow massive resuscitation and can lead to secondary ACS [10].

Limitations on abdominal wall compliance can affect any of the soft tissue boundaries of the abdominal cavity. Ventilated patients with high PEEP have a functional splinting of the diaphragm. The anterior abdominal wall's compliance is decreased after abdominal surgery, major burns or trauma and prone positioning of the patient. Obesity and high BMI also affect the abdominal wall's compliance as can pregnancy.

General risk factors for development of ACS include sepsis, shock or hypotension and increase age. Having the head of the bed raised to more than 30° has also been shown to be a risk factor.

If one considers that many patients have more than one risk factor, clinicians should perhaps be more alert to the possibility of the development of ACS, even in elective cases. For instance, laparoscopic bariatric surgery by definition occurs in obese patients and can involve having the head of the bed elevated significantly, mechanical ventilation with possibly high PEEP and the pressures of the pneumoperitoneum may need to be high. Abdominoperineal resection is an abdominal operation that can involve a significant period in the prone position whilst being ventilated.

It is, therefore, important not to consider ACS and IAH to be a condition only occurring in the critically ill or emergency patient. Clinicians must be aware of its causes and be alert to the early signs so that elective patients do not become critically ill.

Diagnosis of IAH/ACS

Diagnosing IAH/ACS starts with being alert to its possibility. A high index of suspicion is needed based on the patient as a whole as well as knowing the risk factors [8]. Clinical examination is not accurate at diagnosing raised intra-abdominal pressure (IAP).

The World Society of the Abdominal Compartment Syndrome (WSACS) recommendations suggest that if a critically ill patient has two or more risk factors for developing ACS, they should have IAP measured [9]. The suggested frequency of IAP monitoring in the intensive care setting ranges from twice a day to continuously [11, 12], whilst some papers suggest it should be measured every 4–6 h [13].

The simplest and most widely used method is by measuring bladder pressures [14]. This has been shown to equate well with directly measured IAP. The bladder is catheterized, and a transducer attached to the catheter drainage system is zeroed at the mid-axillary line, a similar method to that of CVP monitoring. 20–25 ml of saline is instilled into the bladder, and the tubing is clamped for 30 min to allow detrusor activity to settle prior to the pressure reading being made. The pressure is then recorded at end expiration when pressures should be at their lowest. The patient positioning should be the same for every measurement as the amount of 'heads-up' does affect the pressure. If having the patient supine for the measurement is not possible, then the actual position should be recorded to allow accurate duplication for subsequent readings.

If the bladder cannot be used, e.g. pelvic injury, haematoma or mass or after cystectomy, pressure measurements can be made using other accessible intra-abdominal areas such as the stomach, rectum, vagina and IVC or by direct intra-abdominal catheter. Other organ systems can also show signs of impending IAH/ACS such as gradually increasing ventilator pressures and worsening oliguria or anuria. If these are seen, this should lead to initiation of IAP monitoring if it is not already in place.

Treatment of IAH/ACS

Ideally, treatment should begin as soon as there is a suspicion of raised IAP in order to try to prevent this evolving into IAH or ACS. Initial management should be aimed at treating any reversible factors that are contributing to the raised IAP. This will depend upon the underlying cause(s) and the degree of IAH/ACS. If we think back to the risk factors, it can be seen that there are many options for non-surgical management.

Medical Management of IAH/ACS [15]

Decreasing the Intra-abdominal Volume

Decompression of a dilated GI tract may be relieved by direct drainage such as properly placed NG tube on free drainage and rectal catheter. Endoscopic colonic decompression may also be indicated. Gastrocolic prokinetic medication and enemas have been suggested as well as decreasing or stopping enteral intake.

Extra-luminal fluid can be drained percutaneously. This may require ultrasound or CT-guided drainage if a specific collection is being targeted. If there is large-volume ascites, the rate of drainage needs to be closely monitored, and the patient may require albumin replacement.

Improving Abdominal Wall Compliance

As can be seen in any patient after open abdominal surgery, if their analgesia is inadequate, they avoid movement because this requires the use of the core abdominal muscles and they have shallow breathing. Once analgesia is optimized, the functional splinting of the diaphragm and abdominal wall resolves. Therefore, ensuring adequate analgesia is a simple first step to try to improve abdominal wall compliance. This can be combined with the use of sedation. In burn patients, escharotomy may be needed to allow any expansion of the abdominal or chest wall, especially for circumferential full-thickness burns.

Treatment of Other Factors

The management of fluid shifts associated with critical illness is a careful balance of maintaining adequate perfusion without causing overload. Accurate fluid balance with goal-directed management should be instigated early. WSACS suggests aiming for a zero to negative fluid balance by day 3 with any ongoing resuscitation using hypertonic fluids or colloids. Haemodialysis or haemofiltration also has a role in fluid management. If a patient is more stable, diuretics may be used.

Patient positioning to ensure that the head of bed is not raised more than 30° has been suggested. In the intensive care unit setting, neuromuscular blockade can also be tried.

Surgical Management of IAH/ACS

If, despite the initiation of the medical therapies detailed above, the IAP remains >20 mmHG with new organ dysfunction or failure, surgical decompression needs to be considered. It is key that once it is clear that medical management is not effective, there should be no delay in proceeding to surgical decompression to maximize the chance for resolution of any actual, or impending, organ failure [15]. At this point, the post-decompression management of the patient also needs to be considered with planning for how the abdominal wound will be managed [16]. Various options for surgical decompression are available [17].

If the patient has developed IAH/ACS following surgery, then reopening the prior incision is the most sensible option as long the incision is adequate to create sufficient decompression and still allow safe wound management. Otherwise, the quickest, easiest and most commonly used approach is a vertical midline incision through the linea alba. The drawbacks include the exposure of much of the small bowel, risking fistulation, and the rapid retraction of the recti laterally.

Other surgical options include using a transverse incision, which takes longer to perform but prevents the lateralization of abdominal wall. One downside is that this incision is likely to involve transection of the nerves that supply rectus abdominis as they travel in an inferomedial direction, which can in turn lead to atrophy of that portion of the rectus. A rooftop incision has been described for cases where the underlying condition has a hepatopancreaticobiliary cause, as this would enable more appropriate access for managing the underlying condition, as well as abdominal decompression.

Another option that has been described is subcutaneous linea alba fasciotomy. This technique involves three small skin incisions to allow access to the fascia of the linea alba. This is then divided subcutaneously, leaving the majority of the abdominal skin, as well as the peritoneum, intact. Although this has the benefit of maintaining a contained abdomen and minimizes the lateralization of the recti, it also limits the amount of decompression achieved. When one considers that the aim of the decompression is to ensure a resolution to the IAH and ACS, it could be suggested that limiting the release achievable is counter-productive.

Management of the Open Abdomen

The open abdomen is associated with significant morbidity and complications relating to the underlying condition as well as the management of the open abdominal wound itself. When contemplating leaving the abdomen open, the surgeon should already have a management plan for the short, medium and long term, which must include aims at preventing and managing the possible complications. Patient with open abdomen require a multidisciplinary approach to their care [18]. In the early stages, this will be led by the intensivists, with a supporting team of nurses, nutritionists, surgeons and physiotherapists [19]. More long term, these patients may need psychological support. On top of this, the open abdominal wound itself needs specific clinical management.

Intensive Care

The initial period after surgical abdominal decompression is focused on stabilizing the patient and continuing measures aimed at treating the original cause of ACS. As such, many of the measures started as part of attempted medical management should be continued.

The open abdomen is a source of significant heat loss, and regaining and maintaining body temperature are important. This is achieved using warmed fluids and air warmers on the ventilator circuit as well as warming blankets. Fluid therapy should be goal directed. The use of vasopressors, and possibly adrenal support by means of IV steroids, may reduce the chance of fluid overload.

Management of sepsis should follow the same guidelines as for those patients who do not have an open abdomen. There is no indication for long-term antimicrobials unless there is unresolved intra-abdominal sepsis. Any antibiotics used will be guided by local antimicrobial policy and should be specific to the case.

Nutrition

Critical illness, including conditions causing IAH/ACS, tends to cause a highly catabolic state with increased nutritional requirements. The state of open abdomen itself has been shown to be a source of significant protein and nitrogen loss thus compounding any nutritional deficit. It has been estimated that an additional 2 g of nitrogen is lost for every 1 L of abdominal fluid output [20]. The nutritional needs of these patients must be assessed as early as possible so as to allow prompt resumption of nutrition by the best route possible.

If the gastrointestinal (GI) tract is intact and accessible, early enteral nutrition with the correct nitrogen balance has significant benefits [21]. In elective GI surgery, early (within 24–48 h) enteral nutrition (EN) has been shown to preserve GI function and integrity and decreased rates of postoperative complications without any increase in anastomotic leak rates. Studies of early EN in the open abdomen have also reported decreased fistulation rates and increased rates of fascial closure. Byrnes et al. [22] also showed there was a reduced level of bowel injury in patients who had EN prior to fascial closure. Other studies have shown a reduced rate of ventilator-associated pneumonia in patients receiving early EN [23].

Patients with any degree of concurrent intestinal failure pose a more difficult problem. For patients with fistulae, parenteral nutrition (PN) alone may be best in the early stages to try to achieve spontaneous fistula closure if appropriate. Stomas or fistulae that are relatively distal (more than 1 m from the duodenojejunal flexure) may be able to be managed by EN with treatment for high-output stoma added as needed. In the initial postoperative phase, they may require additional PN support to ensure nutritional requirements are met. Proximal stomas will need PN until restoration of bowel continuity can be achieved.

Classification of the Open Abdomen

In 2009, Bjorck et al. described a classification system for OA [24]. This followed from the consensus meetings on IAH and ACS. The original system was devised to provide a grading system to allow consistency in the description of the OA and therefore allow comparison between studies. The updated consensus definitions and clinical guidelines from WSACS 2013 revised the Bjorck classification as it was felt that the gradings should take into account the complex and variable nature of OA with the overall aim that a higher grade of OA was associated with the likelihood of poorer outcome [9, 25].

This revision took into account the ‘fixity’ of the abdominal wall and contents, ranging from none through developing adhesions up to the ‘frozen’ abdomen. The presence of enteric leakage was also clarified. Leakage of enteric contents without an established fistula formation was considered a much better prognosis that an established enteroatmospheric fistula (EAF). EAF is being defined as ‘a permanent enteric leak embedded in granulation tissue’. This is a much more complex situation than a stoma or enterocutaneous fistula draining away from the OA wound for which the OA is classified as clean since it does not directly impact on the OA wound.

The system was shown to have good reliability when tested [26].

Grade	Description
1A	Clean, no fixation
1B	Contaminated, no fixation
1C	Enteric leak, no fixation
2A	Clean, developing fixation
2B	Contaminated, developing fixation
2C	Enteric leak, developing fixation
3A	Clean, frozen abdomen
3B	Contaminated, frozen abdomen
4	Established enteroatmospheric fistula, fixed frozen abdomen

Open Abdomen Classification System 2013 [9]

This classification system can be used to grade the OA in a specific patient and can monitor its development over time. This can in turn direct any ongoing management decisions. The aim of any treatment is being to prevent a worsening of the OA score.

Management of the Open Abdominal Wound

There are recognized complications of the open abdomen that relate to the wound itself. These include evisceration, damage to abdominal organs and desiccation of the bowel predisposing it to fistula formation, loss of fluid and protein, bleeding and infection. With the midline open, the muscles of the lateral abdominal wall are unopposed which leads to lateralization of the recti and loss of domain, which in turn makes ventral hernia a more likely outcome.

Temporary abdominal closure (TAC) has evolved as OA has been more widely used and understood. The ideal TAC system is one that can minimize the risk of these complications occurring and prevent worsening of the grade of open abdomen. It has to control and protect the abdominal contents and prevent their adherence to the abdominal wall or to the dressing itself. It should maintain as far as possible the integrity of the abdominal wall in order to make definitive fascial closure more straightforward whilst not causing IAH. It should also be simple to apply, prevent fluid loss, facilitate nursing care and allow easy access to the abdominal cavity for re-laparotomy [27]. Ideally it should also be cost-effective.

Temporary Abdominal Closure (TAC)

There has been a steep learning curve in the management of the open abdominal wound. This has been associated with advances in wound management techniques and equipment [28].

The earliest and most simple techniques were aiming to cover and control the abdominal contents and prevent evisceration whilst trying to prevent excess fluid losses. Approximation of the skin edges, using towel clips or simple sutures, without closing the fascial layer does this to a degree, but as with the subcutaneous midline fasciotomy, closing the skin limits the decompression achieved and reintroduces an element of abdominal pressure which may be sufficient to cause recurrent ACS.

The Bogota bag [29] was the next step. An appropriately sized piece is cut from a sterile fluid bag and shaped to fit the defect. This is then sutured to the skin edges. It does allow good decompression but does not address many of the other problems associated with OA management.

Bridging meshes have also been described to act as TAC. Mesh is cut to the shape of the fascial defect and then sutured to the fascial edges. Re-entry to the abdomen is achieved by making a new ‘midline incision’ through the mesh. This can in turn be sutured closed, and as the intra-abdominal pressure and oedema reduce, the mesh can be more tightly closed in an attempt to bring the recti back towards the midline. Non-absorbable meshes were associated with an increase in fistula formation [30] that wasn’t seen with resorbable meshes [31]; however, the trade-off was an acceptance that the patient will develop a delayed hernia.

The Wittmann patch [32] acts in a similar way. Two opposing sheets that resemble Velcro™ are cut to fit the wound with one sheet being secured to each side of the defect. In order to gain entry to the abdomen for relook, the sheets could be disconnected from each other and at the end of the procedure the Velcro reapplied. By adding tension on closing the patch, some medialization of the recti could be achieved.

All of the above methods concentrate on the wound edges and coverage of the abdominal contents. None address the domain loss or the developing adhesions between viscera and the abdominal wall which will cause fixity and lateralization and in turn a frozen abdomen. With all of these techniques, it was accepted that it was necessary to achieve fascial closure within 7–14 days [18], or the combination of adhesions, abdominal wall fixity and lateral retraction of the recti would make early fascial closure impossible, and this in turn would necessitate a planned ventral hernia.

Negative-pressure wound therapy (NPWT) for OA was first described by Barker et al. [33, 34]. The procedure involved placing a perforated polyethylene sheet into the abdominal cavity to lie between the viscera and the abdominal wall to prevent fixity. This was covered by a moist sterile surgical towel and two drains placed on top of that. A plastic drape was then applied over the top to create a seal and the drains attached to suction. They reported a 2–3% fistulation rate, but a fascial closure rate was only 30%.

For the last 15 years, we have had access to commercial NPWT devices designed specifically for managing OA. With similarities to Barker’s system, a fenestrated membrane is placed between the abdominal viscera and the abdominal wall. Polyurethane sponges are then cut to size to fit and then placed in the abdominal wall defect before an adhesive clear membrane is used to seal the abdomen. A sealed suction unit is then applied on top of the sponge area, and variable negative pressure can be applied. This system has been shown to decrease the amount of exudate from the abdomen. The updated version, ABThera™, has a modified first membrane that aims to create a more equal distribution of the negative pressure.

When applied correctly, the benefits of NPWT are the prevention of fixity of the abdominal wall to the viscera which gives more time to try to achieve fascial closure if needed. The sponges placed in the defect also encourage granulation of the wound edges and are seen to decrease the overall size of the defect.

For all systems, the aim is best management of the OA whilst working towards fascial closure. All systems need to be changed every 48–72 h. At each relook, as well as careful washout of any residual infection, there should be an attempt to close or partially close the defect. Where complete closure is not possible, one or two interrupted sutures at either end of fascial defect can be placed at each dressing change to gradually close the defect.

The National Institute for Health and Care Excellence (NICE) reviewed NPWT for the open abdomen in 2013 [35] and concluded that they lead to reduced exudate, earlier fascial closure, lower morbidity and reduced length of hospital stay. The commercial systems have been compared to Barker's original technique; they achieve better rates of early fascial closure [36]. Other benefits included the promotion of tissue granulation.

The risk of developing enteric fistulation associated with NPWT has been debated, but more recent studies have shown no statistically significant increased risk of fistulation with NPWT [37]. Fistulation rates are higher in patients with abdominal sepsis, probably due to the bowel being inflamed and oedematous [38]. Exposed anastomoses are also at risk of fistulating. In order to minimize the chance of fistula formation, any anastomoses should be buried, and wherever possible bowel should be covered by omentum. Direct contact of suction to bowel should be avoided. Where there is insufficient omentum, a layer of a sterile non-adherent dressing such as Mepotil™ can be applied prior to placement of the membrane.

In an attempt to increase the rate of early fascial closure, systems to add medial traction to the fascia, such as ABRA [39, 40], have been described to use in conjunction with NPWT [41]. Some have shown a fascial closure rate of 80%, but there is still a tendency to develop incisional hernias due to the underlying nature of critically ill patients [42].

Definitive Abdominal Closure

As stated earlier, the plan for definitive closure of the abdominal wall should be considered early in the management of the patient with open abdomen. The only reason for leaving the abdomen open is to prevent or treat IAH/ACS. The TAC methods, if correctly used, can prevent the lateralization of recti and fixity of the abdominal wall which should allow fascial closure to be achieved once the cause of the ACS has been resolved and the bowel oedema and dilatation have settled. This should be carried out as soon as possible. If complete fascial closure is achieved at the index admission, it can be defined as early (within the first 8 days of formation of OA) or delayed (after 8 days or more) abdominal fascial closure (EAFC, DAFC) [43]. Gradual closure of the defect with a few sutures at either end of the fascial defect when possible will increase the chance of total fascial closure or at least minimize the residual defect [5].

Once abdominal wall fixity has occurred, fascial closure will be impossible [44] until the abdominal wall and contents have recovered fully, usually at least 6 months. In these cases other methods of restoration of the abdominal wall need to be applied.

The use of bridging mesh to support the defect has already been discussed as a TAC method. However, for some patients, temporary may mean 6 months or more, which equates to the period of recovery prior to elective abdominal wall reconstruction. It is well documented that abdominal closure using a resorbable mesh bridge results in a planned ventral hernia. Newer biologic meshes have been used to bridge defects, but their strength is derived from contact with other tissue planes rather than simply being sutured to a fascial edge. They also have a tendency to stretch over time if used for bridging. This means that with time, a delayed bulge at the site of the defect is likely, and whilst it may not represent a true hernia, it is likely to have a similar effect on the patient. Either type of mesh, when used as a fascial bridge, can be dressed with NPWT that will encourage granulation tissue ingrowth and cause the overall defect size to decrease. Once the wound has completely granulated, it can be skin grafted or left to epithelialize.

Definitive abdominal wall reconstruction should be delayed until the skin graft shows signs of lifting from the underlying bowel, which is a sign that the abdomen may be suitable for further surgery. Some patients decide that they would rather live with their hernia than undergo further surgery.

Component separation techniques can be used to achieve fascial closure without tension. They are unlikely to be successful in the frozen abdomen or one with any degree of abdominal wall fixity as they will not achieve as much medialization as usual due to the tethering effect of the underlying bowel. Anterior component separation requires lifting of large lipocutaneous flaps, which, in the presence of infection, creates increased risks for wound breakdown. It may be preferable to reserve this technique for a delayed abdominal wall reconstruction rather than use this option early. Where acute component separation may be useful is to achieve fascial closure in patients with no fixity, in an uncontaminated abdomen that would otherwise require bridging.

Wounds complicated by enteroatmospheric fistulae create their own set of difficulties. NPWT dressings can still be used if the fistula is isolated from the area being subjected to NPWT. This is complicated and time-consuming even in centres with the necessary expertise. Once the wound has granulated, it is treated in the same way as for the bridging mesh. It can be allowed to epithelialize, although this takes time and is difficult to isolate the fistula whilst epithelialization occurs. Skin grafting is useful, but fistula isolation without disturbing the graft can be problematic. Once healed, the patient can have definitive abdominal wall reconstruction and fistula repair at the same time. This is a complex procedure which should be carried out in a centre with the necessary expertise and should not be attempted until the fistula and graft mature, usually between 6 and 12 months.

Timing of definitive abdominal wall reconstruction should not only be based on the state of the healing wound. The timings should be considered as a minimum, not an absolute. Many of these patients will have been in a hospital environment for months. It is important to ensure that they are ready for further surgery nutritionally, physically, emotionally and psychologically. There is no urgency to undertake abdominal wall reconstruction.

Summary

The open abdomen is a useful technique but is subject to many risks. Its use should be limited to the prevention or treatment of ACS, where non-surgical options have failed. Creating an open abdomen is the easy part of a complicated patient management pathway that needs to be managed by a multidisciplinary team with a heavy early reliance on the intensive care team. Planning for the short-, medium- and long-term management should be in process from early in the treatment pathway. Definitive abdominal fascial closure may take many months to achieve, and some patients may choose to live with a residual hernia, rather than subject themselves to further surgery.

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Open Repair

25

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Introduction

Signs and Symptoms

An incisional hernia is defined by Pollock and his colleagues as "a bulge visible and palpable when the patient is standing and often requiring support or repair" [1].

Sixty percent of patients with incisional hernias do not experience any symptoms; however, symptoms that predicate medical advice include difficulty in bending, cosmetic deformity, discomfort from the size of the hernia, persistent abdominal pain, and episodic subacute intestinal obstruction. Incarceration persisting to acute intestinal obstruction and strangulation necessitate emergency surgery.

Spontaneous rupture of incisional hernia is an unusual but life-threatening complication (Fig. 25.1). This complication is more likely in infraumbilical hernia. It may be exacerbated by friction of clothes or corsetry [2]. Hernias after gynecological and obstetric interventions are most at risk [3].

Fig. 25.1 Spontaneous rupture of an incisional hernia

The demonstration of small incisional hernias may be very difficult. Patients with tiny protrusions of extraperitoneal fat and a small peritoneal sac may complain of a tender lump, which is not always there, but which causes quite severe localized pain when it is present. Physical examination of the patient supine and relaxed usually reveals the cause. Ultrasound examination is a useful diagnostic test and will often reveal an impalpable defect, particularly in the obese patient. However, the sonographic examination of the abdominal wall is dependent upon a skilled interpreter. It is sometimes difficult to differentiate between a hernia and subcutaneous fat or small bowel in the hernia, as opposed to being in close proximity to a weakened anterior fascia. In most situations and particularly for massive complex incisional hernias, CT scan may be much more efficient and accurate in defining the defect and planning the preoperative preparation of the patient and the operation chosen. CT scan is particularly helpful in obesity and in patients with extensive laparotomy scars as it defines the contents of the sac especially if the abdominal wall hernias are clinically occult. In addition it distinguished them from other conditions such as hematoma, abscess, and neoplasia [4].

Classification of Incisional Hernias

Different grading scores have been proposed to classify ventral hernias, and classifications are important to allow better understanding in operative reports, databases, and trials. The EHS published a comprehensive classification for both primary and incisional hernias that is easy to use

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Table 25.1 European Hernia Society classification for incisional abdominal wall hernias

EHS incisional hernia classification			
Midline		Subxiphoidal	M1
		Epigastric	M2
		Umbilical	M3
		Infraumbilical	M4
		Suprapubic	M5
Lateral		Subcostal	L1
		Flank	L2
		Iliac	L3
		Lumbar	L4
Recurrent incisional hernia?		Yes O	No O
Length: cm		Width: cm	
Width cm	W1 <4 cm O	W2 ≥4–10 cm O	W3 ≥10 cm O

and understand [5]. It defines localization of the defect, if it is recurrent or not, and its size, as shown in Table 25.1.

Besides the EHS classification, Rosen et al. proposed a grading score based on the likelihood of SSI (Surgical Site Infection) occurrence [6]. It is based on the CDC wound classification, but proposes a three-grade score only, with grade 1 cases without any risk factor, grade 2 patients with comorbidity, and grade 3 contaminated cases.

Conservative Management

The low risk of developing complications of a ventral hernia, such as strangulation and/or intestinal obstruction, has strengthened the nonoperative treatment in asymptomatic patients. Assessment of comorbidities and postoperative risks is a key in this decision process. Bellows et al. observed a small cohort of patients over a period of 24 months, and there was no effect on quality of life during the period and only one episode of incarceration during this time period [7]. A prospective cohort of 636 patients (295 with incisional hernia and 341 with umbilical/epigastric hernia) showed that active surveillance is a safe strategy in anterior abdominal wall hernias [8].

Preoperative Care

The preoperative condition of the patient can strongly impact the surgical outcomes in ventral repairs. Several risk factors should be analyzed and the pre-optimization is a key step for the best result. The modifiable risk factors should be addressed.

Obesity

Obesity is the number one patient modifiable risk factor predictive of SSI [9]. There is not a magical cutoff BMI. Some groups do not perform elective ventral repairs in patients over BMI of 35; others are more liberal and have a BMI of 40 as a cutoff. The International Endohernia Society guidelines for treatment of ventral hernias point that a BMI over 30 brings increased risk of bigger defects and recurrence [10]. A strategy to lose weight should be implemented in the preoperative period for elective incisional hernias. Self-diets and exercises have very high failure rates. A medical weight loss specialist should be consulted, but good results usually happen only in very motivated patients. Bariatric surgery is an option, and a sleeve gastrectomy is the procedure of choice, once the traditional gastric bypass requires small bowel mobilization, which requires hernia content mobilization. The hernia defect and content management is very critical during the bariatric surgery. If possible, the content and defect should not be touched. If content mobilization is necessary, the defect left open can lead to small bowel obstruction. Primary closure of the defect prevents this complication, but when it is not feasible, an omental patch can be sutured to the edges of the defect to avoid new bowel incarceration. The definitive hernia repair should be done once the weight loss is stable, usually after 6 months.

Diabetic Control

Glucose levels can significantly impact wound healing, once hyperglycemia leads to several alterations in wound healing as glycosylation of collagen, which is resistant to enzymatic degradation and remodeling, which decreases the strength of the scar, less granulation tissue, fewer fibroblasts in the dermis, and altered WBC function (chemotaxis, oxidative burst, phagocytosis). The level of hemoglobin A1c correlates to SSI. HA1c higher than 8 is correlated to a two times incidence of a SSI in cardiothoracic surgery [11]. A strict preoperative control of DM and glucose/HA1c levels should be implemented.

Smoking

Tabaco is still a huge world business with a global market over US$ 700 billion, and yearly growth around 4%, with over 5 trillion cigarettes produced per year. Smoking results in abnormal wound healing, reduced neutrophil blood count, alteration in collagen metabolism, and reduced levels of vitamin C [12]. Tobacco use is a significant independent predictor of wound infection in ventral repair [13]. Abstinence partially reverses the effects and should be requested for at least 4–6 weeks prior the surgery. Nicotine blood test should be done in the week before the surgery to prove the abstinence.

Prevention of Infection

MRSA (*methicillin-resistant Staphylococcus aureus*) decolonization with mupirocin/chlorhexidine has shown decreased

SSI by *S. aureus* and can be done universally instead after screening, one it seems to be more cost-effective this way [14].

A randomized trial comparing the use of antibiotic prophylaxis against no antibiotic in prosthetic incisional hernia repair has never been carried out. Nevertheless most surgeons consider it the best practice to administer a systemic dose of antibiotics preoperatively. When combined with a second dose of antibiotics, a significant reduction in wound infection occurs even in the context of a clean operation without contamination [15]. When there are other risk factors such as diabetes, obesity, and previous wound infection, the need for antibiotic prophylaxis becomes imperative.

Nutrition

The preoperative nutritional status is very important for any major operation, and the ventral repairs should not be different. Preoperative albumin is the single best predictor of overall procedure risk [16]. Besides the adequate nutrition, arginine supplementation seems to decrease overall infection rates and hospital stay in elective surgery and can be given for 5–7 days before the surgery [17].

Loss of Domain

The definition of loss of domain has been very subjective and no reliable criterion has been published. In huge and obvious cases, it is not difficult to make the diagnosis, but in some smaller cases, it can be not that easy. The volume calculation of the hernial sac and the abdominal cavity by CT scan can give a ratio between these two variables that when reaches over 25% gives the diagnosis of loss of domain as described by Tanaka et al [18].

Pneumoperitoneum As an Aid in Surgical Treatment of Giant Hernias

Management of giant incisional hernia is often compromised by obesity, intrahernial adhesions, and contraction in the volume of the abdominal cavity—the hernial contents have lost their "right of domain." The use of pneumoperitoneum before attempting definitive repair of giant hernias was originally suggested by Moreno in 1940 [19]. The advantages of the technique are:

- Stretching of the abdominal wall, creating a larger cavity into which the hernial contents can be replaced
- Reduction of edema in the mesentery, omentum, and viscera in the hernial sac, creating less mass to be reduced
- Stretching of the hernial sac leading to elongation of adhesions, making dissection and reduction easier [20]
- Increased tone of the diaphragm, allowing preoperative respiratory and circulatory adaptation to the elevation of the diaphragm [21]

The technique has evolved during the last decades, and recently a simpler technique using a double-lumen intra-abdominal catheter inserted through a Veress needle in the left hypochondrium has been popularized [22]. Daily insufflations of ambient air are utilized over a period or an average of 9.3 days. A total of between 1000 and 4000 cc of air is insufflated, depending on patient comfort. The maximum intra-abdominal pressure reached should be no greater than 15 mm of mercury (measured by sphygmomanometer). Successful hernia repair is subsequently possible in most patients.

In practice, the patient is ready for operation at about 2 weeks after induction of the pneumoperitoneum, the end point being judged by the tension of the abdominal wall, which should feel as tight as a drum, especially in the flanks. The patient should be operated on at this stage—if possible most of the dissection should be performed with the hernial sac unpunctured and distended. When this dissection has been completed, puncture of the sac allows easy reduction of contents and the slack parietes will facilitate repair. Air is only slowly absorbed from the peritoneal cavity, and often after the first 2 or 3 days, absorption is so reduced as to become inconsequential.

Contraindications to pneumoperitoneum include abdominal wall sepsis, prior cardiorespiratory decompensation, and suspected strangulation of hernial contents. Complications, which are very rare, include visceral puncture, hematoma, and the risk of an embolism into a solid organ if the liver or spleen is needled prior to insufflation. Mediastinal and retroperitoneal surgical emphysemas are rare complications. Prophylatic anticoagulation for DVT and respiratory physiotherapy are key to avoid complications and should be routine.

Botox Injection

Ibarra et al had showed that botulinium toxin injections are a potential preoperative mean to counteract abdominal wall tension, reduce hernia size, and facilitate fascial closure during the definitive procedure [23]. A recent meta-analysis showed a significant hernia width reduction (almost 6 cm) and an increase in lateral abdominal wall muscular lengthening (more than 3 cm), showing a potential use especially in complex ventral hernia management [24]. These excellent results were corroborated by other systematic reviews demonstrating excellent results with the use of botulinum toxin in abdominal wall defects [25].

Principles of Open Repair

The following principles should be followed:

1. Whenever possible the normal anatomy should be reconstituted, prior to placement of prosthetic mesh. In midline hernias this means the linea alba must be reconstructed; in more lateral hernias, there should be layer-by-layer

closure as far as possible. The use of sutures alone for the repair of incisional hernias is associated with a rate of recurrence that is at least as high as 43% [26].

2. Only tendinous/aponeurotic/fascial structures should be brought together. In situ darning over the defect without adequate mobilization and apposition of the aponeurotic defect gives a 100% recurrence rate [27].
3. The suture material must retain its strength for long enough to maintain tissue apposition and allow sound union of tissues to occur. A slowly absorbable suture material is recommended.
4. The length of suture material is related to the geometry of the wound and to its healing. Using bites at not more than 0.5–1.0 cm intervals, the ratio of suture length to wound length should be 4:1 and not more than 5:1 [28, 29]. Other fascial defects should be closed similarly.
5. Repair of an incisional hernia inevitably involves returning the viscera to the confines of the abdominal cavity with a resultant rise in intra-abdominal pressure. It is important to minimize this.
6. Every care must be taken to prevent abdominal distension due to adynamic ileus, which will lead to additional stress on repair suture lines. For this reason, handling of the viscera should be minimized.
7. Postoperative coughing can put an additional unwarranted strain on the suture lines. Hence, pulmonary collapse, pulmonary infection, and pulmonary edema must be avoided.
8. The repair must be performed aseptically; inoculated bacteria, traumatized tissue, and hematoma should not be features of these wounds.

Drawing these eight points together, appropriate preparation for operation includes measures to reduce the risk of subsequent infection: all skin lesions and erosions should be resolved before surgery, and pulmonary function should be optimized. A carefully planned procedure using a repair with prosthetic reinforcement is recommended in appropriate patients [30].

Surgical Techniques

Tissue Repair vs. Mesh Repair

Due to the poor results of tissue repairs, it is mandatory that a prosthesis is used in all incisional hernia repairs. Even if the fascial defect is less than 4 cm, a prosthesis is recommended. The prosthetic materials that are available are described in Chap. 7.

There are limited clinical data and short-term follow-up for only a few of the many biological tissue grafts, and additional clinical studies are required [31]. Prosthetic, synthetic meshes are designed to withstand the theoretical maximum intra-abdominal pressure of 20 kPa at an average human body diameter of 32 cm. From this it is calculated that the maximum required tensile strength of any material to maintain abdominal wall closure is 16 N/cm. All synthetic prosthetic materials used for incisional hernia repair are designed to this standard, and the choice is left to the individual surgeon. In a contaminated or potentially contaminated field, a biological mesh is favored, and there are many new products to choose from [32].

The tissue repair or Mayo procedure for repair of abdominal incisional hernia gives unacceptable results with recurrence rates of up to 84% with 5.7 years of follow-up [33]. When suture repair for incisional hernia is compared with mesh repair, the incidence in recurrence at 36 months is reduced from 43% (suture) to 24% (mesh) in patients with a vertical midline incision of less than 6 cm in length [26]. However, in this study patients only received 2 cm overlap of mesh which currently would be considered inadequate, and the 10-year cumulative rate for recurrence was 32% for the mesh repair, a figure that would now be highly unacceptable [34]. Further insight into the benefit of mesh came from a comparative retrospective study of 421 incisional hernias on 348 patients undergoing 241 Mayo repairs and 180 mesh repairs over a 25-year period [35]. The total recurrence rate following Mayo repair was 37% in contrast to 15% after mesh implantation. In the mesh repair group, the only significant prognostic factor concerning quality of life and recurrence was the size of the mesh implanted. There were more wound-related complications in the mesh repair group, and recurrences occurred at the upper and lower edges of the mesh where there had been insufficient overlap.

Position of Patient

If the hernia is located in the midline or lateral aspects of the anterior abdominal wall, the patient is placed in the supine position on the operating table.

The Incision

A wide elliptical incision is made to enclose the cutaneous scar. The incision must generally be extended at either end to give adequate access to all the margins of the defect. The direction of this initial incision will depend on the shape of the original scar through which the hernia has come. Care should be taken not to excise too much skin: at this stage the minimum excision of cutaneous scar tissue is carried out (Fig. 25.2).

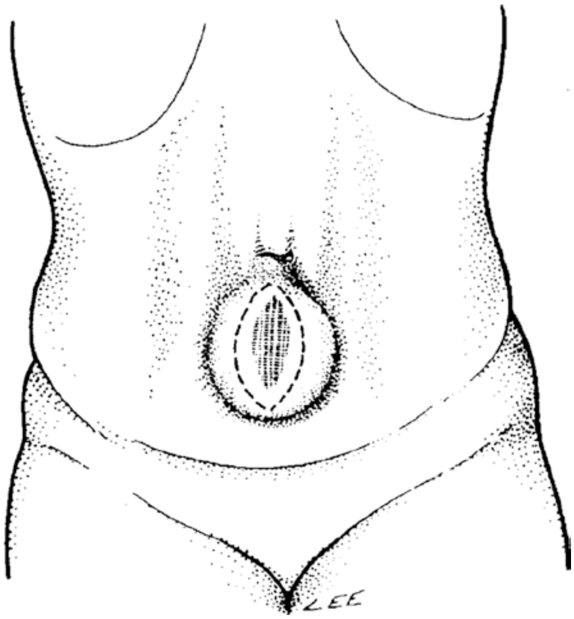

Fig. 25.2 Elliptical incisions are made on either side of the hernial cicatrix

Removal of Overlying Redundant Tissue

The redundant skin and scar are separated from the underlying hernial sac, which is often lying just under thinly stretched skin, especially near the fundus of the hernia. Redundant skin and scar tissue are removed (Fig. 25.3). This is a significant advantage of the open approach compared with the laparoscopic method because a better cosmetic result is achieved.

If the hernia is very large, the skin and underlying peritoneal sac may be virtually fused into one layer near the fundus of the hernial protrusion. When removing the redundant skin, care is necessary to avoid damage to the hernia contents which may be adherent over wide areas inside the sac (Fig. 25.4).

Exposure

The hernia is dissected from the surrounding subcutaneous fat by raising skin flaps (Fig. 25.5). The surgeon may choose to use the scalpel blade, scissors, electrocautery pencil, and/or the ultrasonic dissection device for this dissection. The coverings of the hernia are stretched scar tissue merging into the stretched abdominal wall aponeurosis at the circumference of the protrusion and a variable amount of extraperitoneal fatty tissue.

The hernial sac is now dissected out completely following the contours carefully until the neck of the sac is reached circumferentially, which in a large hernia will require the

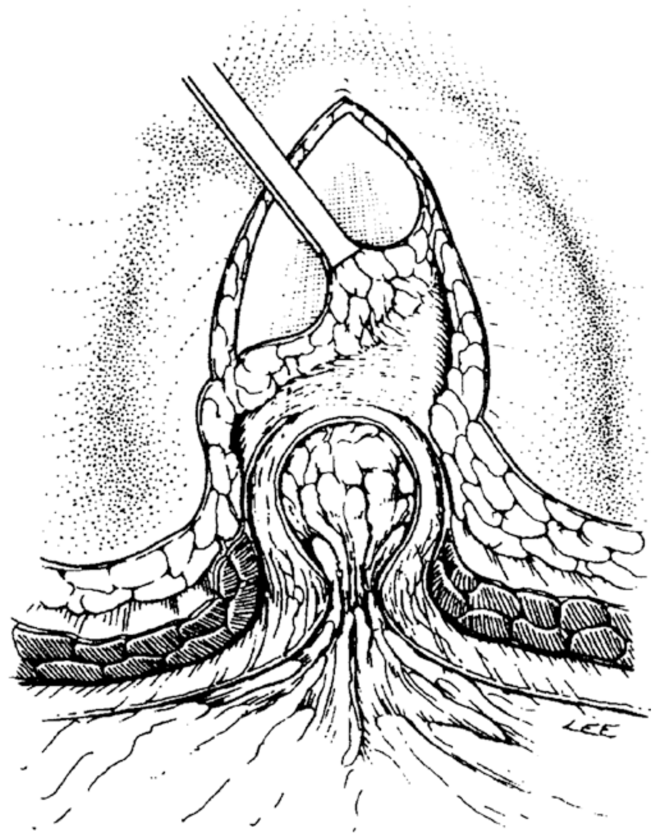

Fig. 25.3 Removal of the redundant scar

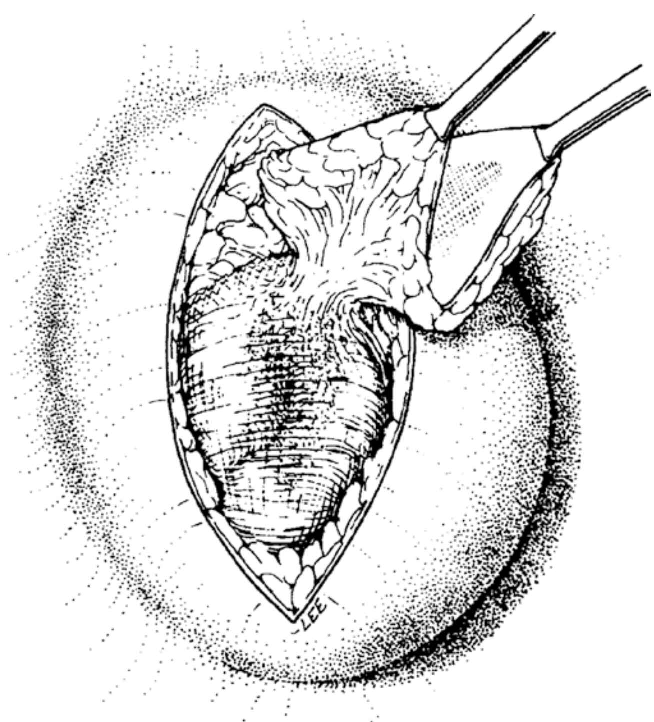

Fig. 25.4 Care must be taken not to remove too much skin and not to damage the hernial sac. The cutaneous cicatrix is often closely adherent to the sac

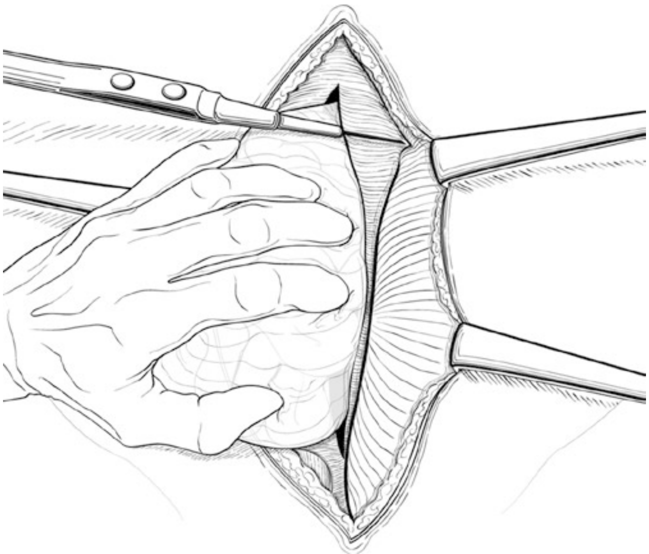

Fig. 25.5 Skin flaps are raised in order to fully dissect out the sac and allow placement of the mesh, with or without "components separation." A 4–5 cm exposure of the anterior rectus sheath is required on each side for an onlay (prefascial) repair; less exposure is required for a sublay (retrorectus) repair

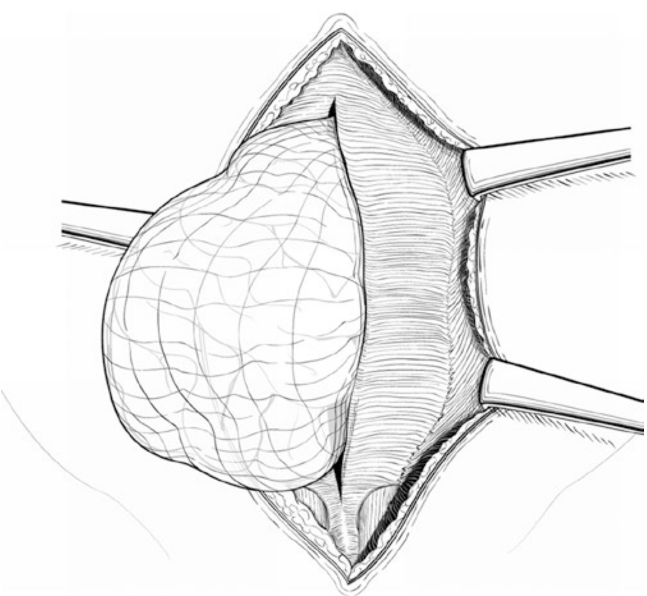

Fig. 25.6 Circumferential exposure of the neck of the sac is achieved

elevation of large skin flaps (Fig. 25.6). These large areas of pannus should be removed later by horizontal panniculectomy (see later) to lessen the incidence of seroma formation collecting in loose folds of the skin.

Managing the Peritoneal Sac

The hernial sac is now opened carefully avoiding damage to the visceral contents of the sac, either at the fundus or by an elliptical incision around the hernia neck, where it merges with the stretched aponeurosis (Fig. 25.7).

It is recommended that the hernial sac is completely resected in all cases because intra-sac adhesions and sac compartmentalization can be a potent cause of intestinal obstruction, if the sac is merely inverted and pushed into the abdominal cavity. The advent of laparoscopic techniques for incisional hernia repair has revealed that at least one-third of hernial sacs contain visceral contents which are adherent to the sac itself. After opening the sac, adhesions of the contents are divided (Fig. 25.8), the viscera returned to the peritoneal cavity, and then the sac is completely excised to the edge of the rectus fascia/linea alba on each side (Fig. 25.9). Since the peritoneal layer will not be sutured separately (it is too weak to retain sutures), complete excision of the sac allows the medial fascial edges of the rectus sheath/linea alba to be seen clearly for accurate suture placement when closing the abdomen. A touch of advice is to reserve the final decision of ressection of the

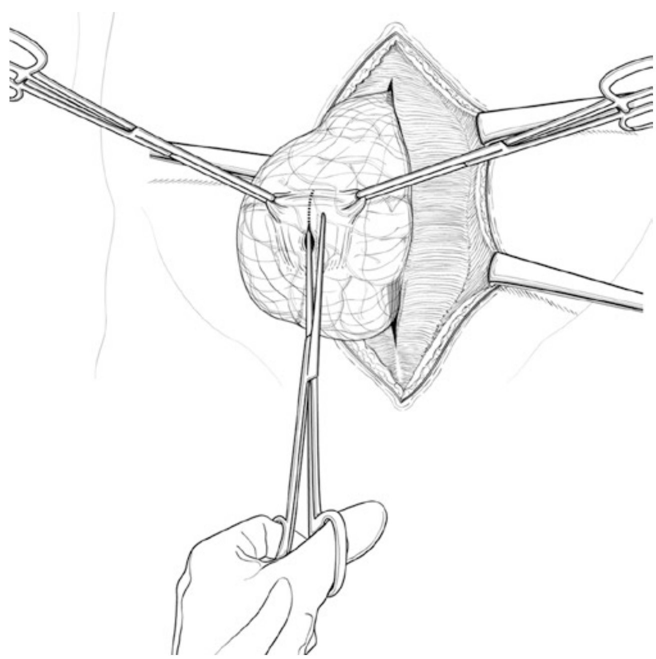

Fig. 25.7 The sac is opened at a point where it is judged that bowel is not adherent beneath it, usually at the fundus

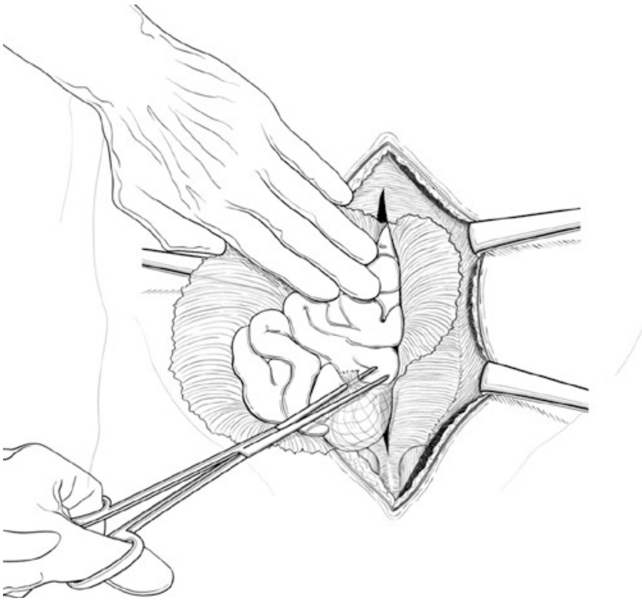

Fig. 25.8 Adhesions between the bowel and sac are divided, and the bowel is returned to the peritoneal cavity

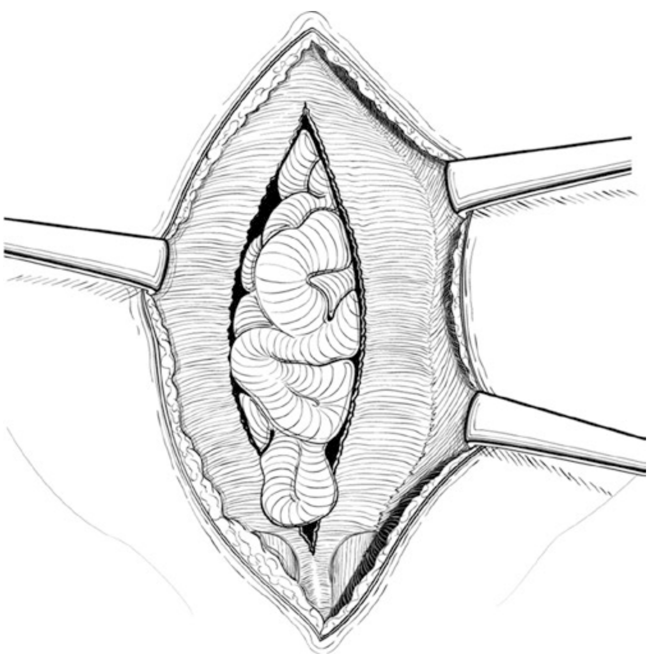

Fig. 25.9 Completion of excision of the sac, laying bare the medial margins (linea alba) of the rectus sheath in preparation for midline fascial closure

hernia sac for after one can assure there will be enough posterior sheet to close the visceral sac.

Contents of the Sac

The sac may contain almost any intraperitoneal viscus, but usually the omentum, small bowel, and transverse colon are found.

Unless the hernia is strangulated and the small bowel non-viable, any adhesions are divided and the small bowel is returned to the abdominal cavity. Strangulated small bowel or omentum can be resected at this stage. The diagnostic decision is now made as to what should be done about very adherent and frequently partially ischemic omentum. If there is any doubt about omentum, it is best excised. To return the omentum of doubtful viability to the peritoneal cavity invites the formation of adhesions.

Particular care must be taken in manipulating and dissecting any colon in the sac. Any densely adherent hernial sac should be trimmed and left adherent to the bowel and returned to the peritoneal sac rather than risk perforating the bowel in a tedious dissection. The greatest care must be taken to avoid puncturing the colon. If the colon is punctured, a minor injury could generally be closed with sutures. A substantial injury must be treated by creation of a colostomy; the reanastomosis of the colon and repair of the hernia can be performed at a later operation after full patient evaluation and colon antibacterial preparation.

Visceroreduction

In extreme situations, when it is not possible to close the aponeurotic layer, there has been some anecdotal reports of resection of visceral contents to achieve abdominal wall closure, normally associated with loss of domain and progressive pneumoperitoneum [36].

This normally starts with the omentum, with resection of the right colon if necessary, extending to the small bowel if the closure is still not achieved [37].

Panniculectomy

Panniculectomy if required is carried out at this stage after complete fascial closure. Depending upon local custom, the subcutaneous fat is either left unclosed or is closed in layers with absorbable sutures. The skin margins are now approximated. Skin closure must be effected without any tension. This may be accomplished with sutures and/or skin staples. It is recommended that interrupted mattress skin sutures are placed at 1 cm intervals. Skin healing is compromised because the raising of skin flaps has reduced the blood supply; therefore sutures should not be removed until the first wound check in the outpatient clinic at 14 days after the operation.

The Choices of Technique in Open Prosthetic Repair

The choice is between the onlay (prefascial, Chevrel) technique, the sublay (retrorectus, Rives, preperitoneal), and an intraperitoneal technique. The use of unprotected intraperitoneal mesh in open surgery is not considered appropriate because it leads to adhesion formation between the mesh and bowel and the risk of fistulation. The retrorectus sublay repair is considered by many surgeons to be the method of choice. The mesh sits in a biomechanically excellent position, and there is less potential space for clinically significant seromas to develop compared to the onlay repair. However the repair can be technically challenging especially below the arcuate line, where there is only a preperitoneal plane devoid of posterior rectus sheath, and for recurrent hernias where the tissue planes maybe severely disrupted and attenuated. An alternative is the onlay technique, in which the mesh is placed over the abdominal wall closure in the subcutaneous prefascial space. This technique was refined and popularized by Chevrel and is technically simpler to perform than the sublay repair, but is often performed poorly without careful attention to closure of the anterior sheath. The main criticisms of the onlay technique are the potential for higher rates of wound infections and seroma formation. A hernia surgeon should be able to perform both techniques well and adopt the most suitable technique for the individual patient.

For very complex abdominal wall reconstruction, techniques of tissue expansion, vacuum-assisted closure devices, abdominal components separation, local and distant muscle flaps, and free tissue transfer can be adopted [38]. However, for the general surgeon performing incisional hernia repair, such advanced surgical techniques should only be attempted in collaboration with a plastic surgeon unless he or she is familiar with these techniques. In general small hernias below 10 cm in size are amenable to laparoscopic repair (see Chap. 16) although they are satisfactorily repaired by the open technique with the additional benefit of achieving cosmesis of the anterior abdominal wall skin. Hernias between 10 and 15 cm in size are best repaired by open techniques although advanced laparoscopic surgeons can achieve good results. Hernias over 15 cm in size usually require a Ramirez “components separation” of part repair because of significant loss of domain [39].

A Cochrane database of systematic reviews in 2008 concerning open surgical procedures for incisional hernia included eligible studies if they were randomized controlled trials comparing different techniques for open incisional repair. Eight trials were identified of which one was excluded and 1141 patients had been enrolled into the studies. Three trials concerned suture vs. mesh repair (onlay or sublay), which revealed that recurrence and wound complications were more frequent after sutured repair. Two trials compared onlay (prefascial) vs. sublay (retrorectus) technique and found no difference in outcome except for a shorter operative time for the onlay method indicating its ease of use. Finally comparison between lightweight and standard mesh showed a trend for more recurrence in the lightweight group. An onlay vs. intraperitoneal mesh trial showed no differences in outcomes except for increased pain in the intraperitoneal group [40]. The review concluded that open mesh was superior to suture techniques for recurrence and reduction in wound infection, but there was insufficient evidence as to which type of mesh or which mesh position (onlay or sublay) should be used. In addition the study also found insufficient evidence to advocate the use of components separation technique, and clearly this requires further study. A quasi-randomized study allocating patients alternately to either a sublay or an onlay arm for meshplasty in ventral hernias, excluding patients with defects greater than 10 cm, found a more favorable outcome for the onlay technique with complications recurring in 22.5% (sublay) vs. 15% (onlay) with similar wound complications [41]. Hospital stay was similar and there were no recurrences.

Onlay (Prefascial, Chevrel) Technique

Chevrel popularized the onlay, prefascial technique more than 30 years ago [42]. Reporting 257 prosthetic repairs, Chevrel reported a morbidity of 10.5% including 6.3% seroma, 2% wound infection, and 4.9% recurrence and favoring the use of polypropylene mesh. In addition Chevrel advocated the use of fibrin glue and relaxing incisions in approximately half of his patients. Relaxing incisions were placed in the anterior rectus sheath, which was a favored technique prior to the introduction of the components separation, which places the relaxing incisions in the external oblique aponeurosis. Similar results have been reported in smaller series which advocate a significant overlap of mesh after the midline fascial closure and extensive suturing of the mesh to the anterior abdominal wall in order to prevent shifting, curling, or movement of the mesh allowing recurrence [43–45]. Recurrence rates in the series ranged from 3 to 16%, which is a satisfactory outcome for large incisional hernias.

Panniculectomy is an important adjunct to surgery of the anterior abdominal wall to allow removement of large flaps of the skin, which are redundant, once the large underlying hernial sac has been removed and reduced [46]. Failure to remove a large pannus or skin flap can result in a troublesome chronic seroma requiring multiple aspirations or surgery if it forms a pseudocyst on the abdominal wall.

Sailes et al. [47] have reported the largest series of onlay repairs (545 patients, all in addition receiving components separation), with an 18.3% recurrence rate. In 2008, Kingsnorth et al. reported the results of onlay repair in a prospective 24-month audit of 116 patients with major (>10 cm) incisional hernias. Quality of life was assessed by a validated questionnaire and telephone follow-up. Fascial closure required components separation in 18%; postoperative seromas occurred in 9.5%, deep wound infections in 1.7%, and recurrences in 3.4% at 15.4 months [48].

Kingsnorth has accumulated a series of 540 onlay repairs, with 2–12-year follow-up (mean 5.6 years) which includes 104 cases receiving components separation. This latter group of 104 complex patients has been audited prospectively with long-term telephone and clinical follow-up. All patients had large incisional hernias (median size 384 cm^2), a transverse gap of 10–30 cm (12.8), age 31–87 years (59), male-to-female ratio of 62:42, ASA grade 1: 2: 3 ratio of 18: 60: 26, BMI of 17–46.5 (38), comorbidities in 49%, and pre-op fistula in 9. The complexity of the cases was demonstrated by the following features: removal of previous mesh required in 42 patients; removal of previous skin graft in 10; bowel resection, anastomosis, or enterotomy in 30; panniculectomy in 16; and parastomal hernia repair in 19. Complete fascial closure was achieved in 93 patients. Mattress skin sutures were used (to be removed at 14 days postoperatively) and suction drains placed under the skin flaps (to be removed at 14 days unless drainage was continuing at >50 cc/day).

Results included postoperative wound infection in 17 patients, of which 11 were superficial and 6 deep infections. VAC dressings were applied in 13. Seroma occurred in a total of 23 cases of which 16 were treated by aspiration on an outpatient basis and 7 required reoperation. In total there were 11 reoperations for wound morbidity. Thirteen patients experienced recurrence: of these three with minor (<5 cm) asymptomatic recurrences which did not require surgery, two with minor (<5 cm) symptomatic, and eight with major (>5 cm) recurrences which were reoperated. Pain was assessed at 1 year; 85 patients were experiencing no pain, 15 had minor pain not interfering with daily activity, and 4 had major pain reducing quality of life.

From this extensive experience, the following recommendations can be made to optimize the results of an onlay repair:

1. Completely *resect the sac.*
2. Use intact linea alba to *close midline with 4:1, suture length to wound length.*
3. Tailor mesh to *no more than 5 cm overlap*, avoiding mesh overkill.
4. Use a *lightweight, large pore mesh.*
5. *Remove* redundant pannus.
6. Subcutaneous *drains* for 14 days.
7. Mattress *skin sutures* for 14 days.

Results of other surgeons are shown in the table below.

Onlay repair results (all reported with <2 years of follow-up)

	Recurrence	SSI
deVries et al. [49] (*n* = 13 in RCT)	33%	
Godara et al. [41] (*n* = 100 in RCT)	15% (22% sublay)	
Venclauskas et al. [50] (*n* = 57 in RCT)	10.5% (2% sublay)	49%
Memon et al. [51] (*n* = 60)	6.7%	21%
Stoikes et al. [52] (*n* = 50) sutureless	0%	
Gemici et al. [53] (*n* = 154) 54 m F/U	5.2%	

It is worth mentioning the results of Venclauskas who, in a poorly designed study, achieved the lowest recurrence reported for a sublay repair and the highest wound infection for an onlay repair.

The onlay technique is the ideal operation to combine with components separation in patients with very large incisional hernias with loss of domain [48] (Fig. 25.10).

Incision and Dissection

An elliptical incision removing the previous scar is used. In order to perform the panniculectomy, triangular wedges of the skin and subcutaneous fat are removed at the lower end of the midline scar, which will eventually produce an inverted T-shaped incision which requires closure with care and accuracy. Beginning at the fundus of the sac, the entire sac is carefully dissected down to its neck in order to expose it completely without opening. At this stage the skin flap should only be minimally dissected in order to mobilize the sac and clearing an area of not more than 5 cm beyond the edge of the rectus muscle. The sac is now opened, and any adhesions between the bowel, peritoneum, and the sac are divided and abdominal contents returned to the peritoneal cavity. In all cases the sac should now be completely excised.

In all cases the surgeon should be able to completely close the midline without tension. Where the width of the gap between the rectus muscles is relatively small, the anterior rectus sheath on each side may be closed with a strong running suture of slowly resorbable suture material. Prior to doing this, the anterior rectus sheath is dissected from

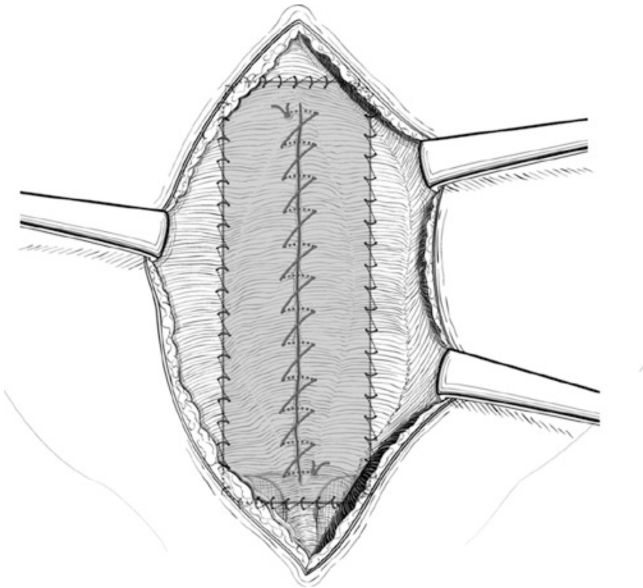

Fig. 25.10 The onlay (prefascial) technique. After construction of the neo-linea alba, a strip of prosthetic mesh 8–10 cm in width and 3–4 cm longer than the abdominal wall closure is placed and secured with a continuous peripheral suture of nonabsorbable suture material and a continuous suture to attach the mesh to the midline closure

the subcutaneous fat for 5–7 cm to accommodate the onlay mesh. The mesh is now cut to size being a width of 10 cm and allowing for 3–4 cm overlap superiorly and inferiorly. If the polypropylene or polyester mesh is allowed to be in direct contact with the intestine, there is a risk of adhesion formation and fistulation. There is also a risk of mesh erosion into the bowel with these types of meshes. In open prosthetic mesh repair, there is no place for the use of newer meshes with incorporated anti-adhesive agents placed over the bowel as an inlay method without midline fascial closure. These dual meshes are specifically for use by laparoscopic surgeons when placed over a defect from inside the abdomen and in which contact with the viscera is inevitable. There are no long-term studies to verify the absence of complications seen many years after the insertion of such meshes. However, the use of such products has been longer than 15 years.

Use of Drains

Although seromas occur in a minority of patients, there are no known risk factors for their postoperative occurrence. Therefore measures should be taken to prevent seroma formation in all patients receiving a mesh repair, regardless of the complexity of the operation. This prophylactic practice is accomplished by the placement of drains in every patient. Closed suction vacuum drains are used (bottle capacity 500 cc, so that changes are infrequent, minimizing contamination), which have a relatively long tube having multiple perforations down its terminal length. Two drains are used. Each is tucked in laterally, under a right or left skin flap, to emerge low-down on the lateral abdominal wall, and sutured to the skin securely.

In the first 24–48 h, a bloody discharge will appear in the drainage bottle. Thereafter the fluid will become serous. The maximum flow of serous fluid is usually at about the fourth to sixth day, mandating against removal of any drain before 1 week postoperatively. Because seromas can persist after the seventh day, all drains remain in situ until day 14 postoperatively, which is the day patients receive removal of skin sutures in the outpatient clinic. Patients can take home spare drainage bottles, which can be changed by a nurse if large volumes of serous fluid are discharged, in the occasional patient. The complications of this management protocol far outweigh the problems associated with the management of large volumes of trapped serous fluid under the skin flaps. If at day 14 the daily discharge is >50 cc, the drains are not removed and the daily discharge is monitored until the flow becomes <50 cc daily. A small number will continue to discharge serous fluid after 30 days, at which time a decision must be made to remove the drain and manage any seroma formation expectantly.

Sublay Repairs

Retromuscular/Rives

The sublay repair places the mesh in the retromuscular space. Rives originally described this technique more than 30 years ago [54]. Placement of the prosthesis in the retromuscular plane requires opening of the rectus sheath near the linea alba to gain access to this space on both sides. After closure of the posterior rectus sheath, the mesh is placed on top of this behind the rectus muscles, and conclusion of the abdominal wall closure is achieved by suture of the anterior rectus sheaths in the midline. Leaving a gap in the anterior or posterior rectus sheath achieves poor results and a high recurrence rate, and the relaxing incision in the external oblique of "components separation" should be applied in order to gain complete midline closure. The mesh overlap achieved is similar to the onlay technique with 5–6 cm in all directions and gives good results [55, 56]. This repair also gives good results in patients with large hernias with significant loss of domain [57].

Each rectus sheath is incised along its medial border and opened in the midline to expose the anterior and posterior aspects of the rectus muscle (Fig. 25.11). With blunt dissection the entire width of the muscle is exposed on its undersurface superficial to the posterior rectus sheath (Fig. 25.12). The posterior rectus sheath is now closed with a continuous running suture of slowly resorbable material and the mesh placed in the posterior retrorectus

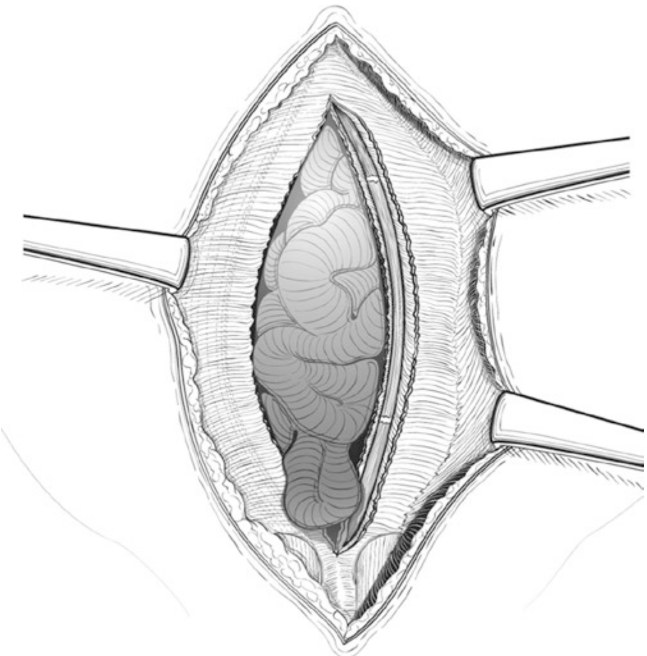

Fig. 25.11 The medial border of the rectus sheath is incised along the length of the fascial defect on both sides

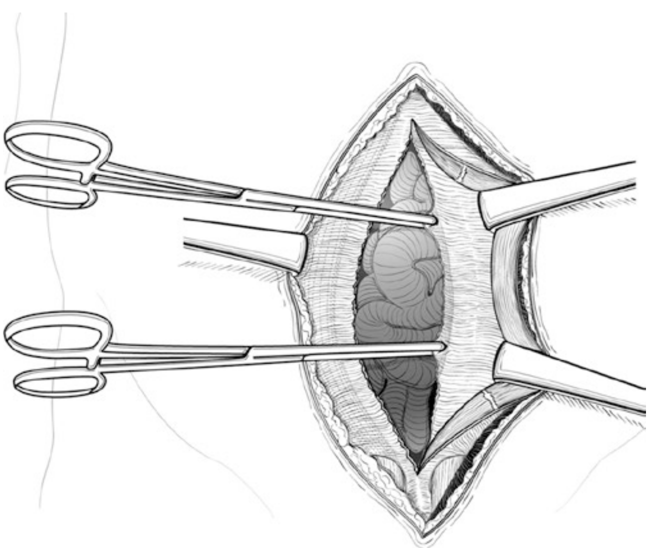

Fig. 25.12 The bloodless plane behind the rectus muscle and anterior to the posterior rectus sheath is dissected to the lateral limit of the rectus muscle

position to occupy the width of the rectus muscles on both sides (Fig. 25.13). A prosthetic mesh approximately 10 cm in width and long enough to achieve a 3–4 cm overlap superiorly and inferiorly is now placed in the retrorectus space (Fig. 25.14). To prevent migration or movement of the mesh, a few absorbable sutures are placed between the mesh and the posterior rectus sheath or peritoneum. It may be advisable to place a suction drain in the retrorectus position prior to closure of the anterior rectus sheath,

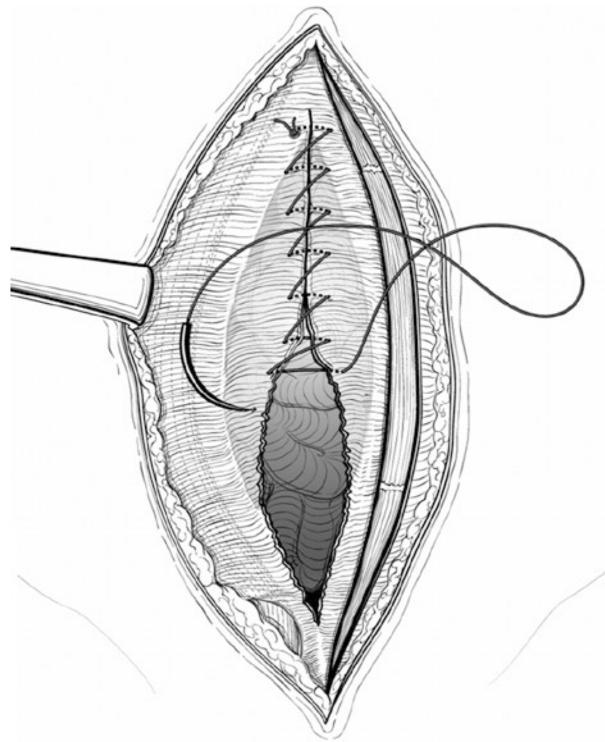

Fig. 25.13 The posterior rectus sheath is closed with a nonabsorbable suture. This should be achieved with negligible tension

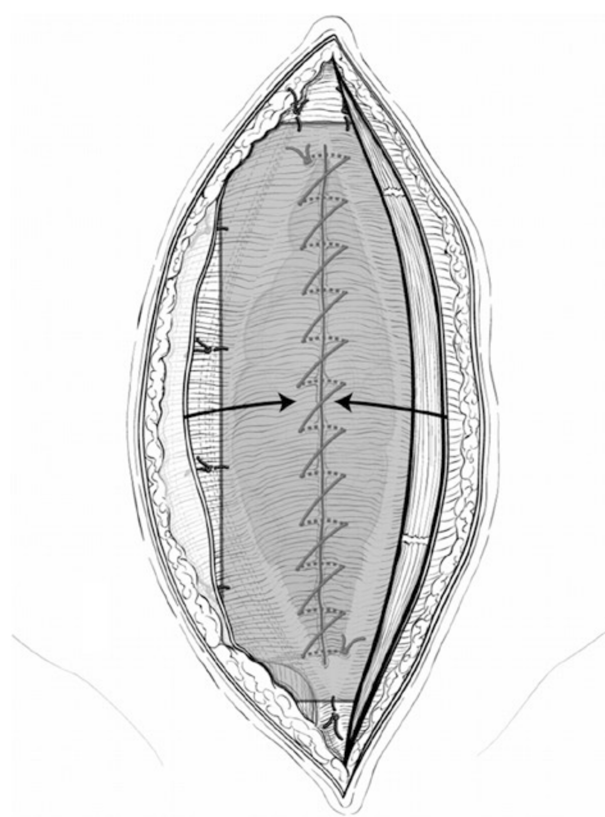

Fig. 25.14 Prosthetic mesh wide enough to cover the space behind the two rectus muscles (about 8–10 cm) and 3–4 cm longer than the midline closure is placed and secured with a few peripheral interrupted absorbable sutures

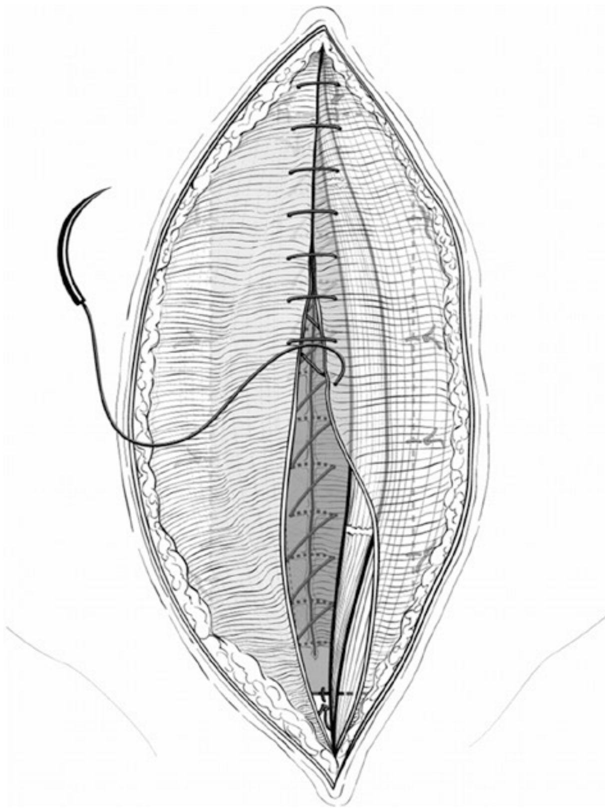

Fig. 25.15 The anterior rectus sheath is closed with a slowly absorbable continuous suture to achieve 4:1 suture length-wound length ratio (5–10 mm bites at 5 mm intervals). Suture bites do not include the muscle

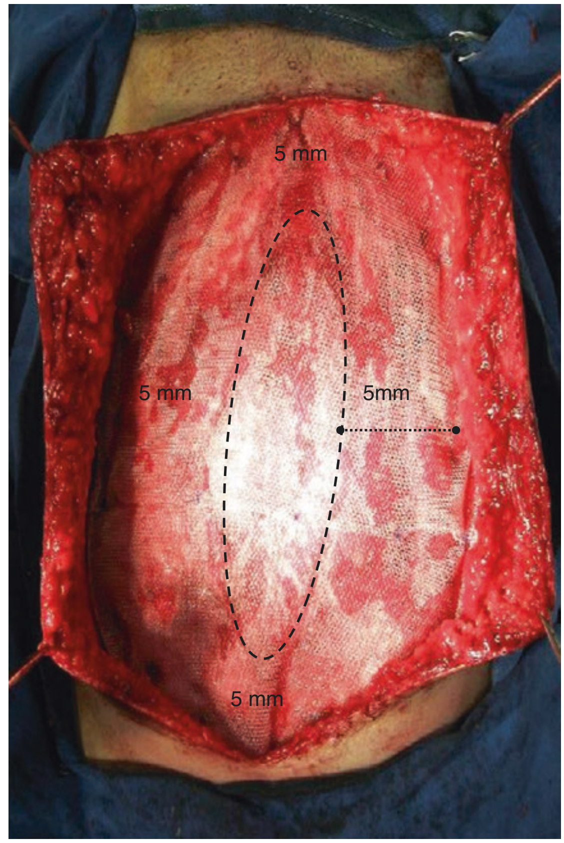

Fig. 25.16 Onlay implanted mesh with adequate 5 cm overlap in all directions

which is achieved by a continuous suture of slowly absorbable material (Fig. 25.15).

Preperitoneal Repair

The preperitoneal repair places the mesh in the preperitoneal space, which below the arcuate line is the same space to place the mesh described by Rives and Soppa and pointed above [54]. The main difference is that above the arcuate line, this is a very difficult layer to achieve due to the thin layer of peritoneum in this area. The dissection should be carried below the rectus sheath taking care not to tear the peritoneum (which is normally difficult to achieve) in order to obtain at least 5–6 cm in all directions to have a good mesh overlap of the defect (Fig. 25.16).

After dissection of the preperitoneal space and confirming that the mesh will have the adequate overlap, the peritoneum is closed with absorbable suture to avoid contact between mesh and abdominal viscera. The mesh is placed in the preperitoneal space created and should be secured with few absorbable sutures between the mesh and the posterior rectus sheath or peritoneum. The posterior rectus sheath is now closed with a continuous running suture of slowly resorbable material.

Open Intraperitoneal Prosthetic Mesh Repair

This alternative technique has been popularized in one or two French centers [58, 59]. The initial steps of the operation are the same as for the onlay or sublay techniques with complete excision of the peritoneal sac to the medial edge of the rectus muscles. The mesh is placed intraperitoneally with 5–6 cm overlap and secured by nonabsorbable through-and-through sutures spaced 2 cm apart and 1 cm from the border of the mesh. The sutures transverse the entire width of the muscular fascial abdominal wall and also the subcutaneous layers, and each is tied through a small incision in the skin. Protagonists of this technique claim that the prosthesis acts as a substitute for the abdominal wall avoiding suture of the two opposite fascial edges of the defect with tension. The muscular aponeurotic edges are closed in the midline as much as possible to isolate the prosthesis from surgical skin contamination. The authors promoting this technique have not encountered problems with enterocutaneous fistula. If this method is used, the choice of a biologic mesh will require the preservation of the hernial sac to be used as a vascularized pedicle to allow for the proper resorption of the collagen product.

New meshes were launched in the last years with the objective of making the intraperitoneal placement and fixation easier. They have a skirted edge or pocket that allows an easier fixation with tackers from "inside" the mesh. Some meshes also have a rigid external ring that help the positioning and opening the mesh and are absorbed after a certain period of time.

For the open intraperitoneal technique, after the complete lysis of adhesions, an appropriated coated mesh should be positioned intraperitoneally and fixated with sutures or tackers in all the peripheral edges of the mesh to avoid exposure of the parietal surface of the mesh to the viscera. It should have adequate overlap in all directions (at least 5 cm) and be fixated in on side first and, after pretensioning of the midline medially, to the other side. This maneuver aims to avoid wrinkles in the mesh after the midline closure, in the same fashion described above.

Postoperative Care

Immediate active mobilization is the key to rapid convalescence. In the absence of extensive handling of the intestines, there is no postoperative adynamic ileus and no need for encumbrances such as nasogastric suction or intravenous drips. The patient is made to take deep breaths; breathing exercises and, where necessary, chest percussion are given. As soon as possible, the patient gets up and walks. Fluids are given for the first day, and then a light diet is started. These patients may experience a significant amount of pain, which will require parenteral analgesia. If this can be controlled with oral analgesics and the patient does not experience a significant ileus, a minimal hospital stay can be expected. Generally, the length of stay will be 3–5 days depending upon the size of the hernia, the amount of dissection required, and the number of comorbid conditions of the patient.

Management of Drains

The use of drains in the onlay repair was previously discussed in this chapter. There is a lot of controversy regarding the need to use drains in the retromuscular space or in the preperitoneal space. Literature lacks evidence (and especially good-quality data) regarding the need to use drains in this space [60]. Most surgeons prefer not to use drains on this space if there is no evidence of continuous pouring after dissection, but since there is little evidence in the literature, the decision should be based on surgeon experience [61].

Conclusions

- Specialists who have developed an interest and experience in incisional hernia repair have significantly better results than nonspecialists.
- Important predictors of recurrence are wound infection, obesity, and previous repairs.
- A critical factor for a good outcome is the pre-optimization of the patient.
- A choice of operative procedure is critical. Fascial closure is paramount, and mesh overlap does not need to exceed 5 cm.
- Mesh fixation should be comprehensive with a continuous peripheral suture for the onlay technique, interrupted sutures for the sublay method, and a peripheral line of sutures or tackers in IPOM techniques.
- Where there is a risk of abdominal compartment syndrome after closure of the midline fascial layer, a components separation is essential and simple.

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Component Separation of Abdominal Wall Muscles

26

Flavio Malcher and Leandro Totti Cavazzola

Introduction

The term separation of abdominal wall components refers to the incision and dissection of muscular planes of the anterolateral musculature of the abdomen. It differs from the simple relaxation incision often used by surgeons, since it has as a precept on the release of the muscular planes so that the lateral components slide in the medial direction in order to affect the closing of the midline of the abdominal wall [1–3].

Its use may occur in cases where the surgeon does not want to use prostheses and needs to close the abdominal cavity (peritonostomies/open abdomen, infected fields, etc.) or in cases where the midline is to be realigned in order to restore the full function of the wall, in addition of the use of a mesh to reinforce the defect [1].

There are many techniques described, but the following will describe the main techniques used in our environment [2, 3].

Anterior Component Separation

Better know as Ramirez component separation, the first step is the complete release of the adhesions of the intracavitary contents to the abdominal wall in order to facilitate the slide into a medial position. The healthy edges of the musculature should be identified in all directions of the hernia defect [1, 3]. This is done by releasing a suitable adipose-cutaneous flap to the level of the muscular borders. Once this border has been identified, one should continue the dissection of the anterior aponeurosis until the lateral border of the rectus abdominis is identified. The maneuver of grasping the rectus abdominous between the index finger and the thumb in a practical maneuver facilitates the identification of this limit (Fig. 26.1). At that moment, a small incision is made 1 cm in the lateral direction of the border of the abdominal rectum in order to incise only the external oblique muscle fascia. No fleshy muscular belly should be visualized at this time. Once making sure that the internal oblique space is reached, the dissection is continued in the caudal direction until the inguinal ligament and cephalically to the costal border. In this cranial portion, the muscle fibers section of the external oblique muscle becomes imperative (crucial) [3].

Once this relaxation incision is created, the avascular interoblique plane should be freed by lateral blunt dissection in order to allow all possible sliding of the medial compartment (Fig. 26.2). After performing these surgical steps bilaterally, the midline alignment can be tested. The release of the posterior sheath of the abdominal recesses can be done bilaterally as usual for the retromuscular repair of Rives-Stoppa to achieve additional sliding and/or to allow the prosthesis to be placed in this space [1, 3].

The midline is then closed in the usual manner by the surgeon (Fig. 26.3), and a prosthesis can be placed in an onlay

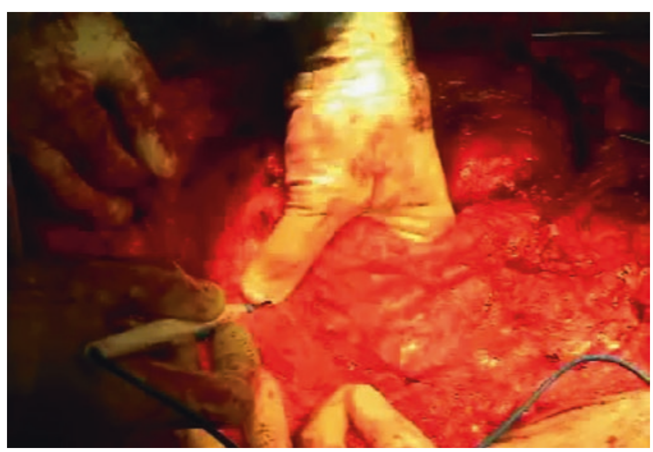

Fig. 26.1 Grasping of the rectus muscle to identify the lateral limit of its sheath (Published with kind permission of © Yuri Novitsky 2017. All Rights Reserved.)

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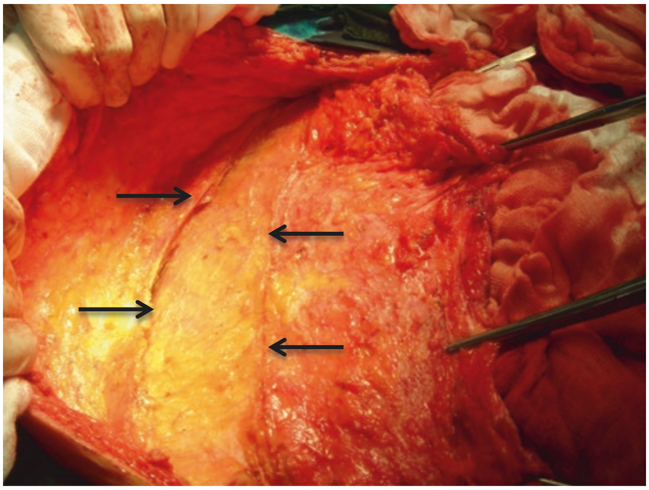

Fig. 26.2 Presentation of the separation area after sectioning the external oblique muscle and creating the interoblique space. Note the medial traction and the medial and lateral edge of the incision made (*arrows*) (Published with kind permission of © Flavio Malcher 2017. All Rights Reserved.)

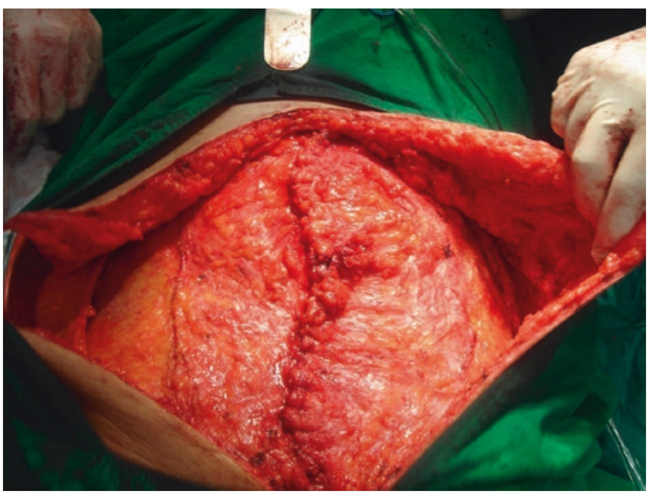

Fig. 26.3 Final appearance after the midline closure (Published with kind permission of © Flavio Malcher 2017. All Rights Reserved.)

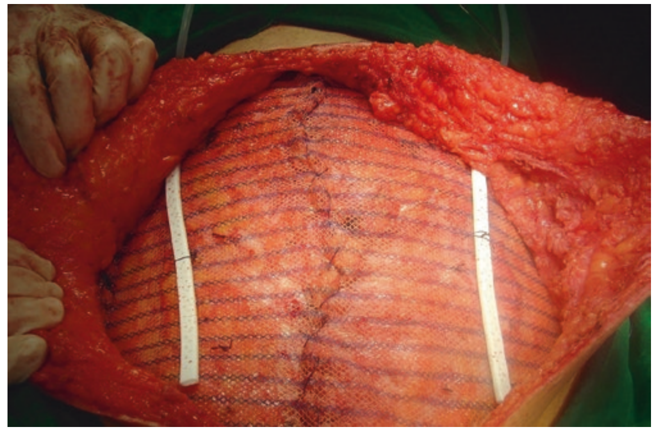

Fig. 26.4 Onlay mesh and drains (Published with kind permission of © Flavio Malcher 2017. All Rights Reserved.)

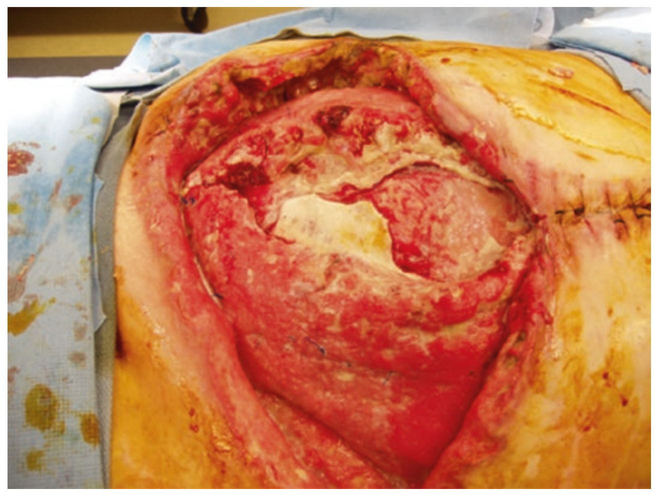

Fig. 26.5 Ischemia, necrosis, infection, and exposure of the mesh after extensive adipose-cutaneous flap (Published with kind permission of © Yuri Novitsky 2017. All Rights Reserved.)

position, covering the separation area, since this area may allow bulging due to lack of a muscular plane (Fig. 26.4). Drainage of dead space should be done with closed systems at the discretion of the surgical team [1, 3].

A slide of up to 8 cm is expected unilaterally at umbilical level and up to 3–4 cm in the epigastrium and suprapubic region.

Postoperative concerns are summarized as abdominal compartment syndrome in cases of tight closure, ischemia, and necrosis of adipose-cutaneous flaps (all care must be taken not to create excessive or non-vascularized flaps) and surgical wound infection (Fig. 26.5) [3].

A variant of this technique is the anterior separation of components with periumbilical preservation of the perforating vessels [4]. The vascularization of the subcutaneous cellular tissue and skin is made in the abdominal wall by the superior and inferior epigastric and thoracoabdominal vessels [5]. Studies have shown that periumbilical perforating vessels are fundamental for the viability of this region, which is the most sensitive to the creation of flaps [5]. Thus, an alternative for anterior separation would be to not perform the adipocutaneous flap in this region. Surgery should follow the steps described above, except for this flap in the region, performing it only in the epigastric and hypogastric regions. From there, a tunnel is made at the height of the section of the external oblique muscle for the previous separation [4].

Another alternative, aiming once again to avoid the adipose flaps, is the so-called endoscopic separation of components described by Rosen [6]. This surgery begins with a subcostal transverse incision at the level of the midclavicular line in the lateral portion of the abdomen, with the open puncture only of the external oblique muscle to allow the placement of a dissector balloon used to create the preperitoneal space in laparoscopic TEP (totally extraperitoneal) inguinal herniorrhaphy. The inflation of this device in the interoblique plane creates the separation between the muscles and allows the placement of two more 5 mm trocars for the use of hook and/or scissors to incise the "ceiling" of this operative field that is the external oblique muscle. This alternative allows a smaller slide, since all the subcutaneous cellular tissue remains fixed in the musculature but has the great advantage of decreasing the risk of seromas, ischemia, and/or necrosis in the postoperative period [6]. Adding a laparoscopic ventral hernia repair with transfascial sutures closing the midline after the endoscopic component separation can lead to a totally endoscopic procedure with restoration of the abdominal wall function in a minimally invasive way even in complex cases [7].

Another alternative is the subcutaneous anterior component separation described by Jorge Daes, where, after the lateral incision, the same dissection balloon is inflated anterior to the fascia, in the SC space. Additional trocars are positioned, and the external oblique muscle is incised, and the separation is completed in the same fashion of the traditional open technique [4].

Posterior Component Separation

The posterior separation of components can be performed in two ways: with intramuscular dissection or with release of the transverse abdominal muscle [3, 8–12].

The initial stage is the same in both techniques and in the previous separation technique it consists of releasing all the adhesions from the viscera to the anterolateral and pelvic abdominal wall and identifying the healthy medial border of the rectus abdominis muscle (Fig. 26.6) [8–12]. After this, a longitudinal incision is made at this border, and the retromuscular space is dissected between the rectus muscle and the posterior sheath, medial to the semilunar line, as traditionally in Rives's retromuscular technique (Figs. 26.7 and 26.8) [8–12]. In intramuscular dissection described by Carbonell, the aponeurosis of the internal oblique muscle is sectioned, which allows access to the plane between the internal oblique muscle and the transverse abdomen. The problem with this technique is that in this plane it passes the neurovascular (intercostal) bundle of the abdominal musculature (Fig. 26.9) and that it is sacrificed [8]. In the posterior separation with release of the transverse abdominal muscle, Novitsky described technique, about 0.5–1.0 cm medial to the semilunar line, when one can already see the nerve and vascular branches reaching the rectus abdominis, a longitudinal

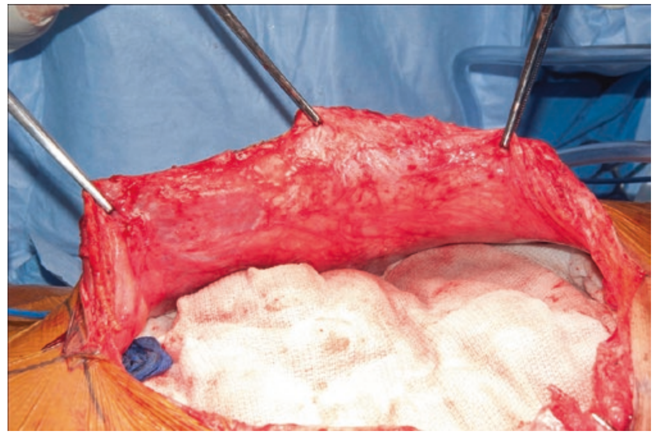

Fig. 26.6 Release of all adhesions to the abdominal wall (Published with kind permission of © Yuri Novitsky 2017. All Rights Reserved.)

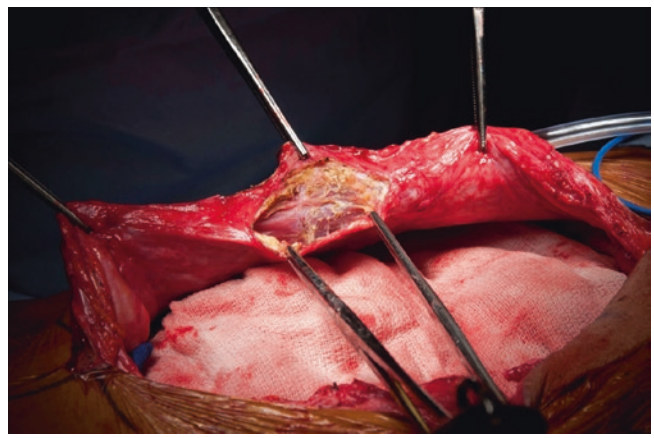

Fig. 26.7 Incision of the rectus sheath to create the retromuscular space (Published with kind permission of © Yuri Novitsky 2017. All Rights Reserved.)

Fig. 26.8 Retromuscular space creation until the semilunar line. Note the medial traction of the medial border of the posterior sheet (Published with kind permission of © Yuri Novitsky 2017. All Rights Reserved.)

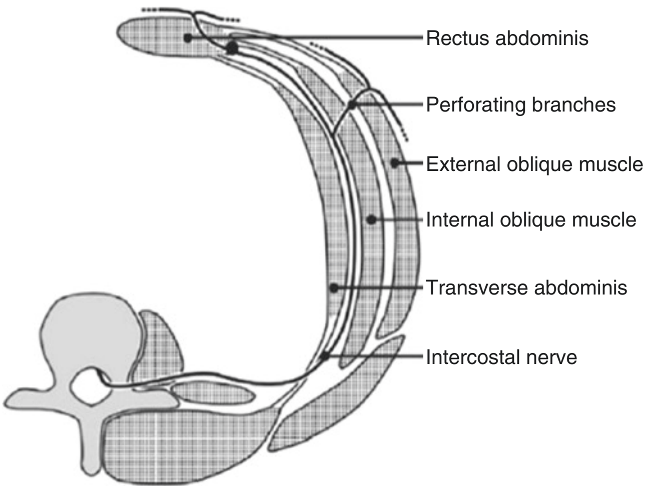

Fig. 26.9 Intercostal nerve path way between the internal oblique and transverse muscles [5]

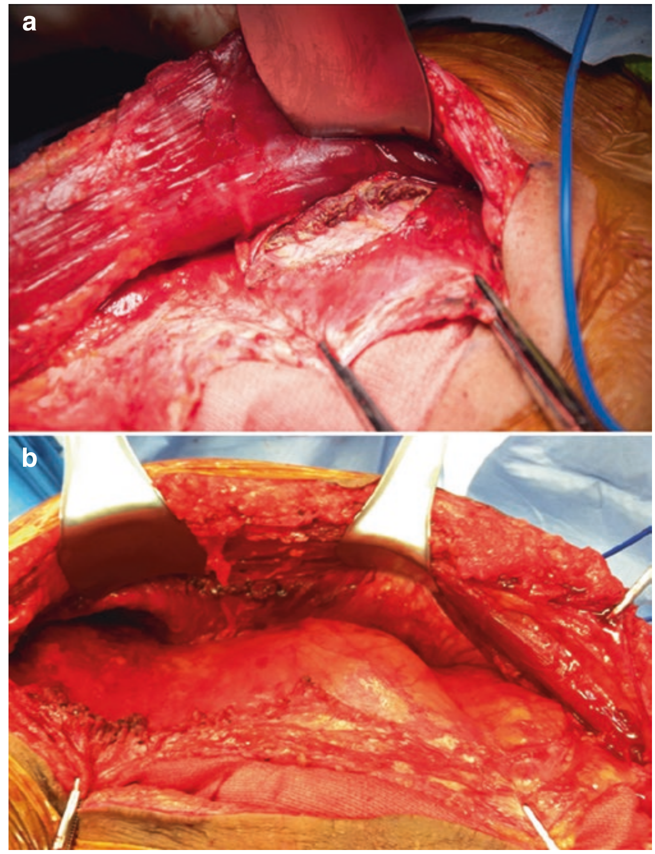

Fig. 26.10 (**a**) Posterior sheath incision with transverse muscle. (**b**) Final aspect after complete transverse release (Published with kind permission of © Yuri Novitsky 2017. All Rights Reserved.)

incision in the posterior sheath of the rectus, exposes the transverse muscle just below. This muscle is then divided along the entire border with electrocautery (Fig. 26.10a and b). From there, with blunt dissection, the space between this muscle and the fascia transversalis and peritoneum (layer is extremely thin and delicate) is accessed. That is, the transverse abdominal muscle, lateral to the semilunar line, remains attached to the internal oblique muscle, and the neurovascular bundle remains intact (Fig. 26.11). This lateral detachment can extend to the psoas, superiorly to the xiphoid and inferiorly to Cooper's ligaments [9–12]. Due to the role of the transversus abdominis muscle acting as a "corset" in the abdomen, its section allows the release of this circumferential tension and results in a satisfactory medial advancement [13].

The posterior sheaths are approached and closed (Fig. 26.12), and the mesh is placed in the sublay position, lying below the rectus abdominis muscle and above the posterior rectus sheath and transverse fascia, fixed with transfascial sutures. The area of detachment and placement of the mesh is drained with drains in a closed system, which should remain until a drainage around 50 mL in 24 h. Because it does not require cutaneous adipose detachment, the technique of posterior separation results in less formation of seromas and necrosis of tissues [12, 14, 15].

It is important not to associate previous separation with posterior separation of components, since the lateral wall of the abdomen becomes very fragile, maintained only by the internal oblique muscle and will eventually bulge outward [12–14].

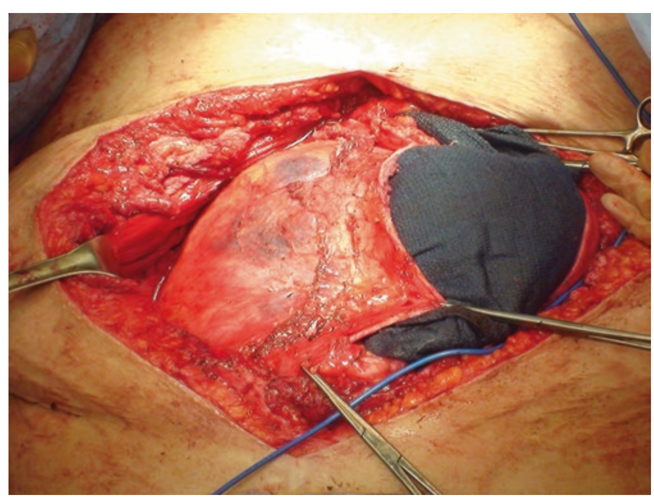

Fig. 26.11 Medial traction of the posterior sheet. Note the thin peritoneum and transversalis fascia layer (Published with kind permission of © Yuri Novitsky 2017. All Rights Reserved.)

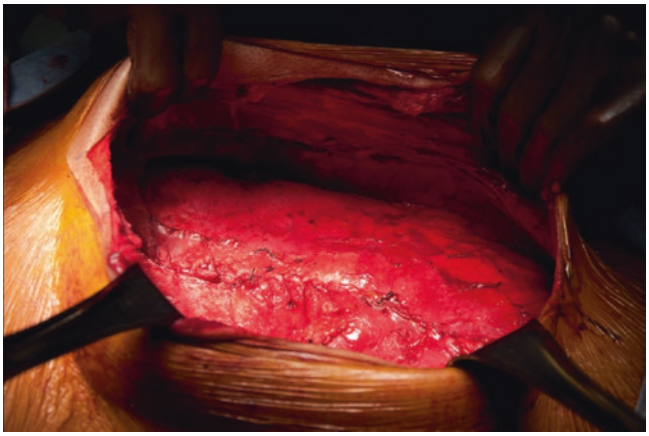

Fig. 26.12 Retromuscular plane ready for mesh placement after posterior sheet closure (Published with kind permission of © Yuri Novitsky 2017. All Rights Reserved.)

Conclusion

The separation of muscular components from the abdominal wall is an extremely useful surgical tactic in the reconstruction of this important structure, which aims at the restoration of physiology/functionality by the closure of the midline [13]. There are several alternative methods described, and the understanding of the laminar anatomy, vascularization, and innervation of the various components is fundamental for the success of the surgery [5]. It is worth remembering that the relaxation incisions are not component separations and do not allow large slides for midline alignment [1, 9].

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27 Minimally Invasive Sublay Mesh Repair of Abdominal Wall Hernias with the MILOS Technique (Mini or Less Open Sublay Repair)

Wolfgang Reinpold

Primary abdominal wall and incisional hernia repair figure among the most frequent operations in surgery. The risk of incarceration is 1–2% per year. The main cause seems to be genetically determined insufficient cross-links between the collagen molecules. Since the advent of synthetic mesh [1, 13, 14], recurrence rates could be reduced from 25–60% to below 15%.

The open sublay mesh implantation based on techniques of Jean Rives and René Stoppa and the laparoscopic intraperitoneal onlay mesh plasty (lap IPOM) are the internationally leading procedures for the treatment of incisional hernias [2–8] (Fig. 27.1a, b).

In open sublay repair, the alloplastic mesh is inserted via a large skin incision between the peritoneum/posterior rectus sheath and the abdominal wall. Today the sublay mesh position is considered most advantageous because direct contact of foreign material with bowel and other viscera is omitted. Because the intra-abdominal pressure pushes the alloplastic prosthesis against the abdominal wall, in many cases only no or minimal atraumatic fixation is necessary. The disadvantages of the procedure are the more invasive access trauma and, according to the literature, the higher infection rates.

Despite the advantages of the small skin incisions in lap IPOM surgery, the pain level is not low. A further concern is the implantation of a foreign body in the abdominal cavity, which is a risk factor for adhesion formation to the bowel and injuries to the viscera. In addition the mesh has to be fixated with many staples, clips, tacks or extensive sutures to the pain-sensitive peritoneum [6, 9–11] (Fig. 27.1a). Expensive implants with adhesion barriers on the area facing the bowel have to be used. Reoperations have shown that all IPOM prostheses can lead to massive adhesions and do not provide secure protection of the viscera. Another disadvantage of lap IPOM repair is the fact that the hernia defect is often not fully closed but only bridged by the synthetic prosthesis. This often leads to a persisting protrusion that frequently regresses slowly or not at all. Current data from the German hernia register "Herniamed" show significantly more 1 year recurrences after lap IPOM hernia repair than after open sublay operations. There are only few publications on minimally invasive sublay repair of abdominal wall hernias [15–17].

For the further reduction of complications and pain in abdominal wall hernia repair, we developed a new minimally invasive technique—the mini or less open sublay (MILOS) repair. The MILOS repair permits insertion of a large mesh in the retromuscular/preperitoneal space and anatomical reconstruction of the abdominal wall via a small transhernial incision. Using the MILOS technique major trauma to the abdominal wall and entering the abdominal cavity is avoided. The MILOS operation can be performed mini-open with light-armed laparoscopic instruments either under direct vision or endoscopically assisted. Today, in our institution all primary and incisional abdominal wall hernias are operated on with the MILOS technique. Exceptions are small hernias with a hernia defect diameter smaller than 2 cm and extremely large hernias.

The MILOS operation starts with an incision of 2–6 cm directly above the centre of the hernia defect. The abdominal wall is lifted with retractors. The preparation is carried out in "mini-open" technique under direct vision or endoscopically assisted. After transhernial mini-open preparation of an extraperitoneal space of at least 8 cm diameter and closing of the abdominal cavity, the procedure can be continued as total extraperitoneal gas endoscopy (Endoscopic TEP of the abdominal wall) using either standard trocars (Fig. 27.2) or a transhernial single port (Fig. 27.3) [12].

The MILOS technique enables the extraperitoneal preparation of the whole rectus compartment and both lateral compartments. Very large synthetic meshes can be implanted (Fig. 27.4) minimal invasively if the size of the hernia requires it. Posterior component separation can be performed

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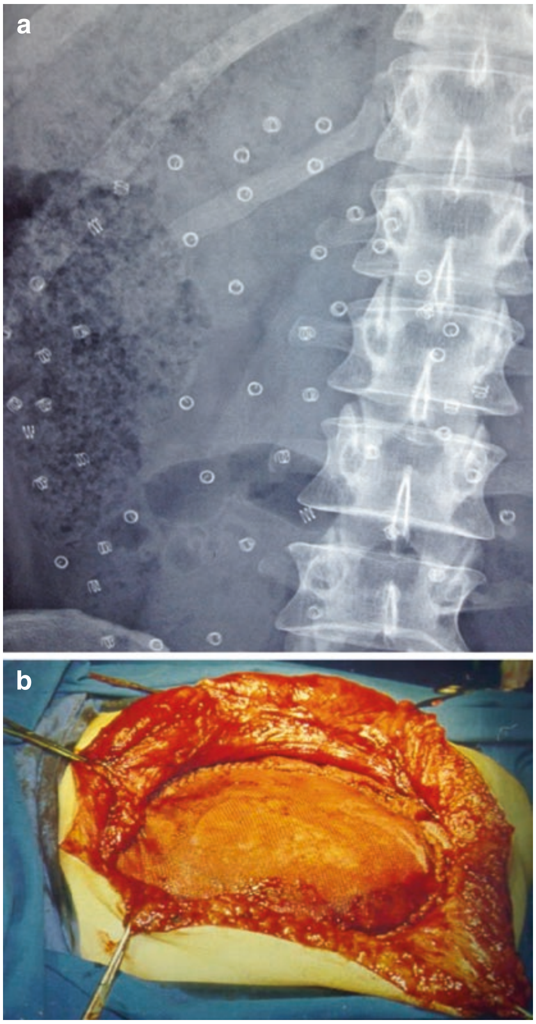


Fig. 27.1 (**a**) Extensive tack fixation of lap IPOM mesh. (**b**) Large incision in open sublay surgery (Published with kind permission of © Wolfgang Reinpold 2017. All Rights Reserved.)

Fig. 27.2 eMILOS-TEP ventral hernia repair with standard trocars (Published with kind permission of © Wolfgang Reinpold 2017. All Rights Reserved.)

Fig. 27.3 eMILOS-TEP ventral hernia repair with single port (Published with kind permission of © Wolfgang Reinpold 2017. All Rights Reserved.)

using the MILOS technique. Thus, a total sublay repair of the abdominal wall is possible.

The surgical steps of MILOS repair:

1. Small incision directly above the centre of the hernia defect (Fig. 27.5).
2. Hernia sac preparation.
3. Small incision of the peritoneum for diagnostic laparoscopy.
4. Resection of abundant peritoneum of the hernia sac.
5. Complete and precise exposure of the fascial edge of the hernia orifice.
6. While the abdominal wall is lifted with rectangular retractors (Figs. 27.6b, 27.7, and 27.8), transhernial extraperitoneal dissection around the hernia gap is performed using laparoscopic instruments armed with a light tube specifically designed by us and Wolf Company (Endotorch ™, Figs. 27.9 and 27.6a, b). Via a 4 cm incision, the Endotorch ™ allows circumferential dissection of the extraperitoneal plane with a radius of up to 20 cm from the fascial border of the hernia gap.

   Transhernial longitudinal incision of the posterior rectus sheath is performed in all quadrants to correspond with the mesh size (Figs. 27.7 and 27.8). Figure 27.10 depicts the endoscopic incision of the cranial section of the left posterior rectus sheath.
7. Closure of the abdominal cavity with absorbable suture.
8. Transhernial extraperitoneal implantation of synthetic mesh. The posterior rectus sheath is closed if possible with low tension. If the posterior rectus sheath is not

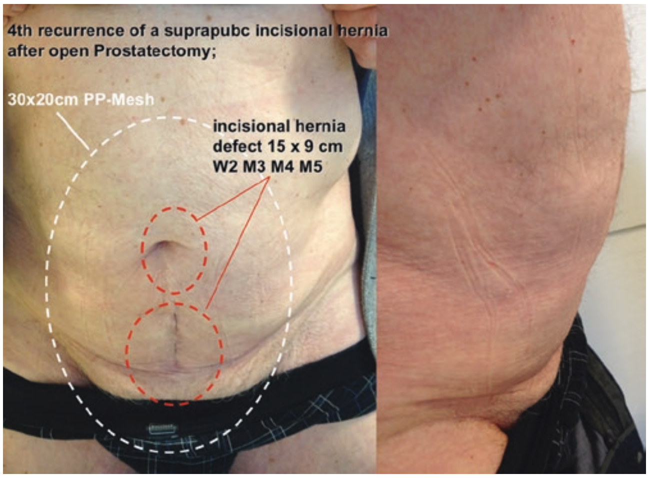


Fig. 27.4 MILOS operation of the fourth recurrence of an incisional hernia after open prostatectomy (Published with kind permission of © Wolfgang Reinpold 2017. All Rights Reserved.)

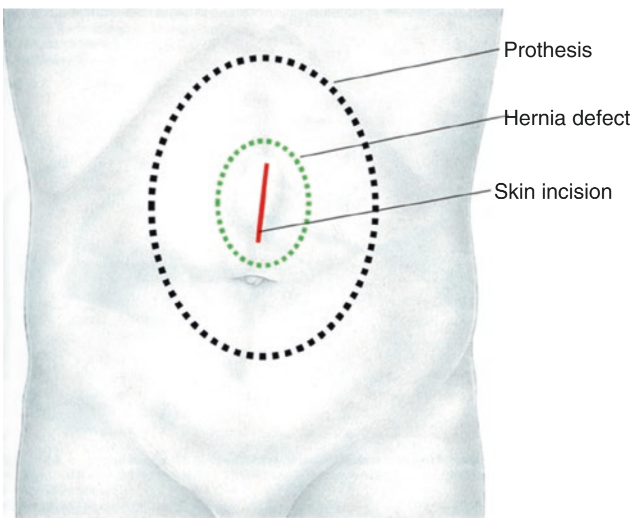


Fig. 27.5 Incision of 2–6 cm directly above the hernia defect showing synthetic mesh (*black interrupted line*). Hernia defect (*green*). Incision (*red*) (Published with kind permission of © Wolfgang Reinpold 2017. All Rights Reserved.)

approximated, the mesh is then placed in the preperitoneal space in the midline and on both sides laterally in the retromuscular position (Fig. 27.11).

9. Mesh fixation is only necessary in cases where the hernia defect cannot be closed with low tension (bridging of large hernia defects). The intra-abdominal pressure fixates the mesh between the peritoneum and supporting abdominal wall. We use large-pore standard polypropylene or polyvinylidene fluoride meshes, which cover the hernia defect with a radius of 5–25 cm (Figs. 27.12 and 27.4) according to the hernia defect size.
10. The hernia defect is closed anatomically with a running non-absorbable or long-term absorbable suture.

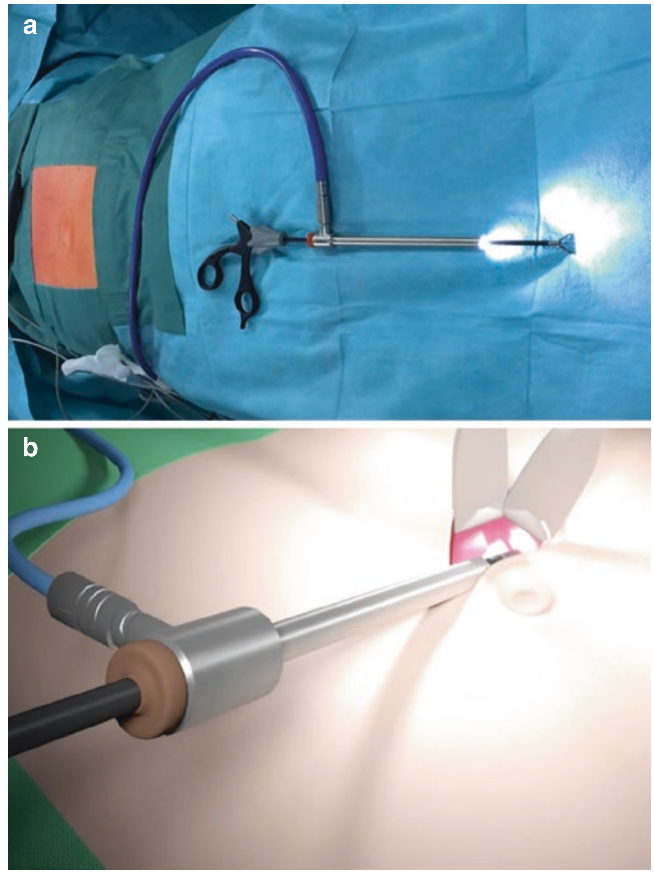


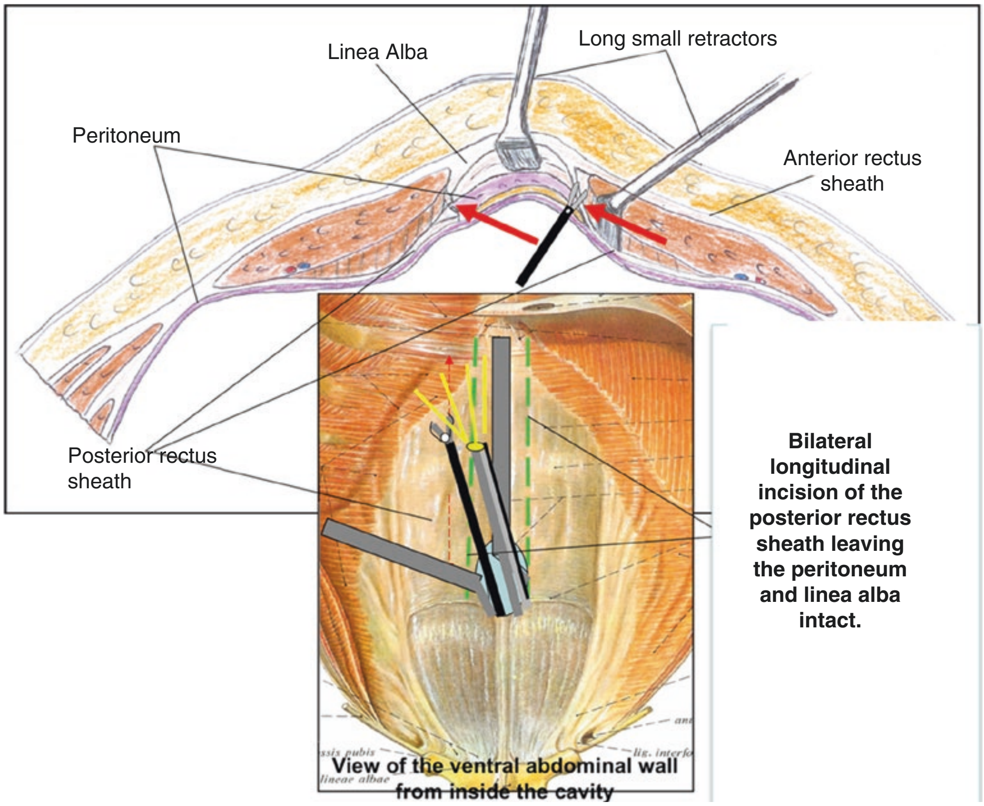
Fig. 27.6 (**a**) Endotorch TM: Light-armed 5 mm laparoscopic forceps. (**b**) Transhernial dissection with Endotorch TM and laparoscopic 5 mm instruments (Published with kind permission of © Wolfgang Reinpold 2017. All Rights Reserved.)

The MILOS technique is also appropriate for lateral abdominal wall hernias. In the case of large incisional hernias, the surgery is carried out in “less open” technique (skin incision > 6–12 cm).

MILOS Operation of Diastasis Recti

Surgical repair of symptomatic diastasis recti may be indicated, especially in cases where concomitant primary ventral or incisional hernias are present. An epigastric or infraumbilical diastasis recti can be closed with the MILOS technique without extending the incision. While the skin is elevated with a pair of adequate retractors (s.a.), MILOS dissection with light-armed endoscopic instruments is performed under direct vision or endoscopically assisted. In order to prevent an ugly cutaneous rim, the subcutaneous tissue is detached from the linea alba and medial aspect of the anterior rectus sheath (2–4 cm on every side). The diastasis recti is anatomically closed by an anterior inverting non-absorbable running suture (0). Alternatively, a mini-open or endoscopically assisted posterior inverting suture is

Fig. 27.7 Transhernial bilateral incision of the posterior rectus sheath (Published with kind permission of © Wolfgang Reinpold 2017. All Rights Reserved.)



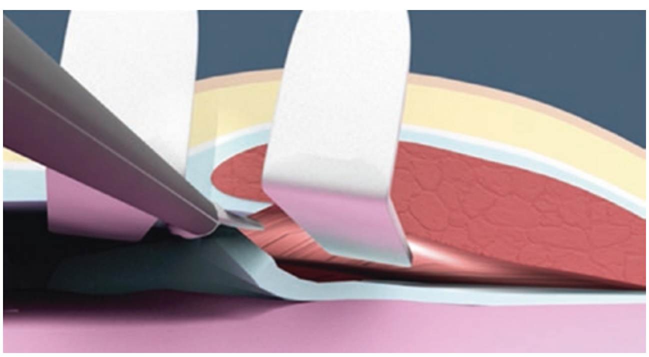


Fig. 27.8 Incision of the posterior recuts sheath 1 cm lateral of the medical border of muscle (Published with kind permission of © Wolfgang Reinpold 2017. All Rights Reserved.)

Fig. 27.9 Set of MILOS instruments (Published with kind permission of © Wolfgang Reinpold 2017. All Rights Reserved.)

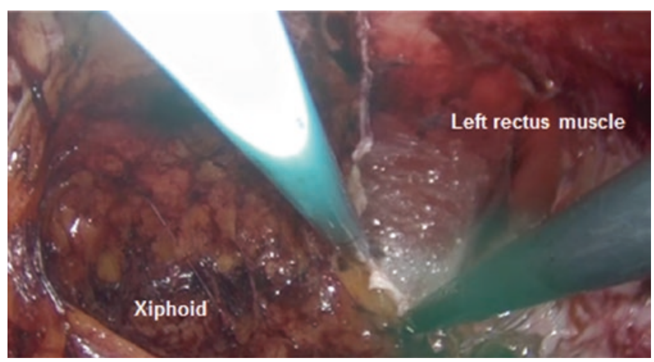


Fig. 27.10 Single port TEP: Incision of the upper left posterior rectus sheath (Published with kind permission of © Wolfgang Reinpold 2017. All Rights Reserved.)

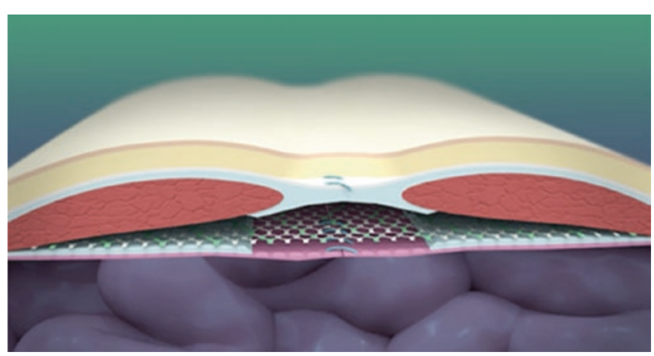


Fig. 27.11 Retromuscular/preperitoneal mesh position; hernia defect is anatomically closed (Published with kind permission of © Wolfgang Reinpold 2017. All Rights Reserved.)

Fig. 27.12 Young woman with 3 cm incisional hernia after umbilical hernia suture repair. MILOS operation with 3 mm instruments, 5 mm endoscope and 2 cm incision. Implantation of a 15 × 15 cm mesh (Published with kind permission of © Wolfgang Reinpold 2017. All Rights Reserved.)

Table 27.1 Size of hernia gap in incisional hernias (MILOS-OP; *n* = 865)

Area (in cm^2)	0–5	6–10	11–20	21–50	51–100	101–200	>200
Number	95	64	115	173	133	173	112

possible. If mesh augmentation is indicated, we prefer the insertion in the sublay position. However, onlay mesh repair is also possible [18].

From January 2010 to February 2017, we carried out 865 MILOS operations for incisional hernias and an approximately equal number of primary abdominal wall hernias. Data on all patients were documented in the "Herniamed" Register.

The hernia orifices and the size of the mesh are given in Tables 27.1 and 27.2. Postoperative consumption of analgesics was comparably low. The standard postoperative pain medication was the non-opioid metamizol 4 × 1 g orally. Additional opioids are necessary in only 10% of the cases. In the case of large incisional hernias, an epidural analgesic catheter is indispensable.

In 42 cases of large ventral and incisional hernias, the MILOS technique was combined with posterior or anterior endoscopic component separation (hybrid procedure) in order to achieve a low-tension anatomical closure of the large hernia defect after the insertion of a large extraperitoneal synthetic mesh.

The average operating time of MILOS incisional hernia repair was 102, 7 and 20 min longer than open sublay (95 min) and lap IPOM repair (82 min), respectively. Complication rates after MILOS incisional hernia repair are very low (Tables 27.3 and 27.4). There were two enterotomies of the small bowel without spillage. The bowel lesions were closed with absorbable sutures. MILOS mesh repair was performed without complications. Three superficial wound infections healed without mesh infection. A recent propensity score matching of MILOS, lap IPOM and open sublay operations of the German Herniamed registry revealed significantly fewer perioperative complications, reoperations, recurrences and chronic pain after 1 year in the MILOS cohort [19].

Table 27.2 Size of mesh in incisional hernia operations (MILOS-OP; *n* = 865)

Area (in cm^2)	0–50	51–100	101–200	>200
Number	0	10	91	764

Table 27.3 MILOS incisional hernia repair at Gross-Sand Hospital (*n* = 865) vs. all incisional hernias in the Herniamed Register (40,066)

	MILOS incisional hernia operations % (*n* = 865)	All incisional hernia operations in Herniamed Register (40,066)
No complications	95.2	86.3
Total number of complications	4.8	13.7
Surgical complications	3.2	9.6
Haemorrhage/postoperative haemorrhage	1.0	1.9
Enterotomy	0.2	0.5
Impaired wound healing	0.3	0.7
Seroma	0.9	4.1
Infection	0.3	1.2
Ileus	0.4	1.2
Revision surgeries	1.9	4.1
General complications	1.6	4.1
Mortality	0.1	0.25

Table 27.4 MILOS incisional hernia operations at Gross-Sand Hospital (*n* = 782) vs. all incisional hernia operations documented in Herniamed Register (*n* = 33.335) with complete 1 year follow-up

	MILOS incisional hernia surgeries (*n* = 782) (%)	Incisional hernias in Herniamed Register (*n* = 33.335) (%)
Recurrence after 1 year	1.8	5.8 (6.8 lap IPOM; 3.9 open sublay)
Pain at rest	3.8	9.4 (9.3 lap IPOM; 9.5 open sublay)
Chronic stress-induced pain	6.6	18.5 (18.6 lap IPOM; 17.1 open sublay)
Chronic pain requiring therapy	2.6	7.6 (7.9 lap IPOM 6.9 open sublay)

Discussion

To further improve abdominal wall hernia surgery and overcome the obvious disadvantages of the currently most widely used open sublay and lap IPOM repair, we have successfully developed the MILOS technique which is the first technique that allows the minimally invasive sublay repair of all primary and recurrent abdominal wall hernias, with the exception of giant eventrations. But even in extremely large primary and incisional ventral hernias, the principles of MILOS repair help to reduce the surgical trauma to the abdominal wall. Our experience with 865 MILOS incisional hernia operations and about the same number of primary ventral hernia MILOS repairs showed the following advantages of this novel technique:

(1) Minimally invasive extraperitoneal implantation of (large) standard synthetic meshes without traumatic mesh fixation.
(2) Closure of hernia gaps and anatomical reconstruction of the abdominal wall with protection of viable abdominal wall structures including nerves.
(3) After MILOS operations there were significantly less perioperative complications, reoperations, general complications, recurrences and chronic pain after 1 year compared to open sublay and lap IPOM repair.
(4) The MILOS technique allows minimally invasive repair of rectus diastases.
(5) The MILOS repair can be combined with endoscopic anterior and posterior component separation.
(6) Very good cosmetic results.
(7) In comparison with lap IPOM operations, there is a saving of around 1.200 € in material costs per operation.

Prospective analysis of MILOS repair in primary ventral hernias with 1 year follow-up also revealed very low complication rates.

Conclusion

The novel MILOS technique allows the minimally invasive endoscopically assisted extraperitoneal repair of primary and incisional eventrations with very low perioperative morbidity, recurrences and chronic pain after 1 year. The technique has the potential to revolutionize abdominal wall hernia repair if future studies of other working groups can reproduce our very promising results.

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Laparoscopic Incisional and Ventral Hernia Repair

28

Karl A. LeBlanc

Introduction

Approximately 350,000–500,000 ventral hernias are repaired in the USA yearly.[1] This common problem has been approached in a myriad of ways, each with various technical aspects that contribute to the long-term success or failure of the repair. Laparoscopic incisional-ventral hernia (LIVH) repair, as first described by LeBlanc in 1993 [1], builds upon the strengths of various techniques that improve overall outcome. The significant mesh overlap in the rectro-rectus repair with transfascial fixation first described by Rives and Stoppa [2, 3] is technically similar to what is achieved in LIVH repair.

Though some still commonly perform primary suture repair of ventral hernias, it has been shown to have a recurrence rate of 54–63% [4, 5]. When primary suture repair was compared to open mesh repair, open mesh repair was found to have a recurrence rate of 32% [5]. Though some advocate the recurrence rate to be equivalent between open mesh repair and LIVH [4, 6], multiple other studies show LIVH to be superior in the rate of hernia relapse [7, 8]. Three prospective trials comparing laparoscopic ventral hernia repair to open mesh repair show the recurrence rate for LIVH to be 2–3.3% in comparison to open mesh repair which is reported to be 1.1–10% in these studies [6, 8, 9]. LIVH has been generally shown to be superior to open mesh repair in postoperative wound complications, hospital length of stay, and identification of multiple defects [6–11]. Recent evidence appears to favor the laparoscopic repair for recurrent hernias [12].

The repair of incisional and ventral hernias by the laparoscopic approach should be performed by high-volume laparoscopic surgeons. The surgeon should be adept at performing the more common laparoscopic operations and also be comfortable to perform the more complex laparoscopic procedures. The assistance of another surgeon during this operation is felt to be of great benefit in most occasions. This chapter will present the concepts, technical aspects, and results of the LIVH as it is currently performed. There are variations of the technique that are presented within this chapter, as is common to every surgical procedure. This methodology is continuing to evolve and undoubtedly will be modified as newer prosthetic biomaterials and instrumentation are developed in the future. One such advancement is the laparoscopic approach to component separation. Multiple studies have shown that myofascial advancement can be achieved with minimal flap dissection and improved wound outcome [13–15].

Preoperative Evaluation

In general, if a patient is a medically appropriate candidate for open hernioplasty, then he or she could be considered a candidate for the laparoscopic approach. Patients that have significant cardiac decompensation may experience physiological abnormalities during the procedure because of the insufflation and resulting decrease in the venous return. Lower insufflation pressures may decrease the hemodynamic fluctuations [16]. Preoperative preparation of the patient is important because postoperative complications are a predictor of recurrence [17].

Generally almost all hernias are candidates for the LIVH. Even the smaller hernias in obese individuals could be repaired with this technique. Recurrence rates have been shown to be higher in obese patients [18–20]. Yet the benefits of less wound complications and the ability to identify the occult defects that are missed during an open approach make LIVH a viable option for obese patients. One may opt to use the open approach in a thin patient if it is apparent that

[1]Society of American Endoscopic and Gastrointestinal Surgeons (SAGES) website (www.sages.org).

This is an updated version of the chapter previously authored by Patrice Carter and Karl LeBlanc. Patrice Carter has not participated in the revision of the chapter for the 5th edition.

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the defect is 3 cm or less [18]. Some even recommend the avoidance of hernia surgery at all if the body mass index is greater than 50 [21]. The laparoscopic method, however, is preferred in this group of patients [22].

A very large fascial defect that nearly encompasses the entire anterior abdominal wall may pose a difficult problem. A laparoscopic approach, however, may be feasible. The decision to attempt the laparoscopic method should be based upon the experience of the surgeon, the number of prior operative procedures, mesh repairs, the type of prosthetic utilized in any previous repair(s), and the location of the potential hernia sites. However, there are currently no "hard and fast" rules about this issue. In those patients with very large defects, a reasonable option would be to commence the operation laparoscopically and convert to an open repair if that appears to be the best alternative. More often than not, this proves to be unnecessary. A probable exception to this sequence is those individuals that exhibit a "loss of domain" of the abdominal contents. In these patients, it is usually impossible to actually enter the abdomen behind the abdominal wall musculature because this musculature has been displaced so far laterally. In these cases, conversion to the open method would occur earlier rather than later. More commonly, however, prudence dictates that the entire procedure should be of the open type rather than even attempting the laparoscopic approach.

Absolute contraindications to the use of the laparoscopic method would be the presence of an acute surgical abdomen. A relative contraindication is intra-abdominal infection from any source. The use of a prosthetic biomaterial in the site of an overt infection may preclude the use of such a product. However, primary closure of the hernia defect with the assistance of a laparoscopic suture passer and biologic mesh [23] may have a role in such instances though an open repair may be indicated for gross contamination. There is data to support the use of mesh in contaminated fields, however [24]. Similarly, while the presence of incarcerated bowel does not prevent the performance of the procedure, strangulation of the bowel necessitates an open hernioplasty.

Because the most common incision of the abdomen is placed in the midline, most incisional hernias (approximately 90%) occur in the midline. When a surgeon begins to perform laparoscopic incisional hernioplasty, it is recommended that he or she should repair midline defects initially to gain confidence in use of the laparoscopic technique. Once this is accomplished, the presence of a non-midline defect or multiple defects that are not adjacent to each other should not preclude the use of laparoscopy. Appropriate positioning of the patient and accurate placement of the trocars will permit an approach to the entire abdominal cavity in most cases.

Previous intra-abdominal surgery is a major consideration in the evaluation of a patient for the laparoscopic procedure. The number and type of earlier operations will influence the choice of patient position, the method of abdominal entry, trocar placement, and the position of the monitors. This preoperative assessment will allow the surgeon to plan the operative procedure and the operative suite based upon these findings. Any previous open laparotomies will, of course, be associated with more potential for adhesion formation than procedures that were performed laparoscopically. Additionally, those patients in whom a previous incisional hernia repair included the implantation of any "unprotected" prosthesis can be expected to have dense scarring in all areas in which the material was exposed to the intra-abdominal contents. This is very uncommon today. This should not deter experienced surgeons from attempting a laparoscopic approach because as many as one-third of these patients will not have any adhesions at all. It is important to note, however, that the difficulty of the procedure can be greatly magnified because of the dissection of the tenacious scarring that is encountered involving the prosthesis and the bowel and/or omentum. The risk of enterotomy is significantly increased in such instances.

Patients in whom there is an additional need for a surgical procedure such as a cholecystectomy, fundoplication of the stomach, inguinal herniorrhaphy, or biopsy of an intra-abdominal or retroperitoneal structure are special subsets that deserve careful consideration. Hernia repairs in such cases are discussed later in this chapter.

Laparoscopic incisional hernioplasty should be individualized in patients with known ascites because it may be challenging to maintain a watertight closure that averts ascitic fluid leakage postoperatively. Moreover, these patients usually have a metabolic problem (e.g., chronic renal failure or hepatic disease) that can cause poor healing and predispose them to development of a hernia at the trocar sites. The use of the 5 mm trocars, however, has made this less problematic, and these patients may also be considered on occasion. Special trocars that do not cut into the abdominal muscle but dilate the tissues to enter through the wall of the abdomen should be used in these patients. The site of entry will be smaller than the actual trocar itself after it is removed thereby further minimizing the risk of leakage of ascitic fluid or subsequent herniation. Though the use of a prosthesis in patients with overt ascites is scarcely reported, some have achieved success with the LIVH in these patients with maximal optimization of ascites [25–27].

LIVH patients are admitted to the day surgery unit of the hospital because they can usually be considered for discharge on the day of surgery. The number and type of comorbid conditions of the patient, the type and location of the hernia(s), the presence of incarceration, and the amount of adhesiolysis required will influence the decision of timing of discharge from the hospital. Many patients now undergo laparoscopic incisional hernia repair in an ambulatory surgery center. Appropriate laboratory testing should be obtained prior to entry on the day of surgery. Patients are routinely given a preoperative dose of either a first-generation cephalosporin or a fluoroquinolone. If a patient has a history of methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin is used for preoperative prophylaxis. If there has been a prior mesh infection, it is preferable to delay surgery for 6 months, if possible, and give the antibiotic used to treat the prior mesh infection preoperatively.

Intraoperative Considerations

Patient Preparation and Positioning

LIVH repair requires the use of general anesthesia to achieve the necessary degree of relaxation and sedation. In most cases, it is not necessary to use an orogastric or nasogastric tube unless the site of initial entry is in the vicinity of the stomach. A urinary drainage catheter is not used if the procedure is felt to be short in length. If the operative site is close to the bladder (e.g., very low midline hernias or concomitant inguinal hernia repairs) or if the procedure will be prolonged, it is then advisable to insert a urinary drainage catheter; preferably a three-way catheter is used if it becomes necessary to fill the bladder for identification. Insertion of a nasogastric tube for procedures in which extensive dissection of the bowel is necessary may help to reduce the postoperative ileus that is likely to develop. It is seldom necessary to leave this tube beyond the intraoperative phase of the procedure, however.

Most patients will be placed in the supine position. Operations upon lateral defects of the abdominal wall, such as those in a subcostal or flank incision, will be facilitated by use of a semidecubitus or full decubitus position. The use of a "beanbag" or "jelly roll" in these instances will greatly aid in the positioning of the patient. The additional use of the tilt capabilities of the operating table will assist in the manipulation of the bowel during dissection. Steep Trendelenburg or reverse Trendelenburg positions will cause the abdominal contents to move into positions that will make visualization of the contents of both the hernia and the abdomen easier. The patient's arms should be tucked in close to the body to allow sufficient room to move around the patient; this is especially important if the defect is in the lower abdomen. Occasionally this may not be feasible due to the size of the individual, but, in general, it is preferred when possible. Use of a protective transparent adhesive drape to cover the skin is recommended.

Abdominal Entry

It is understood that the method of access into the abdomen should always be the safest approach possible. Many surgeons use the open type of Hassan entry because it is familiar to them. An open entry such as this could result in a poor seal around the trocar, which makes maintenance of insufflation pressures difficult resulting in inadequate visualization throughout the procedure. This method also requires the use of a larger trocar thereby posing a risk of postoperative herniation at that site despite the best attempts at fascial closure.

In the patient with a primary ventral hernia or a single small defect, a Veress needle could be considered for insufflation before introduction of the first trocar. A "safe" area for needle insertion is usually in the right upper quadrant because it is generally free of adhesions of bowel and omentum. A site in the upper midline could also be used if it can be placed far enough away from the hernia so as not to interfere with the repair of the hernia.

Another method to gain access into the abdominal cavity uses an "optical" trocar for abdominal entry. These non-bladed trocars are designed to provide visualization of each layer of the abdominal wall as the trocar passes through them. This is accomplished because the laparoscope is inserted into the trocar, and these structures are seen as the trocar is passed. This is gaining in popularity (Figs. 28.1, 28.2, and 28.3).

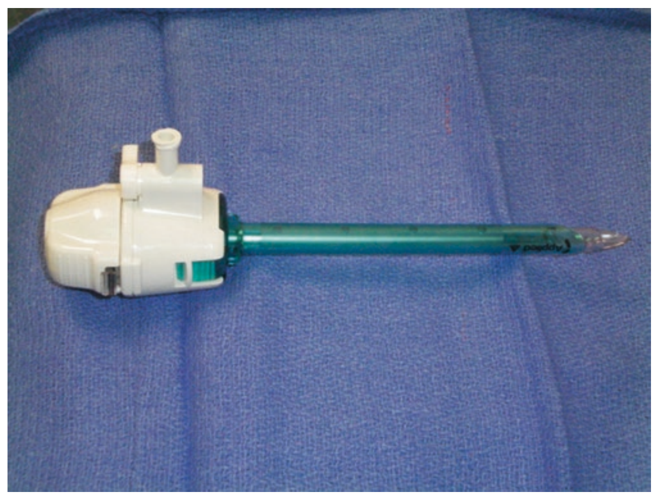

Fig. 28.1 A typical optical trocar with a clear non-cutting tip

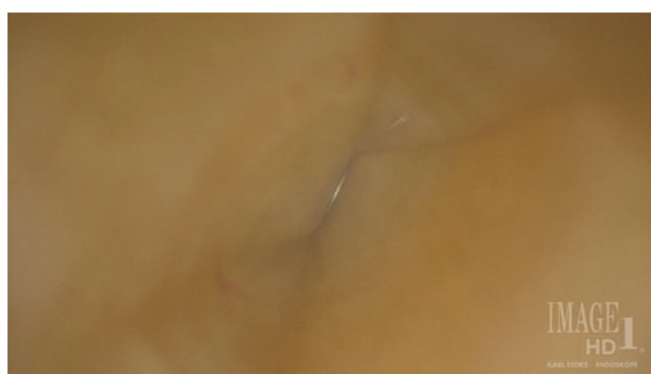

Fig. 28.2 View of subcutaneous layer through an optical trocar

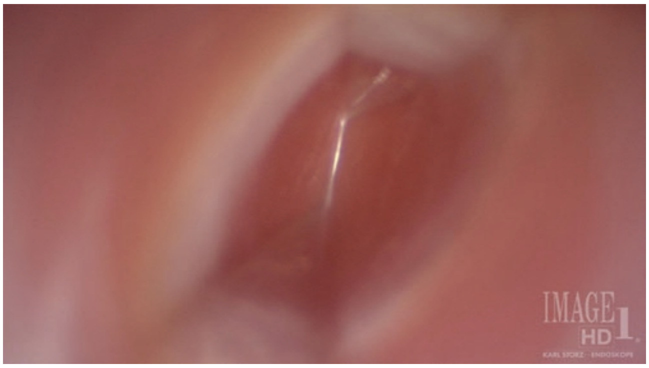

Fig. 28.3 Muscular layers seen as the optical trocar is passed into the abdomen

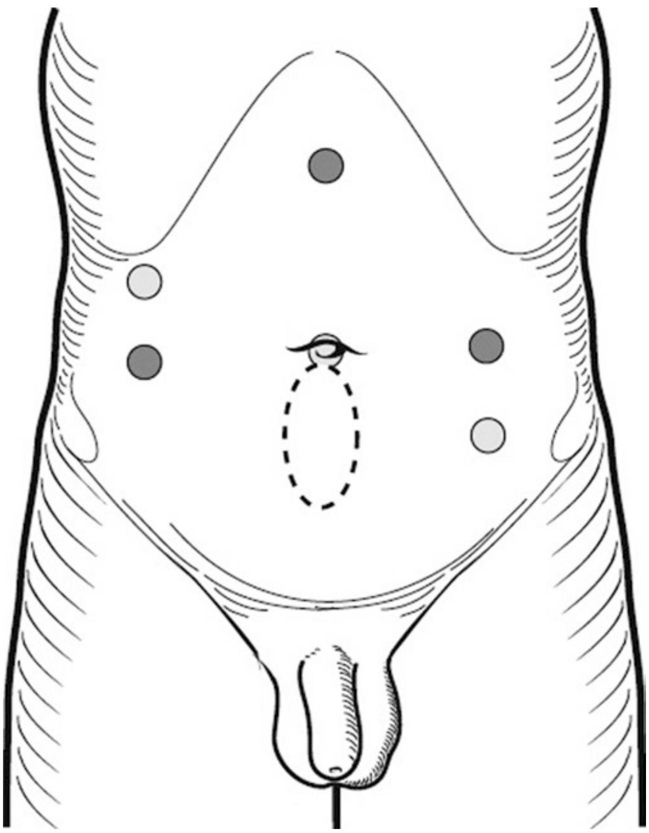

Fig. 28.4 Typical trocar positions for a lower midline hernia. The dark circles represent the location of the initial trocars. The upper midline trocar will accommodate the laparoscope. The other circles represent the location of additional trocars if these are needed to complete the procedure

In the majority of patients with an incisional hernia, the view of the abdomen is, at least partially, obscured by adhesions. To enhance visualization and to free up enough space for placement of additional trocars, blunt and/or sharp dissection of these adhesions is necessary. The primary goal after the insertion of each of the additional trocars will be placement of the final number of necessary trocars. After the insertion of each additional trocar, the laparoscope should be placed through it to inspect the abdomen. The new view that is afforded from that vantage point will identify the optimal location of the sites of the other trocars. Additionally, the collection of these different views is important to identify any bowel that may be at risk during adhesiolysis. This is extremely important because, in some cases, neither the surgeon nor the assistant will appreciate the proximity of the bowel from only the view that is available from an individual trocar position.

When determining the best locations for the trocar positions, the selection should avoid the problem of "mirror imaging" during the manipulation of the instruments from the side in direct opposition to the viewing laparoscope. This produces an image of any manipulation that is viewed from that port that is opposite the action taken. That is, a move of the laparoscopic instrument to the left will be seen as a move to the right and vice versa. Placement of the camera in the midline of the abdomen will avoid this problem (Figs. 28.4 and 28.5). An alternative is the insertion of an additional trocar on the ipsilateral side of the location of

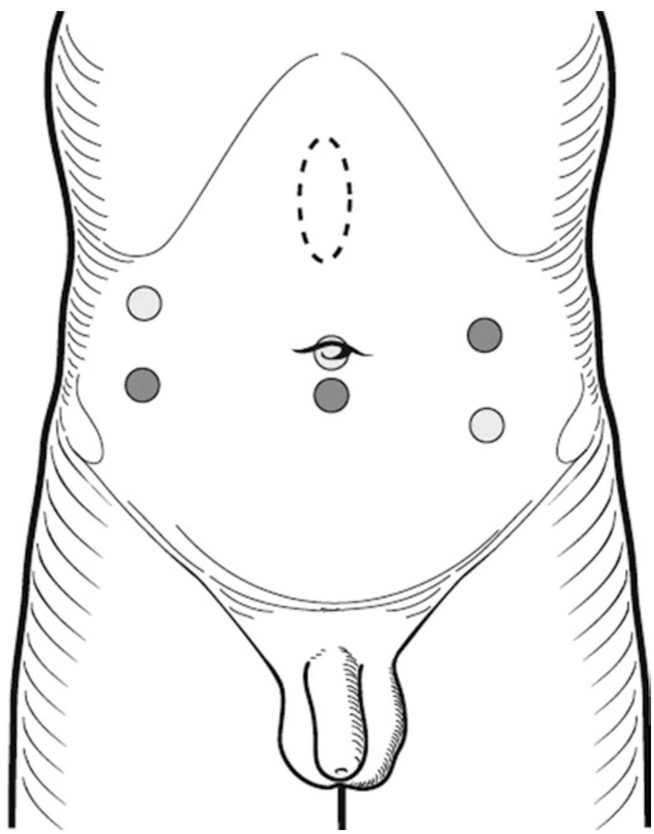

Fig. 28.5 Typical trocar positions for an upper midline hernia. The representations of the trocar sites mimic that of Fig. 28.4

the camera. With practice, many surgeons can overcome this technical problem without the use of additional trocars. Most of this difficulty can be eliminated if the assistant surgeon can use the instruments from his or her side of the patient. One should not hesitate to insert additional trocars when this problem cannot be corrected easily to ensure the safety of the operation.

Instruments

The choice of laparoscope (0, 30, or 45°) used for incisional hernia repair depends upon the familiarity of the operating team with the instruments, the planned position of the trocars, and the habitus of the patient. While the 0° laparoscope is the primary choice of this author, the majority of surgeons utilize the 30° laparoscope because it will allow good visualization of the undersurface of the abdominal wall. Additionally, one may view to the left and right of the operative field without changing the location of the optics. This is particularly beneficial in thin patients with firm muscle tone. The 45° laparoscope is seldom necessary for this operation. If the optics of the camera and system are optimal, the 5 mm laparoscopes will perform as well as do the 10 mm ones. A benefit of the smaller scopes is that they utilize smaller trocars, which diminish postoperative pain and minimize the risk of herniation at the site of the trocar.

The most significant and potentially fatal complication of laparoscopic incisional herniorrhaphy is an injury to the bowel. This will occur during the dissection of the adhesions that are frequently encountered. The method of dissection is critically important in order to minimize the risk of injury to the intestine. If the adhesions encountered are few and rather filmy, one may use the scissors with the additional application of electrocautery. This should only be done if there is absolute certainty that there is no bowel adjacent to the area that will be affected by the lateral extension of the electrocautery burn. The transection of the falciform ligament is an example of this situation. In most patients, dissection of omentum and/or bowel from the abdominal wall will be required. Multiple devices are available that limit the lateral spread of heat. Though these devices may be used for adhesiolysis, this should not allow the surgeon to become complacent in the use of an energy source within the abdominal cavity. The use of any type of an energy source can result in an injury to the intestine if used improperly. It is recommended that if the intestine is densely adherent to the abdominal wall or to a mesh from a prior failed repair, the use of scissors without cautery should be preferred. It is sometimes felt that the open procedure has less risk of intestinal injury compared to the laparoscopic approach because of the dissection of the intestine. Research does not show this to be true [28]. The risk of bowel injury is generally 1.78% and cannot be absolutely avoided. One needs to ensure that the dissection proceeds in as safe a manner as surgically feasible.

Not uncommonly, the hernia contents are known to be incarcerated preoperatively and cannot be reduced with dissection and traction. In such cases, the fascial defect must be enlarged to allow reduction of the involved organs. Electrocautery scissors are used if the fascia is thick. Sometimes the ultrasonic dissector will be sufficient to cut the tissue, but this is infrequent. Generally, a 2 or 3 cm incision into the fascia will suffice. The size of this incision is not that important because the resulting defect size will be covered by the prosthesis.

Prosthetic Biomaterials

There are currently many different products that are available for the repair of incisional hernias. The unprotected polypropylene and polyester biomaterials are prone to adhesion formation and pose a significant risk of fistulization. Most surgeons will choose a biomaterial that has been manufactured with some method to shield the intestine from coming into direct contact with the base material. There are expanded polytetrafluoroethylene products or composites of these materials available as well. These products are described in detail in Chap. 7.

Adhesiolysis and Identification of the Fascial Defect(s)

Before insertion of the prosthesis, the entire fascial defect(s) must be uncovered (Fig. 28.6). This usually requires removal of all the adhesions (Fig. 28.7) within the abdomen especially those attached to the anterior wall. It is best to dissect all of the adhesions that may potentially interfere with the appropriate positioning of the prosthetic material. It is also important to ensure that the parietal surface of any prosthetic material is in direct contact with the fascia and not with adipose tissue or omentum. Any fatty tissue that is interposed between the abdominal fascia and the prosthesis will inhibit the appropriate ingrowth of tissue and subsequent incorporation of the biomaterial. A technical problem can develop if all of the adhesions are not adequately removed in the area of the final location of the prosthesis. If it becomes apparent that the adhesions are inhibiting the final attachment of the mesh, then the procedure must be temporarily delayed to

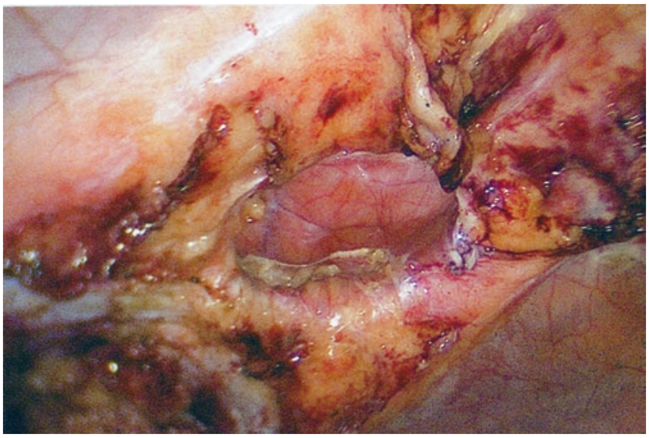

Fig. 28.6 Laparoscopic view of fully dissected incisional hernia (note the preperitoneal fat has been removed to expose the fascia)

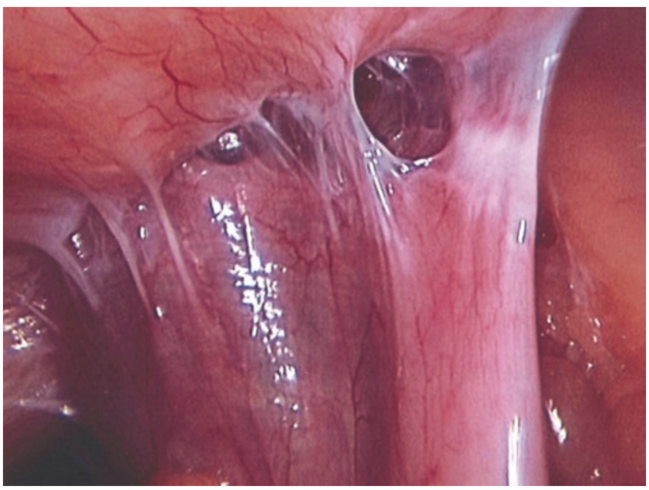

Fig. 28.7 Typical adhesions of the small intestine that require dissection from the abdominal wall

allow for the additional adhesiolysis. This process can be particularly difficult once the prosthesis is partly attached to the abdominal wall, hampering visualization and further dissection. With this in mind, it should be noted that it is particularly important to dissect the falciform ligament or lower abdominal preperitoneal fat to expose the fascia adequately.

Dissection of the hernia sac is difficult and can result in bleeding while not producing any appreciable benefits for the patient. Therefore, it is not necessary to remove it. Some surgeons apply electrocautery or argon beam to the site of the peritoneal lining of the hernia sac in an effort to obliterate it and thereby reduce seroma formation. It is not known whether this has the desired effect. Closure of the fascial defect is not routinely performed, though some promote routine fascial closure during LIVH [23]. There is a growing opinion that this should be done when feasible, although this will be limited by the size of the defect. The security of the hernioplasty depends upon an adequate overlap of the fascial defect by the prosthesis and adequate patch fixation. It does appear that closure of the defect will reduce seroma rates in most but not all reported series [29–32]. Others have reported either no benefit or an increase in adverse outcomes with defect closure [33, 34].

It is essential that the measurement of the hernia defect is accurate. This size of the defect will determine the size of the prosthetic. If this measurement is performed with the abdomen fully insufflated, the resulting size determination will be artifactually larger than the proper measurement. The size of the defect must be measured with the insufflation pressure reduced from the working amount of 14–16 mm Hg to near zero. Reducing the pressure prevents the inflation artifact that occurs because this measurement is done on the external surface of the abdominal wall rather than on the interior surface. After desufflation, the defect is outlined on the skin over the abdomen with a skin-marking pencil (Fig. 28.8). If the choice of prosthetic size is made based on the measurement in the insufflated position, it is likely that the prosthesis will be much larger than is required. Use of that material can be exceedingly difficult because some of the trocar sites can be covered with the biomaterial. One must then trim the patch as it lies within the abdomen, which is cumbersome. The entire circumference of the defect should be identified to ascertain its maximum dimensions. To ensure adequate coverage with the prosthesis, a minimum of 5 cm is added to the maximum measurements in all directions. In other words, if the defect were 7 × 12 cm, the minimum patch size would be 17 × 22 cm. Current thought is that a 5 cm overlap is ideal [35]. Recent evidence suggests that using overlap alone is insufficient to properly size the mesh [36]. In this study, the mesh-to-defect (M/D) ratio was used to size the mesh. It was determined that a M/D ratio of 13 or larger resulted in a recurrence rate of 4% with a <5 cm mesh overlap and a 1% recurrence rate if the overlap was 5 cm or greater. The authors of this paper, that with larger hernias, the laparoscopic approach may be insufficient to cover the defect appropriately.

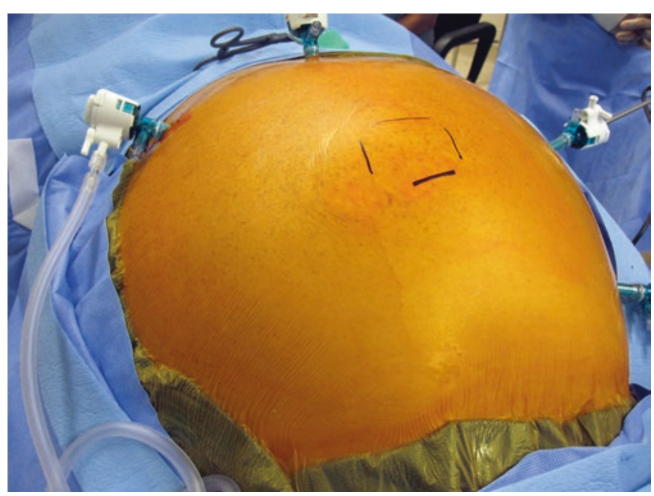

Fig. 28.8 Skin marks placed to identify the edges of the fascial defect

The choice of the prosthesis will be made based on the available sizes that are manufactured. In many cases, this will provide coverage in excess of 5 cm requirements. This is felt to be advantageous. If the patient is morbidly obese, it is preferred that a larger overlap disperses the intra-abdominal pressure over a larger surface area to diminish the risk of recurrence. We also believe that it is preferable to cover the entire length of the original incision even though only a portion may have an actual hernia defect. This will avoid the future occurrence of a hernia either above or below the actual repair of the original hernia. Several different techniques may be used before patch insertion to ensure that the prosthesis will be oriented properly and cover the defect adequately. One approach is to tie ePTFE sutures (CV-0) at either side of the midpoint of the long axis of the patch and mark both sides of the midpoint of its short axis with a marking pencil prior to its insertion into the abdominal cavity [37]. It is important to mark both sides of the midpoints of the prosthesis (Figs. 28.9 and 28.10). This can be done with a marking pencil if this is possible to do so; if the biomaterial does not allow this, then one may mark these points with sutures. Once the prosthetic is inserted, the surgeon will need to visualize both surfaces of the biomaterial to assure the correct axial orientation along the abdominal wall. Some surgeons mark the short axis by placement of a contrastingly colored nonabsorbable suture, such as Prolene® or Ethibond®. Others place four or more sutures at the corners or periphery of the patches prior to insertion. The more sutures that are placed into the prosthesis prior to insertion, the more likely that there will be a tangle of suture material that can be cumbersome to separate and pull through the abdominal wall. The use of sutures in this repair

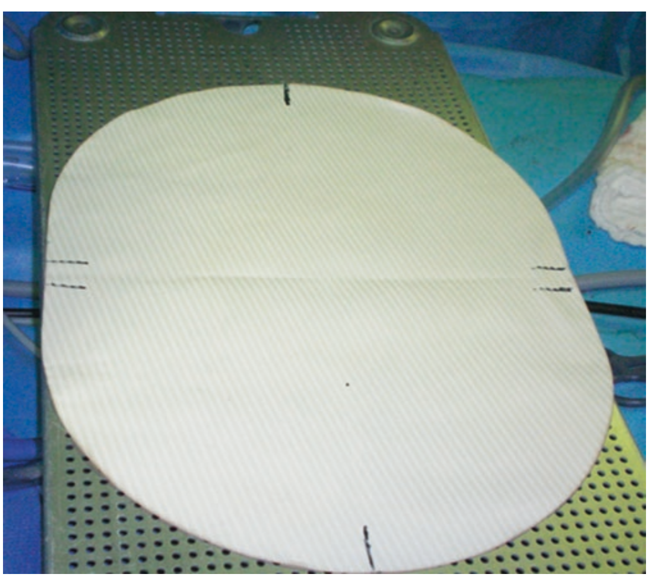

Fig. 28.9 Marks place to identify the midpoints of the parietal surface of DualMesh Plus

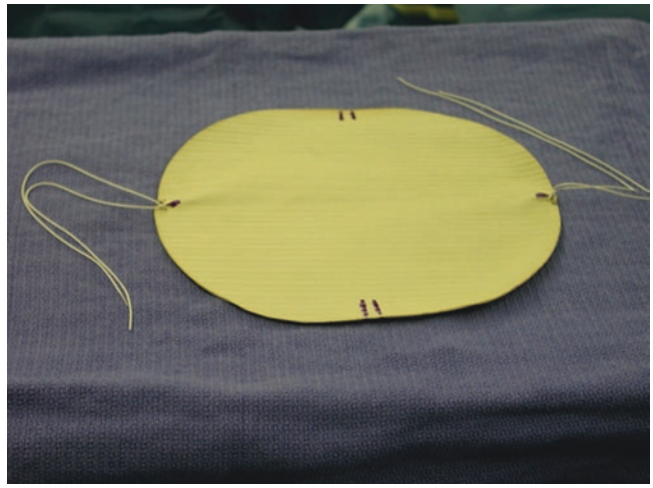

Fig. 28.10 Initial two ePTFE sutures placed at the midpoints of the long axis of the prosthesis

continues to be discussed. Some surgeons do not believe that transfascial sutures are necessary [38], but others feel that this is absolutely indicated [37, 39, 40]. Data on prostheses and the final decision on the use of sutures will continue to evolve. It seems that if the overlap is 5 cm or greater, then transfascial sutures can be omitted [41]. However, many surgeons, the author included, believe that the benefit of the sutures out ways the risk of the few patients that may develop pain postoperatively. In certain instances, such as hernias distant to bony prominences, tacking alone may be sufficient [42].

The patch with any attached sutures is rolled or folded for introduction into the abdomen. The method of folding the patch is simplest if the material is folded into sequential halves after the prior fold [37]. As shown in Figs. 28.10, 28.11, 28.12, 28.13, and 28.14, the sutures are placed into the first fold, and the subsequent folds result in a smaller size of the biomaterial. Early in the learning curve, it is suggested that 10 or 12 mm ports be utilized to insert the patches. As experience is acquired, one will find that the use of only 5 mm trocars will often suffice. Some of the prostheses that are available today, such as the polypropylene- or polyester-based biomaterials, require the use of the larger trocars for their insertion into the abdominal cavity. With those products that can be compressed adequately, such as DualMesh® Plus (which is 50% air by volume), one can pull them into the abdomen with the use of the 5 mm ports. In these instances, the skin incision at the site of patch introduction should be made larger than that which is necessary for placement of the trocar itself (typically 7–8 mm). Generally, particularly for the larger patches, a grasping instrument is passed through a trocar on the opposite side of the abdomen, which is then passed outward through a trocar on the other side. The trocar through which the instrument is exited is then removed

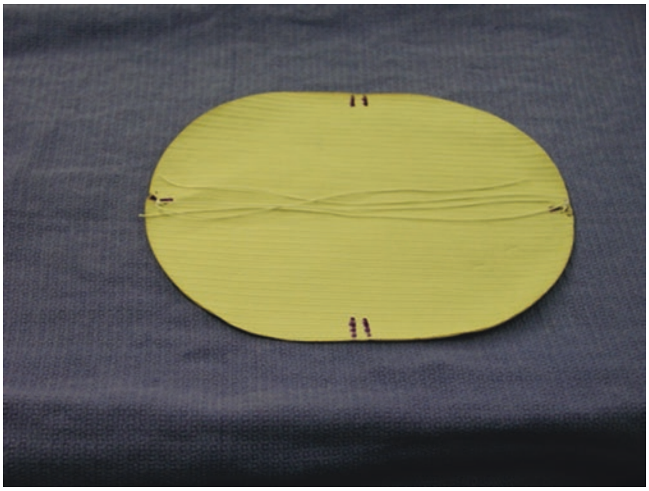

Fig. 28.11 These initial sutures are placed on the parietal surface prior to folding the mesh

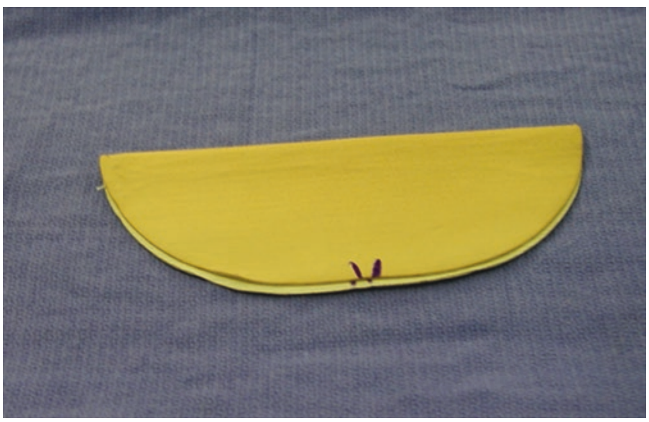

Fig. 28.12 The first fold of the prosthesis encloses these sutures (note that the edges of the mesh are offset from each other to make it easier to grasp them intraperitoneally after introduction)

Fig. 28.13 The second fold of the mesh is shown

(Fig. 28.15). The tightly rolled and/or twisted biomaterial will be grasped by the instrument and pulled into the abdominal cavity (Figs. 28.16 and 28.17). The assistant surgeon can assist this maneuver by maintaining the "twist" of the patch as it is introduced. The pliability of the abdominal wall musculature will accommodate the insertion of even the largest

Fig. 28.14 After the folding, the product will be tightly rolled to ease introduction

Fig. 28.15 A grasper is put through a trocar, which is then removed. The instrument will grasp the mesh and then pull it into the abdominal cavity

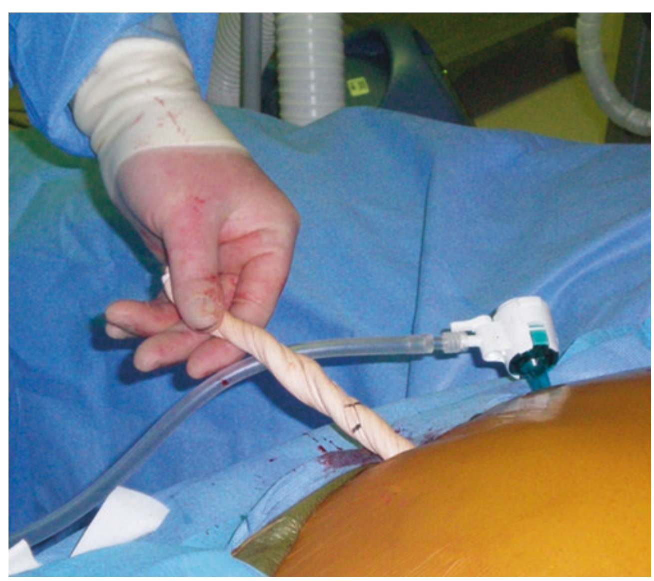

Fig. 28.16 External view of the mesh as it is pulled into the abdomen

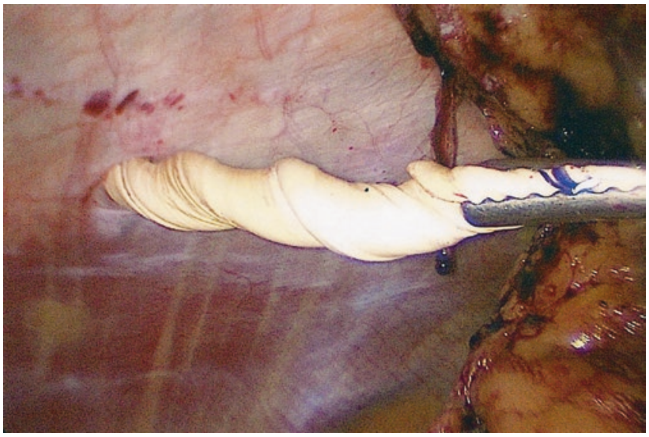

Fig. 28.17 Laparoscopic view of the mesh as it is pulled into the abdomen

Fig. 28.18 Suture passing instrument has been introduced to grasp one of the initial two sutures

of the ePTFE patches available (24 × 36 cm). This maneuver can, of course, be duplicated with other meshes and the larger trocars. If the larger trocars are used, however, the smaller patches can frequently be inserted directly through the trocar rather than by the above method.

Placement of the Prosthesis

After insertion, the patch must be returned to its original flattened shape. The biomaterial is placed onto the viscera whereupon the surgeon and the assistant will then assist each other in the manipulation of the biomaterial to completely flatten it as much as is feasible. This will facilitate the fixation of the material to the abdominal wall. If this is not possible, it may be easier to unroll the prosthesis after one or both of the initial sutures have been passed through the abdominal wall. It is preferable, however, to do this only if the above method fails because the maneuverability of the prosthesis will be impaired once the fixation is initiated.

If a single central suture is used, this will be drawn through the abdominal wall in the center of the fascial defect. If one has chosen to use only two initially placed sutures, these are now pulled through the entire abdominal wall with use of a sharp suture passing instrument inserted through a small skin incision (Fig. 28.18). There are several different devices that are available for this purpose. These two sutures are placed along the long axis of the defect taking care to center the prosthesis over the defect. If necessary, the laparoscope can be placed into another port to confirm that it is centered with the necessary 5 cm minimum overlap and drawn tautly. If these two facts cannot be confirmed, then one or both of these sutures must be repositioned. This is critical because "mesh shift" has been identified as a source or recurrence [43]. Once the optimal position is achieved, the sutures are tied. Even in large patients, the knots can usually be pulled down to the level of the fascia. It is important to make sure that these and all the subsequent sutures are tied sufficiently tight to pull them to the fascia without any laxity. It is sometimes necessary to enlarge the skin incision slightly to allow the surgeon enough room to properly tie the suture down to the fascial level. An additional method of confirmation will be simply to examine each suture laparoscopically once tied or at the completion of the entire procedure. If the suture is loose, then it must be cut and replaced.

The next step will be to confirm that the correct orientation along the short axis of the patch is correct. The surgeon and the assistant will grasp the previously marked midpoints on either side of the biomaterial. The material is then positioned over the desired final location. Either the assistant or the surgeon then uses a fixation device to attach the midpoint of one side placing only one or two tacks at that time. The tacking instrument is then given to the other surgeon, and the unattached midpoint is likewise secured with one or two tacks. Inspection of the position of the biomaterial is again performed usually by moving the laparoscope to one of the other trocars to visualize the position of the biomaterial from different angles before the insertion of the additional tacks and sutures that will permanently secure the patch. After this inspection, the tacks are deployed along the periphery of the prosthesis by inserting them 2–4 mm from the edge of the patch, 1–1.5 cm apart (Fig. 28.19) [37]. Multiple tackers are available for use in both permanent and absorbable configurations (see Chap. 7).

Several authors have identified the need to place transfascial sutures to ensure adequate fixation of the biomaterial [37, 39, 44, 45]. It is generally believed that the insertion of the tacks is merely an initial step and serves mainly to approximate the prosthesis to the abdominal wall to ensure adequate tissue ingrowth. In one study, the rate of hernia recurrence without the use of these transfascial sutures

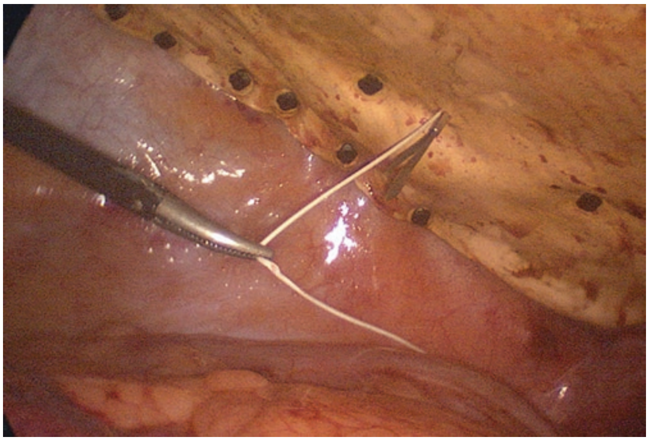

Fig. 28.19 The laparoscopic instrument has grasped an additional suture from the suture passing instrument

Fig. 28.20 External view of the suture passer retrieving a suture from the abdomen

resulted in a recurrence of 13%, while there were no recurrences seen in those patients that had the use of sutures [44]. A recent meta-analysis showed that the degree of overlap can influence the need for transfascial sutures. Generally, in some hernioplasties with a 5 cm overlap, transfascial sutures may not be needed [41]. Tacking is followed by placement of nonabsorbable sutures (e.g., ePTFE) of size 0. These sutures will be placed through all musculofascial layers of the abdominal wall and tied above the fascia in a manner similar to the tying of the initial two sutures. This method is reported to be preferred to minimize recurrence risk [18]. During the insertion of the sutures, one should avoid clamping of any portion of the suture material that will remain within the patient. If this occurs, the suture will be permanently weakened and may fracture at that site which can lead to failure of the suture and a recurrence of the hernia.

Using the view of the laparoscope, the planned sites of suture placement are marked at intervals of 5–8 cm apart. A mark is made with the skin-marking pen at these points whereupon a no.11 scalpel blade is used to make a 1–2 mm skin incision at each of these points. Then at each site a suture is passed through the skin incision with one of the many fascial closure or suture passing devices that are available (Fig. 28.20). The suture passer pierces the patch at the appropriate place. The assistant (from the opposite side of the abdomen) retrieves the suture with a grasping instrument, and the suture is released (Fig. 28.21). The device is now withdrawn into the subcutaneous tissue and reinserted through the patch approximately 1 cm from the previous puncture site. The previously inserted suture is retrieved from the assistant and withdrawn from the abdomen onto the skin (Fig. 28.22). The two tails of the suture are grasped with a hemostat, and the suture is cut with sufficient length to allow for the tying of the suture. These maneuvers are

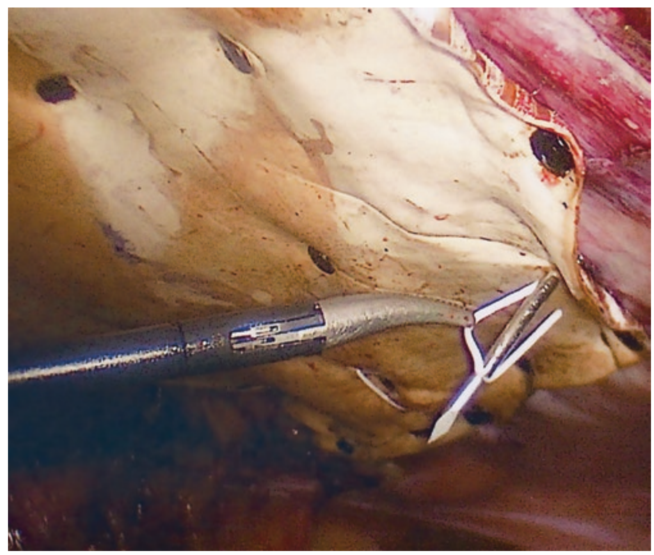

Fig. 28.21 Another view of the “hand-off” of a suture

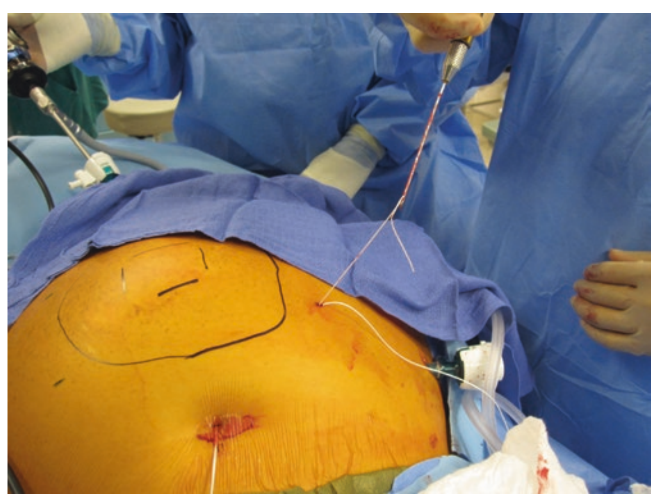

Fig. 28.22 Another view of suture retrieval

repeated then along the entire edge of the patch (Fig. 28.23). Once the sutures are tied, the patch should lay flat and obliterate the fascial defect. A final examination of the prosthetic is performed to insure that all sutures are tight and that all edges of the patch are secured (Fig. 28.24). Any laxity of the sutures will require that these be replaced with others that provide sufficient fixation without looseness.

When the sutures are tied down, a dimple of the skin may develop at the site of the incision where the suture has been passed. This is caused by the fixation of the subcutaneous tissue that may have been grasped by the knots of the suture. This dimple can be removed by placing a fine pointed hemostat into the incision to lift the skin away from the suture (Fig. 28.25). It is important to inspect the abdominal wall with the abdomen fully insufflated after the completion of the suture fixation so that any dimples are removed. If this is not done, the cosmetic result will be unacceptable to the patient.

Rather than placing the additional sutures as described above, in some centers, an additional row of fasteners is placed near the fascial edges. The result is two concentric rows of tacks that secure the prosthesis. This "double-crown" technique is popular in some centers [38]. Current follow-up data appears to be favorable, but longer-term data will be necessary to verify its effectiveness.

After the removal of the trocars and closure of the skin incisions, an abdominal binder is frequently used and left in place for at least 72 h. It is preferred, however, if the use of this binder could continue for 4–6 weeks. It is believed that the use of this binder aids in the prevention of a postoperative seroma at the site of the hernia. It assists in the management of postoperative pain and does not appear to affect the respiratory effort of the patient.

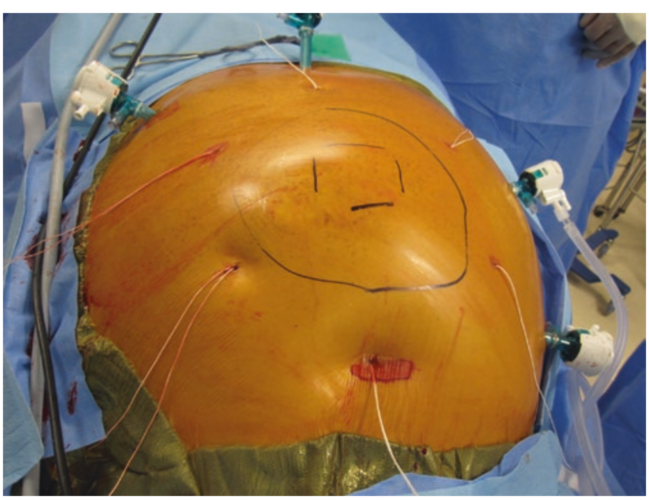

Fig. 28.23 Completed passage of the transfascial sutures

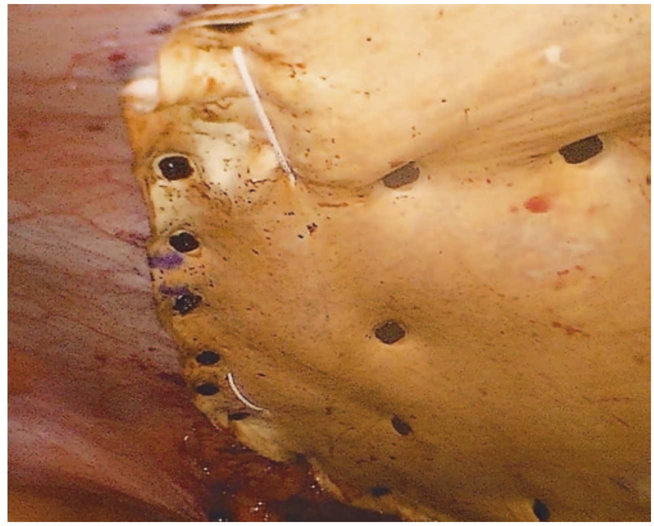

Fig. 28.24 Laparoscopic view of the completed fixation of the prosthesis with sutures and fasteners

Fig. 28.25 Use of a hemostat to release the subcutaneous tissue from the suture to remove skin puckering

Immediate Postoperative Considerations

Approximately 50% of these patients can be discharged on the same day of surgery. Generally, this will be the patient that has a single defect, a hernia dimension of less than 25 cm^2 [1], few adhesions, and no incarcerated contents of the hernia. The average length of stay is 1–2 days [6, 7, 11]. Patients can consume liquids the day of surgery and resume taking any regular medications immediately. Oral and parenteral sedatives are given as needed. Postoperatively, many patients will experience some degree of abdominal distension, which is usually proportional to the extent of adhesiolysis and the extent of bowel involvement. However, most patients can resume a regular diet the day after the operation. Occasionally, some patients will experience prolongation of the ileus. This should be managed by the usual methods, which would include a nasogastric tube when necessary.

Pain may be used as the guide to determine when patients can resume their normal activities. They are allowed to shower the next day. Patients may return to their daily activities, including work, as soon as they can do so without marked pain. The majority of patients are able to drive within a week and resume job-related activities in 7–14 days. Most surgeons do not restrict the activities of these patients but allow the level of pain to dictate the increase in the level of activity.

After removal of the binder, many patients will note a firm bulge at the hernia site. The bulge may represent a seroma in the first few weeks, but subsequently this area represents the cicatricial event that occurs in the majority of these patients. Seroma formation is a common occurrence after LIVH. However, it is rarely, if ever, necessary to aspirate these fluid collections, as they will generally resolve without intervention. Aspiration will also expose the patient to a risk of the introduction of infection into the seroma.

Fig. 28.26 Postoperative appearance of erythema that is not abnormal and noninfected

Late Postoperative Considerations

In most patients with the cicatricial "bulge" and/or seroma at the hernia site, resolution will be noted within 2 months, depending on the size of the hernia and its contents. Occasionally the skin of the abdominal wall that overlaid the hernia will become erythematous within 4–6 days postoperatively, usually in association with a distinct surface firmness but with little tenderness and without the presence of fever, chills, or leukocytosis (Fig. 28.26). This situation, which is seen in approximately 5–7% of patients, can persist for a few weeks and can be most unsettling. This is believed to be the result of resorption of fatty tissue or the hernia sac that was left in place during the initial operation. This appears to be particularly common after the repair of hernias that had minimal soft tissue between the skin and peritoneal sac and/or a significant amount of incarcerated tissue. No treatment is necessary unless there is a strong suspicion of infection.

Usually within 2–3 months, the abdominal wall will have completed its postoperative changes (Figs. 28.27 and 28.28). Infrequently, an apparent seroma can still be felt. Ultrasonography or CT scan could evaluate this finding if there is a concern regarding the possibility of a recurrence of the hernia.

In less than 2% of patients, prolonged pain (>3 months) at the site of the transfascial sutures will occur [46]. Usually this can be treated effectively with nonsteroidal anti-inflammatory drugs or direct injections of xylocaine or other local anesthetic [47]. If this problem persists despite these maneuvers, the surgeon might consider performing a laparoscopic examination to inspect the patch, tacks, and sutures. This is rarely necessary, but occasionally transection of the offending suture will be necessary to effect a permanent relief of these symptoms.

Fig. 28.27 Preoperative appearance of a large incisional hernia following a trauma laparotomy

Hernioplasty of Infrequent Defects

The majority of incisional and ventral hernias will occur in the midline of the abdomen. One will encounter other hernias that offer a particular challenge whether repaired by the open or the laparoscopic technique. One such hernia is that which lies very high in the midline, perhaps at the exit site of a mediastinal drainage tube used for open-heart surgery.

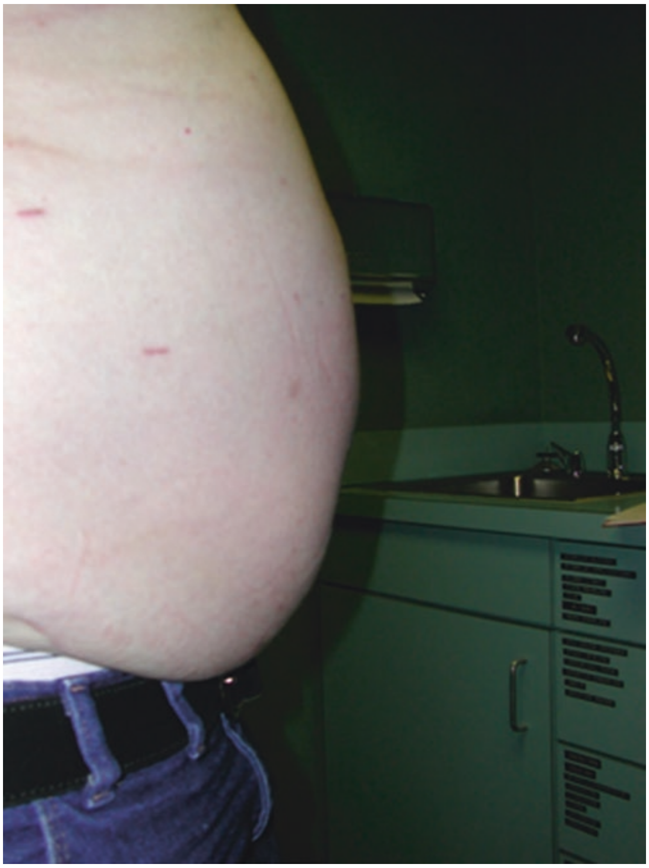

Fig. 28.28 Postoperative appearance of the same patient in Fig. 28.27 3 months after LIVH

Repair of this defect may require that the prosthetic patch be placed near or onto the diaphragm. It may be impossible to achieve an adequate amount of counter pressure necessary for the tacking device to provide adequate penetration of the tacks. For a defect in the pericardial area, it is advisable to use only sutures to secure the patch in order to avoid penetration of tacks into the myocardium or development of pericarditis requiring removal of the tacks [48]. There have been anecdotal reports and unreported events of cardiac penetration and tamponade with the use of fasteners other than sutures this high in the abdominal cavity. In this situation, nonabsorbable sutures should be placed. Additionally an oversized patch is recommended to provide a greater overlap (8 cm or greater) than usually required due to this fixation problem.

Hernias that extend to the symphysis pubis or are associated with an inguinal hernia can also present a challenge. To repair these defects, it will be necessary to attach the lower part of the patch to Cooper's ligament. To accomplish this, it will be necessary to dissect the preperitoneal space similar to the laparoscopic transabdominal preperitoneal inguinal hernia repair. This must be done to provide for strong fixation of the patch to the muscle wall of the lower abdomen and the periosteum of the pubis because transfascial sutures cannot be placed in this location. Additionally, interposing preperitoneal fat and peritoneum that remains between the patch and muscle will compromise subsequent tissue attachment. After the patch is secured, the preperitoneal flap can be secured in its usual position to the maximum extent possible, if desired.

Incisional "hernias" that occur after nephrectomy or an anterior approach to the spine are usually not true hernias as they generally do not exhibit a well-defined fascial defect. The repair of these deformities is not currently established in the literature. Surgeons that do attempt to repair these deformities must pay particular attention to the positioning of the patient. Patients with such defects should be placed in a lateral decubitus position on a "beanbag." Defects along the upper flanks that involve denervated musculature rather than a true fascial lesion require a very large patch that is secured tightly with more than the usual number of sutures to achieve an acceptable cosmetic result. The laxity of the muscles will frequently require that sutures be placed above the rib margin to secure the prosthetic biomaterial. Additionally, one may need to place sutures onto the diaphragm to ensure fixation. It is may be necessary to place additional trocars through the biomaterial itself (Fig. 28.29) to allow for the accurate placement of all the methods of fixation. In my series of patients with this repair, the results are good, but I have found that the hybrid repair described below is preferable to the purely laparoscopic method.

Hybrid procedures may be necessary for complex hernias such as the above or for patients with significant adhesions. The hybrid procedure combines open and laparoscopic techniques to achieve adequate overlap of the defect and safe adhesiolysis. Often for denervation hernias that occur after lumbar surgery, the initial muscle mobilization can be performed through the original lumbar incision.

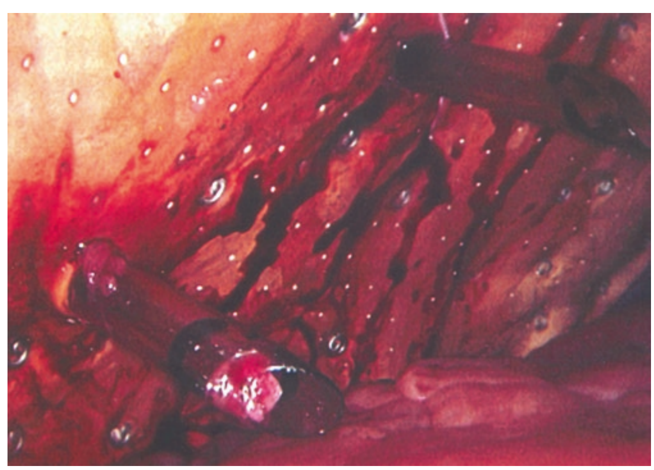

Fig. 28.29 Trocars placed through a prosthesis to place fasteners on the medial aspect of this repair

The prosthetic of choice is placed in the abdomen after mobilization of viscera and lysis of adhesions. Transfascial or tacking sutures, such as to the diaphragm, can be placed during the open portion of the procedure. Trocars are then placed under direct vision. After the mesh is secured appropriately, the muscle layers can be plicated, an onlay mesh is placed, and the skin is closed. The abdomen is then insufflated, and laparoscopic suturing and tacking can be performed for adequate overlap and adherence to the abdominal wall (Figs. 28.30 and 28.31). This type of procedure has been reported in a small series of patients with 1-year follow-up and no evidence of recurrence [49]. In my own series with longer than a 4-year follow-up, no recurrence has been noted. In most patients, there will always be an amount of asymmetry compared to the opposite side due to the lack of musculature tone of the denervated muscle.

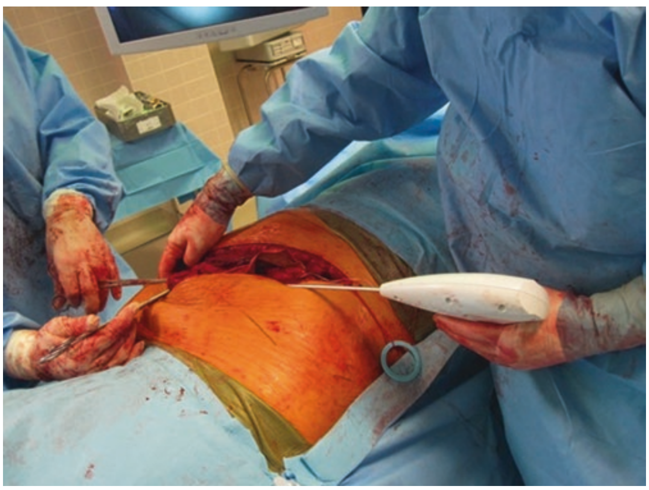

Fig. 28.30 Use of laparoscopic fixation device during the open portion of the hybrid procedure

Fig. 28.31 Completed open portion of hybrid procedure with laparoscopic trocars in place

Many patients who present for laparoscopic incisional hernia repair may also require surgical treatment of a concomitant illness. This most commonly will include cholelithiasis, inguinal hernia, gastroesophageal reflux disease, or a need for biopsy of an intra-abdominal or retroperitoneal structure [44, 50]. Most commonly, the primary procedure is not the incisional hernia repair and, as such, will be performed initially. If the primary operation can be completed without contamination, the hernia repair could then be performed. If contamination does occur, a prosthetic hernia repair may or may not be done. This will be dictated by the amount of contamination and the risk of infection. An open repair such as a component separation or primary repair with or without a mesh could be considered but should be individualized to the patient's risk factors, prior operations, and/or prior hernia repairs. Preoperative discussions with the patient should have examined this possibility. In those individuals in whom the hernia repair can be attempted subsequent to the primary procedure, placement of additional trocars may be necessary. The surgeon could plan on the future trocars at the initiation of the primary procedure but should not compromise the first procedure by the inappropriate positioning at that point. Any additional necessary trocars should be placed in the locations most appropriate for the hernioplasty once the decision is made to proceed with the second procedure. One should not avoid using more trocars when deemed necessary to carry out the second operation in a safe and effective manner.

Results

In the past decade, there has been a significant amount of literature comparing LIVH to open mesh repair including four prospective trials, three retrospective trials, and multiple meta-analysis and review papers (Table 28.1). Yet the literature fails to provide a standardization of technique in open mesh repairs. The Rives-Stoppa repair has a known recurrence rate ranging from 0 to 14% [54]; however, Burger described a recurrence rate of 32% in open mesh repairs [5]. The majority of laparoscopic repairs described in comparative trials [6, 8, 9, 11, 51–53] do adhere to the basic tenets of LIVH which include 3 cm or greater mesh overlap and both transfascial sutures and tacks for mesh fixation as promoted by LeBlanc and colleagues [55]. This discordant approach to open mesh repair has challenged a true comparison to LIVH in terms of overall recurrence rates.

Pring and colleagues attempted to standardize their technique by using ePTFE as an underlay with transfascial sutures in both open and laparoscopic repairs. Their results yielded a recurrence rate of 4.2% for open mesh repairs and 3.3% for laparoscopic repairs; this recurrence

Table 28.1 Comparison of recurrence rates, post-op stay, and OR time

	Study type	Year of publication	Recurrence rates		Post-op stay (days)		OR time (min)		Follow-up	
			Open	Lap	Open	Lap	Open	Lap	Open	Lap
Ballem [51]	Retrospective	2008	28%	29%	–	–	–	–	7.5 years[a]	7.5 years
Bencini [52]	Retrospective	2003	6%	0%	8[b]	5[b]	112	108	18 months[b]	17 months[b]
Bencini [53]	Retrospective	2009	11%	14%	2[a]	3[a]	35	70	60 months[a]	56 months[a]
Olmi [9]	Prospective	2007	1.1%	2.3%	9.9[b]	2.7[b]	151	61	24 months[a]	24 months[a]
Pring [6]	Prospective	2008	4.2%	3.3%	1[a]	1[a]	43	44	27.5 months[a]	27.5 months[a]
Lomanto [8]	Prospective	2006	10%	2%	4.7[b]	2.7[b]	93	91	20.8[b]	20.8[b]
McGreevy [11]	Prospective	2003	–	–	1.5 [b]	1.1[b]	102	132	30 days[c]	30 days[c]
Forbes [10]	Meta-analysis	2009	3.6%	3.4%	–	–	–	–	6–40.8 months	6–40.8 months
Pierce [7]	Meta-analysis	2007	12.1%	3.1–4.3%	4.3[b]	2.4[b]	104.5	103	20.2[d]	25.5[d]

[a]Median
[b]Mean
[c]Completed length of follow-up
[d]Unspecified

rate was not statistically different [6]. A meta-analysis performed by Forbes et al. reviewed eight randomized controlled trials [10]. A similar study was done by Sajid et al. on five randomized controlled trials, and Sains and colleagues reviewed five comparative trials [56, 57]; all of these meta-analysis report no statistical difference in the recurrence rate between LIVH and open mesh repair. One of the largest meta-analysis was performed by Pierce and colleagues at Washington University. They reviewed 45 studies, of which 14 were paired studies and reported a recurrence rate of 3.1–4.3% for LIVH and 12.1% for open mesh repair [7].

In a review of recent literature, the cumulative average of operating room time for LIVH was 87 and 91.5 min for open mesh repair, which supports a number of comparative studies that report no statistical difference in OR time [8, 52, 56, 58]. However, other studies do show a statistical difference; LIVH has been shown in one meta-analysis to take 12 min longer than open mesh repair on average [53, 57]. This discrepancy is most likely secondary to the lack of standardization of open mesh repair and the learning curve for LIVH represented in earlier studies.

LIVH has been shown to have favorable results in shorter postoperative lengths of stay and overall decrease in wound infections and mesh removal [7, 10, 11, 56, 58, 59] (Table 28.2). Pierce and colleagues found wound infections to be 4.6–8-fold higher in open mesh repairs when compared with LIVH [7]. In a review of the National Surgical Quality Improvement Program (NSQIP) database, total complications were twice as high in open mesh repair in comparison to LIVH [58]. A common sequelae of LIVH are seroma formation. This complication is often underreported because it is routinely of no clinical significance. Very few studies document persistent seroma formation that required intervention.

LIVH is often accompanied with significant adhesiolysis. A dreaded consequence of extensive adhesiolysis is injury to the intestine. Injury may be a result of direct laceration secondary to sharp or blunt dissection, but heightened vigilance is required for injuries caused by traction and remote serosal injuries that may go unrecognized. In a review of the literature by LeBlanc et al., the enterotomy rate for LIVH was 1.78% out of 3925 LIVH. According to this review, approximately 18% of the time, an enterotomy is unrecognized which is associated with a mortality rate of 7.7% [28]. Some have shown a higher rate of enterotomy with laparoscopic versus open surgery in a meta-analysis [60]. Should an enterotomy occur and is recognized, the injury should be repaired, of course. The next decision is whether or not to proceed with the repair of the hernia itself. The use of a prosthesis is to be avoided in conventional teaching, but there is a growing opinion that the use of lower-weight meshes or an absorbable prothetic material might be considered in this situation as these seem to be less prone to infection. A primary repair of the hernia will be associated with a high risk of recurrence. Therefore, many experts recommend that the primary repair be avoided and the patient be returned to the operating room in several days [61].

The overall cost of LIVH has been shown to be equivalent with open mesh repair. A single institution prospectively collected data on 884 incisional hernias. There was no statistical difference in overall hospital cost for LIVH when compared to open mesh repair. LIVH was shown to have shorter length of stay, though operating time and cost of supplies were higher in LIVH. LIVH costs $6725 compared with $7445 for open mesh repair in total hospital costs and postoperative encounters [62]. Recent evidence confirmed that the minimally invasive approach is preferred due to cost, length of hospital stay, outcomes, number of days off from work, and number of outpatient postoperative visits [63].

Table 28.2 Postoperative complications

	Ballem [51]		Bencini [52]		Bencini [53]		Olmi [9]		Pringe [6]		Lomanto [8]		McGreevy [11]		Forbes [10]		Pierce [7]	
Complications	Open	Lap	Open	Lap	Open	Lap	Open	Lap	Open	Lap	Open	Lap	Open	Lap	Open	Lap	Open	Lap
Enterotomy	–	–	2%	5%	0%	4%	–	–	–	–	–	–	0%	1.5%[a]	0.9%	2.6%	1.2%	2.9%
Fecal obstruction	–	–	–	–	–	–	1.1%	1.1%	–	–	–	–	–	–	–	–	–	–
Ileus	–	–	10%	2%	–	–	–	–	–	–	10%	2%	4.2%	0%	–	–	–	–
Mesh Infxn/ removal	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3.5%	0.7%	3.2%	0.9%
Neuralgia	–	–	–	–	–	–	0%	4.7%	–	–	–	–	–	–	–	–	–	–
Pulmonary embolism	–	–	–	–	–	–	1.1%	0%	0%	6.6%[b]	–	–	–	–	–	–	–	–
Seroma	9%	16%	10%	14%	3%	11%	1.1%	7%	33%	17%	6%	10%	4.2%	3%	15.5%	11.7%	12%	12.1%
Urinary retention	–	–	–	–	–	–	–	–	0%	6.6%	–	–	–	–	–	–	–	–
Wound infxn	9%	7.5%	12%	0%	8%	0%	8.2%	1.1%	16.7%	3.3%	6%	4%	8.4%	0%	10.1%	1.5%	10.4%	1.3%

[a]Unrecognized
[b]Preexisting procoagulant disorder

Obesity and LIVH

Obesity has been shown to be a major factor in hernia recurrence. In a study of 160 patients, obesity was compared to other risk factors for hernia recurrence such as smoking, diabetes, steroid use, and pulmonary disease. Obesity was the strongest predictor for hernia recurrence. Patients with a body mass index (BMI) of 38 were 4.2 times more likely to have a recurrent hernia in comparison to a patient with a BMI of 23 [20]. Congruent results were identified in a multi-institutional study of five academic centers. This retrospective review found the recurrence rate to be significantly higher in morbidly obese patients with an odds ratio of 4.3 [19].

Though some report a higher recurrence rate in obese patients, LIVH is safe and effective in this population of patients [4]. LIVH has been shown to have less risk of wound complications, greater identification of multiple occult defects, and wider mesh overlap. In a review of 168 patients at a single institution, perioperative complications after LIVH were not found to be statistically different from non-obese patients. Recurrence rates were related to defect size and size of mesh rather than obesity [64]. Ventral hernia repair is even promoted during laparoscopic bariatric surgery when concurrently identified. In patients who did not have their ventral hernia repaired during laparoscopic gastric bypass, there was an increased risk of intestinal incarceration during patient follow-up [65].

Conclusion

LIVH has a proven track record as an effective, safe, and durable option for ventral hernia repairs. There is general consensus that LIVH has comparable recurrence rates to open mesh repair, if not less risk of recurrence as seen in some prospective trials. Wound complications and mesh infections occur infrequently. Hospital stay is shortened, and increasingly, LIVH is becoming the first and only attempt at a disease that is commonly identified in 10–20% of postlaparotomy patients [4, 23, 54, 66].

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Laparoscopic Ventral and Incisional Hernia Repair with Closure of the Fascial Defect

29

Adam S. Weltz, H. Reza Zahiri, Udai S. Sibia, and Igor Belyansky

Introduction

Ventral and incisional hernias are extremely common diseases addressed by general and reconstructive surgeons worldwide. In the United States alone, it is estimated that 360,000 ventral and incisional hernia repairs are performed annually [1]. Incisional hernias are an unfortunate common complication of laparotomy, occurring in 3–20% of patients [2–4]. Although numerous studies support the use of minimally invasive surgical (MIS) techniques to address ventral and incisional hernias, open repairs are still performed far more commonly. Data from the American College of Surgeons National Surgery Quality Improvement Program (ACS-NSQIP) database reveals that the majority (83%) of ventral and incisional hernia repairs are performed via open technique [2]. Several factors may explain the low adoption rates for laparoscopy. These include the need for additional MIS training, expensive equipment, technical limitations pertaining to access, and ergonomic and anatomic factors such as patient body mass index, hernia size, and/or dissection complexity. Regardless, the hesitation to adopt the laparoscopic approach must be offset by the reality of its benefits, reduced wound morbidities, expedited return of bowel function, decreased hospital length of stay, and superior cosmesis [5–9].

Among the tenets of open ventral/incisional, hernia repair is to recreate the linea alba [10, 11]. For large complex defects, this often necessitates a variety of abdominal wall reconstructive techniques utilizing separation of components [11]. Failure to properly close hernia defects may lead to not only functional deficiencies but cosmetic dissatisfaction due to bulging known as eventration. Although not a true hernia, eventration may be mistaken for recurrent hernia by patients or non-hernia specialists. Reapproximation of the midline may also allow for maximum core abdominal function by restoring the rectus abdominis muscles to their native position. Furthermore, obliteration of the defect through closure eliminates potential spaces and puts the mesh entirely in contact with the abdominal wall, facilitating its integration [12, 13]. Until recently, complex abdominal wall reconstruction was exclusively performed in an open fashion which required large incisions and subjected patients to significant morbidity.

The first laparoscopic ventral and incisional hernia repairs (LVIHR) were performed by LeBlanc and Booth in 1993 [14]. They introduced a safe, feasible, and reproducible minimally invasive approach that later became referred to as intraperitoneal onlay mesh placement (IPOM) repair. The procedure consists of reducing the hernia contents and patching the abdominal wall defect with an overlapping nonabsorbable synthetic mesh, which is tacked to the abdominal wall. In LeBlanc's original technique, the tacks were metallic. Their experience in the first 100 patients led to reinforcement of the tacked mesh with additional penetrating transfascial mesh-fixing sutures, which decreased their hernia recurrence rate from 9 to 4% in the next 100 patients [15]. This repair has withstood the test of time for over two decades with low recurrence rates and wound morbidities. However, debate continues among surgeons regarding the benefits of defect closure versus a bridged repair [13].

In recent years, the fascial closure technique with IPOM reinforcement in LVIHR, referred to as IPOM-Plus, has progressively gained support and appeared in the guidelines for the laparoscopic treatment of ventral and incisional abdominal wall hernias published by the International Endohernia Society (IEHS) in 2014 [12]. In addition, the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) newest guidelines endorse closure of fascial defect when possible [16]. These guidelines have taken into account the benefits of this approach may culminate into reduced wound complications through better integration and reduction of seromas [12, 13]. Our practice and experience have been in parallel with these guidelines, and our center emphasizes the importance of defect closure.

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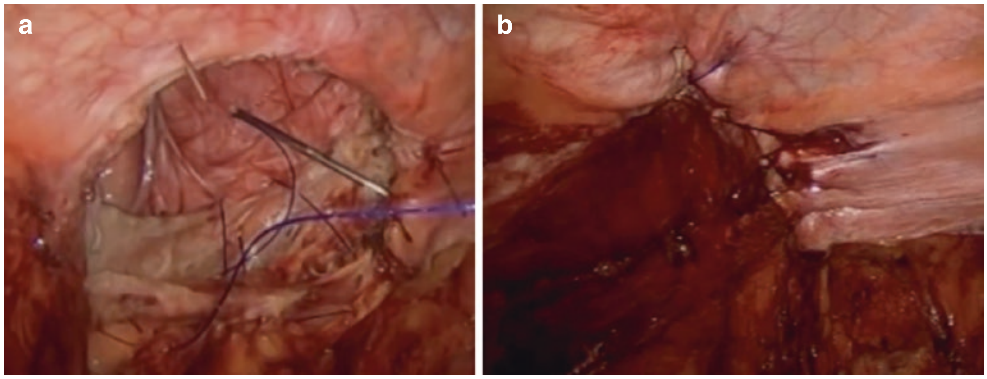

Fig. 29.1 (**a**) Transfascial suture placement for defect closure. (**b**) Defect closed

The technical approach to facial closure has also been an area of debate and evolution. Early attempts at laparoscopic primary defect closure with IPOM-Plus were performed with penetrating transfascial sutures (Fig. 29.1a, b). By closing the fascial defect, only the newly created suture line is left. We select the size of mesh based on the original defect and ensure an overlap of 5 cm or more. This has been supported in a recent meta-analysis of the literature looking specifically at defect closure [17]. Some very large defects cannot be closed utilizing this laparoscopic technique and previously needed to be converted to an open approach.

Traditionally, transfascial mesh fixation has been noted as an important method of fixation in laparoscopic IPOM cases, albeit associated with chronic pain. The pathophysiology of this outcome likely involves abdominal wall nerve entrapment and focal muscle devascularization [18, 19]. A large series of over 250 patients who underwent ventral/incisional hernia repairs with transfascial sutures reported chronic abdominal pain in 27% of patients [20]. Others studies have advocated removal of transfascial sutures to alleviate chronic pain [21] and reduce surgical site infections [22]. Because of these key problems associated with penetrating sutures, a recent focus in hernia repair has been to limit their use when possible [19].

When considering reconstruction of linea alba, advances in suture technology such as barbed suture (V-Loc™, Medtronic, Minneapolis, MN, USA) now enable easier intracorporeal closure of defects, thus reducing the need for penetrating fascial closure devices, without negatively impacting recurrence rates.

These contemporary advances in laparoscopic ventral and incisional hernia repair combine with new minimally invasive component separation techniques, such as transversus abdominis release (TAR), to more broadly address complex hernia defects [23]. In this chapter, we discuss our approach to laparoscopic ventral and incisional hernia repair, including more complex defects requiring components separations.

Preoperative Considerations

Standardized preoperative workup for all hernia patients is imperative, regardless of hernia location. This begins with a detailed history, physical examination, and biochemical studies to assess the patient's baseline health. Defect number and size, prior or current wound infections, presence of ostomy, excess skin, and contour abnormalities are part of the physical exam and critical in selection of the proper operative approach for hernia patients.

Special effort and attention should be made to review prior medical and surgical records in order to gain a thorough understanding of patients' prior interventions and their anatomy and presence of any mesh or fixation devices in the case of patients presenting with recurrent hernia disease. To further supplement your understanding and preparation, we recommend all patients undergo an up-to-date computed tomography study of their abdomen and pelvis for preoperative planning.

Any patient with a large panniculus, excess, thinned, or ulcerated skin, may benefit from open repair with concomitant panniculectomy. Additionally, patients with active infection should be treated with properly selected antimicrobial therapy with resolution of their infection before implantation of synthetic mesh compounds.

Flank hernias should also be considered for defect closure and proper mesh overlap. Parastomal hernias may be repaired utilizing a modified Sugarbaker technique. Subxiphoid defects pose a significant challenge with regard to defect closure due to their proximity to the costal margin and fascial resistance to reapproximation. Finally suprapubic hernias require a detailed understanding of the myopectineal orifice anatomy.

Regardless of hernia location, a multidisciplinary approach should be utilized to optimize patients for surgical intervention. These efforts include cardiopulmonary assessments by cardiology and pulmonology specialists as indicated. Endocrinologists should be consulted as needed for blood glucose control to maintain HbgA1C levels below 7.4. We also strongly advise for smoking cessation. We require at least 4 weeks of abstinence from smoking prior to surgical intervention in our center. Compliance can be assured with serum nicotine level drawn on the day of surgery. Finally, preoperative weight loss must be strongly encouraged, and if available to your practice, we recommend that all obese patients undergo full consultation with registered dieticians and/or nutrition experts who may provide valuable education and support through the perioperative process.

Patient education is also critical during preoperative planning, with the goal to establish reasonable expectations. Despite the minimally invasive nature of these procedures, patients may still experience significant amounts of pain requiring inpatient management. Possible complications including seroma, hematoma, deep or superficial abscess, and bowel injury and their respective management options must be discussed. Lastly, for complex revisional procedures, the possibility for conversion to open operations is typically higher and warrants additional discussion.

Patient Positioning and Theater Setup

Patients are generally positioned supine with both arms tucked at their sides to allow surgeon and camera operator to stand on opposite sides of the operating room table. Many hernia repairs require significant surgeon movement around the operating room table, necessitating the flexibility of having both arms tucked. The operating room table is then placed in deep Trendelenburg with the legs extended down 30° to allow for greater instrument range of motion for the operating surgeon and his/her assistant (Fig. 29.2).

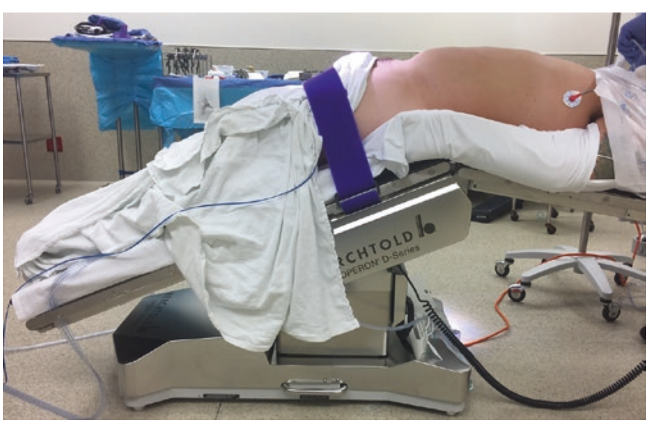

Fig. 29.2 Operating room table is then placed in deep Trendelenburg with the legs extended down 30°

Failure to adequately hyperextend the operating room table can result in significant ergonomic challenges. Moreover, flexing the bed will often result in the surgeons hand or arm colliding with the patients' body while trying to suture defects and thus bed flexion should typically be avoided.

In contrast to most laparoscopic procedures, the surgeon position, monitors, and trocar positioning may vary greatly depending on location of the hernia defect and degree of domain loss. Monitors are typically placed at the head of the bed when addressing an upper midline incisional hernia defect and at the foot of the bed when addressing lower midline incisional defects.

Prior to incision, relevant anatomy should be designated by marking the patient's xiphoid process, bilateral subcostal margins, symphysis pubis, linea alba, and semilunar lines. Preoperative antibiotics should be properly selected and dosed according to weight-based hospital protocol, and a discussion in regard to chemical and mechanical DVT prophylaxis should be tailored to the individual patient.

Incision and Access

Safe access to the peritoneal cavity is a key first step in most laparoscopic procedures. Access may be gained using a variety of techniques including an optical trocar or Veress needle or by cutdown. Unique to our method of laparoscopic ventral hernia repair is that our first critical step is gaining access to the retromuscular space, *not* the peritoneum. The eTEP access approach relies on initiating the dissection in one of the retrorectus spaces and then crossing over to contralateral retroretus space, thus connecting the two spaces. The decision where to cross over as well as initial port setup depends on the defect location. The ports are positioned next to linea semilunaris thus setting the surgeon up for an ergonomic way to suture the defect at the completion of the case.

Upper Midline Defects

When dealing with upper midline hernia defects, consideration should be given to performing the crossover below the level of the umbilicus and developing preperitoneal and retromuscular space that has not been previously violated. Figure 29.3 demonstrates the initial port position for upper midline defects. The first incision is made 2 cm below a horizontal line drawn through the umbilicus and just medial to linea semilunaris. The anterior rectus sheath is identified and incised sharply. Single-site balloon dissector is used to develop the retrorectus space in cephalad and caudal directions. It is critical to avoid overinflation which may rupture the linea semilunaris and injure the rectus abdominis muscle. Once the space of Retzius is developed, ports #2 and 3 are placed under direct vision. A 30° scope is placed through port #3, and procedure commences as retrorectus dissection is performed heading in the cephalad direction (Fig. 29.4a). After crossing over, bilateral posterior rectus sheaths are released from caudal to cephalad direction thus connecting retrorectus spaces (Fig. 29.4b).

Lower Midline Defects

For a right-handed surgeon, we found that lower midline defects are easier to address by initiating the dissection in the upper portion of left retrorectus space. Figure 29.5a demonstrates the typical port position that we chose to use for this approach. The balloon dissector is used at port 1 position to develop left retrorectus space; under direct vision, ports 2 and 3 are then placed into the developed space. Blunt dissection is performed in caudal direction, and the pubis is identified. Considering that upper midline has not been previously violated, above the level of umbilicus, medial aspect of left posterior rectus sheath is incised, and preperitoneal space is entered, just superficial to falciform ligament (Fig. 29.5b). Right posterior rectus sheath is identified, and medial aspect of it is incised and released from cephalad to caudal direction (Fig. 29.6) followed by blunt dissection in the right retrorectus space. Port 4 is then placed under direct vision through the upper aspect of right rectus abdominis muscle; this then becomes the camera port. The retrorectus dissection then carried out in the caudal direction completing bilateral release of posterior rectus sheaths. When encountering the hernia sac, we try to sharply dissect the distal attachments of the sac, thus mobilizing it down. Alternatively, the sac can be sharply entered and laparoscopic adhesiolysis is performed.

For more complex defects that require large mesh placement, transversus abdominis release (TAR) procedure is utilized [11, 23]. The incorporation of TAR was found beneficial in cases with especially large defect or when dealing with poorly compliant abdominal wall. Any defects in posterior layer are closed with 2-0 absorbable suture. The abdominal wall defect is primarily closed using 0 barbed suture in a running fashion, while pneumoperitoneum is dropped to 8 mmHg (Fig. 29.7).

Finally, the developed retrorectus/preperitoneal space is measured for appropriate mesh size selection. We typically use medium-weight macroporous polypropylene mesh, deployed through our 12 mm trocar. Mesh is positioned to widely cover the developed space (Fig. 29.8). Mesh can be secured with several transfascial sutures or glue. In our more recent experience, some of us have migrated to no fixation. While traditionally we used drains in subfascial space, we have moved away from their use without observing increase in wound morbidity. Once satisfied with mesh position, pneumoperitoneum is released under direct vision assuring that the implant is laying flat between the posterior and anterior layers.

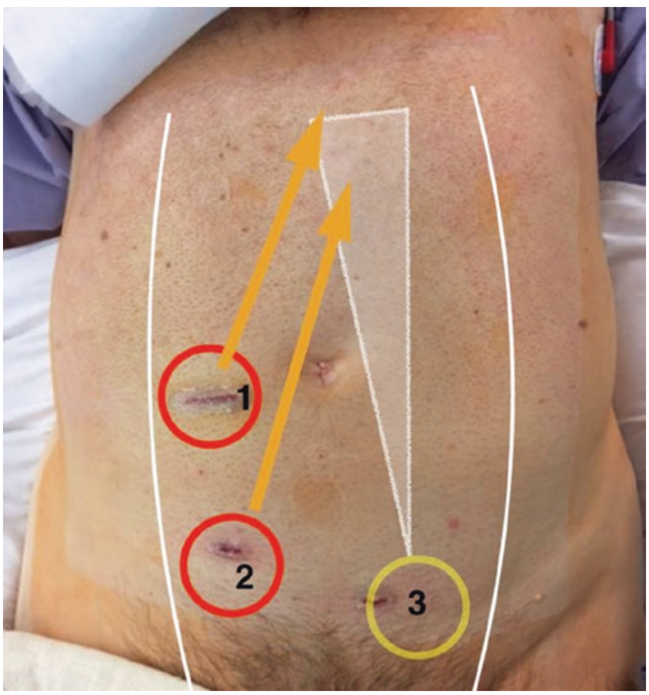

Fig. 29.3 Port position for upper midline defects

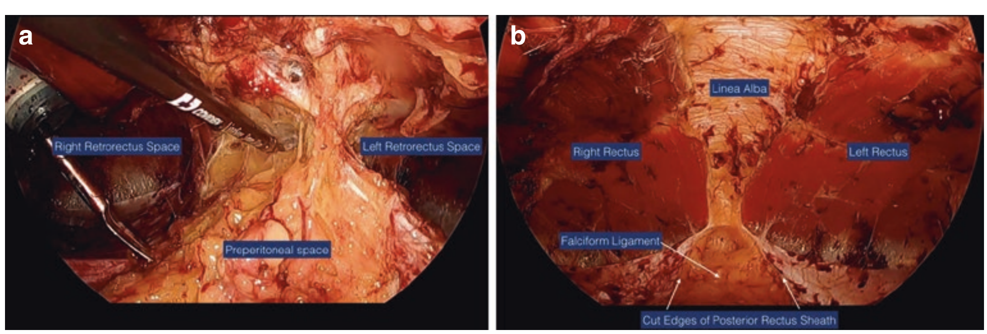

Fig. 29.4 (**a**) Retrorectus dissection is performed heading in the cephalad direction. (**b**) Bilateral posterior rectus sheaths are released from caudal to cephalad direction thus connecting retrorectus spaces

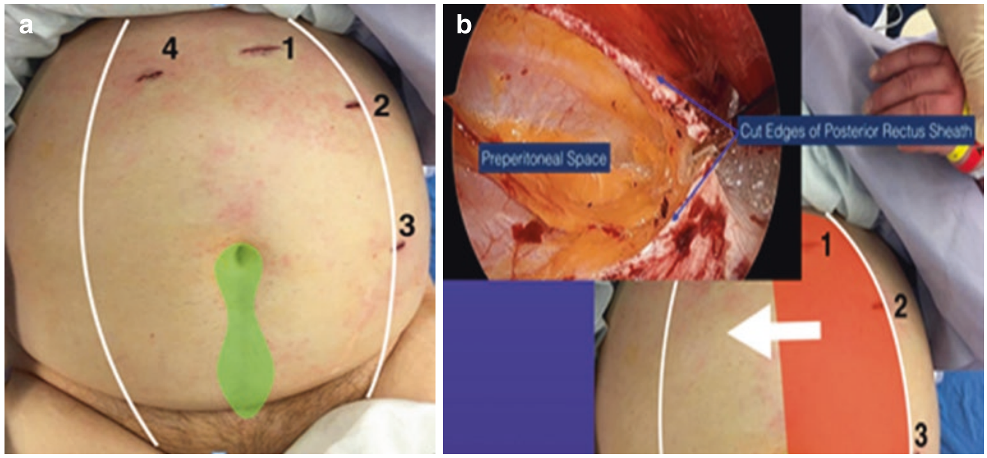

Fig. 29.5 (**a**) Port position for lower midline defects. (**b**) Medial aspect of left posterior rectus sheath is incised, and preperitoneal space is entered, just superficial to falciform ligament

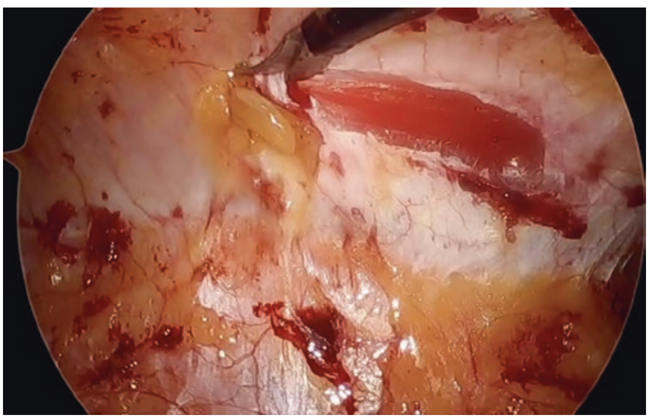

Fig. 29.6 Right posterior rectus sheath is identified, and medial aspect of it is incised and released from cephalad to caudal direction

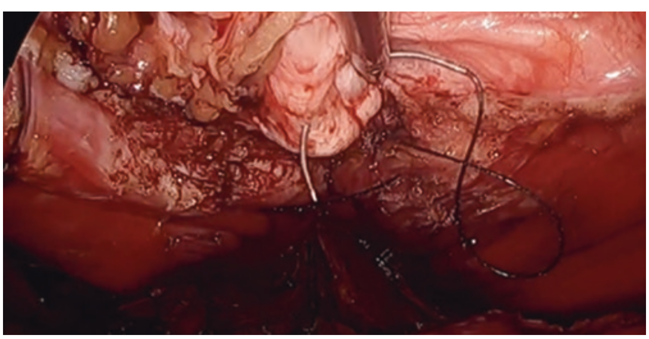

Fig. 29.7 The abdominal wall defect is primarily closed using 0 barbed suture in running fashion

Postoperative Management

Diet is restarted once anesthesia has worn off, and they are discharged from PACU. While the vast majority of patients are discharged home on the day of surgery, those that underwent addition of TAR procedure are typically kept for additional 23 h of observation. All patients are encouraged to ambulate early and often.

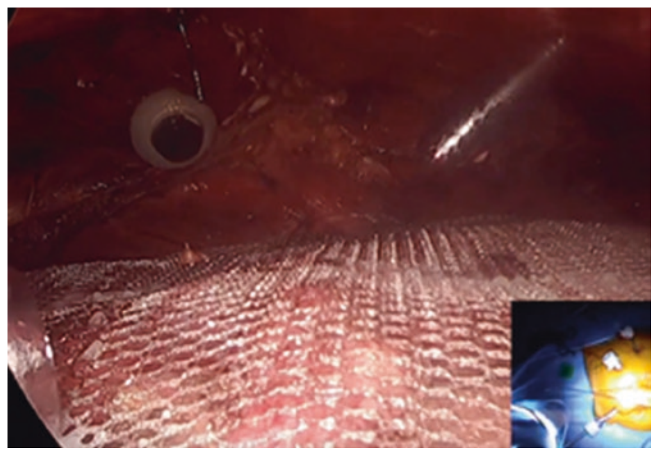

Fig. 29.8 Medium-weight macroporous polypropylene mesh, deployed through our 12 mm trocar, is positioned to widely cover the developed retrorectus space

Those that stay overnight have their postoperative pain controlled with patient-controlled analgesia devices (PCAs), which are substituted the morning of POD#1 to oral analgesics.

All inpatients are provided incentive spirometers (IS) to assist in their pulmonary toilet and instructed to use these devices 10×/h to minimize any respiratory complications. They are also given sequential compression devices (SCDs), as well as subcutaneous heparin or lovenox DVT prophylaxis until they are ambulating. Abdominal binders are offered to all patients to help support their abdominal wall and assist with early ambulation.

Once patients are ambulating well, tolerating PO intake, and able to control their pain without the need for intravenous medications, they are discharged from the hospital. Patients are typically seen 4 weeks following surgery for their first postoperative clinic visit.

Tips and Pitfalls

Proper bed positioning is critically important for surgeon comfort and ergonomics.

Initial port placement needs to be medial to the linea semilunaris to gain access into the retrorectus space.

Medial port position setup enables closure of the defect in ergonomic fashion.

Overinflation of the balloon dissector may rupture the linea semilunaris.

For patients with a long torso, a bariatric needle driver may be required to reach the superior aspect of the defect for closure.

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30 Robotic Incisional Hernia Repair

Karl A. LeBlanc

Introduction

The Intuitive Surgical Robot (Intuitive Surgical Inc., Sunnyvale, CA) was approved in the United States for use in the repair of hernias in April of 2014. Experienced robotic surgeons were actually using the device in the repair of hernias of all types prior to this approval. Prior to that approval, these innovative surgeons saw the potential value in this technology for these operations. There were (and are) many technical aspects of the repair of incisional hernias that are still undergoing development and critical appraisal.

In my own experience with this device, I have noted several aspects of this operation that required new considerations and technique changes of a procedure that was well described and understood. Having lived through the era of conversion from open to laparoscopic surgery, it was anticipated that personal challenges would be found and the dreaded "learning curve" would be revisited. If one decides to undertake this change, a commitment to perform at least 50 cases should be made. This should be considered a "firm" goal if one is transitioning from no robot experience to the robot surgical technique. However, if one is already an experienced robotic surgeon, then this number could be reduced.

There is a slow introduction of data regarding the use of the surgical robot in the repair of incisional hernias [1]. As with any new method, surgeons will closely evaluate this data and develop strategies and methods and will more fully understand the expectations and outcomes of this technology as time moves forward. It is incumbent on all hernia surgeons to assess, study, and learn from such data. The information that follows is based upon my own learning curve and the available data.

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Preoperative Considerations

The workup of patients that are to be considered for this repair does not differ in that of the traditional laparoscopic repair. Comorbid conditions and anticoagulation requirements of these patients will dictate the appropriateness of the operation. Generally if there is a significant amount of scarring of the skin, such as from an open abdomen, this may not be the best option. Resection of large amounts of scar and loss of domain are potential limiting factors in the choice of this method.

Very small patients with very large hernias may require that the robot be "double docked" during the operation. This requires the insertion of the trocars on one side of the abdomen for the majority of the operation, but then additional trocars will be placed on the opposite side to finish the suture fixation of the mesh due to the limitation of visualization of the mesh very near the camera itself. This is considered a more advanced technique but can easily be performed with experience.

Smoking and obesity are well-known risk factors for hernia development and recurrence. Smoking cessation for at least 1 month should be mandatory. Preoperative testing will confirm the fact that the patient has truly stopped the use of tobacco. Weight reduction should be undertaken in all patients that are obese. There have been some reports that have recommended that anyone with a BMI > 50 should not have elective hernia repair [2]. These considerations could apply to the elective repair of these hernias, but in an urgent or emergent situation, these will, of necessity, be overlooked.

If the patient has had prior incisional or ventral hernia repairs, an attempt should be made to obtain the prior operative reports. This will assist in the identification of any prior meshes within the abdomen and determine the likelihood of the need of removal of that prior material(s). Other items that are helpful would be the size of the defect, the size of the mesh selected, and the method of mesh fixation.

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Unfortunately, in many instances, these facts are not included in the operative report.

I believe that a preoperative CT scan is required on nearly all patients, especially those that have had multiple procedures and/or hernia repairs. Close personal review of these scans (rather than just the printed report) will greatly assist in the knowledge of the contents of the hernia, the location of all of the hernias, and the size of the defect(s) and provide identification of other possible pathologies within the abdomen. The size of the fascial defect is critical to the determination of the feasibility of the robotic repair. One could assess the potential need of a posterior component separation repair with the CT image.

Patient Positioning and Theater Setup

A larger operating room is preferred when the robot is used. This will allow the staff to more easily maneuver the robot into position. The type of robot will also influence the need for space to move the device. It is best if several traditional laparoscopic instruments are available to the surgeon because occasionally adhesiolysis must be done prior to introduction of the robotic trocars. There must be enough distance from the trocars to allow for the wrists of the robotic instruments to move to perform their respective tasks.

A urinary catheter and an orogastric tube are used on all patients. If there is a significant amount of dissection that involves the intestine, then a nasogastric might be preferred. The arms of the patients can be tucked or not. This will depend to a large degree on the size of the patient and the location of the hernia. One must be aware of the superior and inferior trocar placement as the motion of the arms of the robot could be limited if they strike the ribs or leg of the patient. Steep Trendelenburg, reverse Trendelenburg, or table flexion is frequently helpful to prevent this event.

It is most common in our facility to dock the robot in the right side of the patient. This will be affected by the layout of the operating room, the location and size of the hernia, and the patient. The robot in this case will be positioned on the patient's left side (Fig. 30.1).

Incision and Access

For midline hernias, I prefer to use a total of four trocars in all cases (Fig. 30.1). Infiltration with bupivacaine containing epinephrine is used at each site prior to incision. The method of entry into the abdominal cavity should not necessarily vary from the method of which one is most accustomed. My preference is to place use a 5 mm optical trocar in the quadrant of the side where the robot trocars will be placed. On occasion, there will have been so many operations on that side that the opposite upper quadrant will be used to place this 5 mm trocar. I make the skin incision above the rib margin and pull down to access the abdominal cavity. This will allow this area to retract above the ribs once the operation is complete. By placing this trocar first, the abdomen will be inflated to 15 mmHg, and the inflated abdomen will expand to allow a 1–2 cm shift to allow placement of the robotic trocars more laterally than would have been possible otherwise.

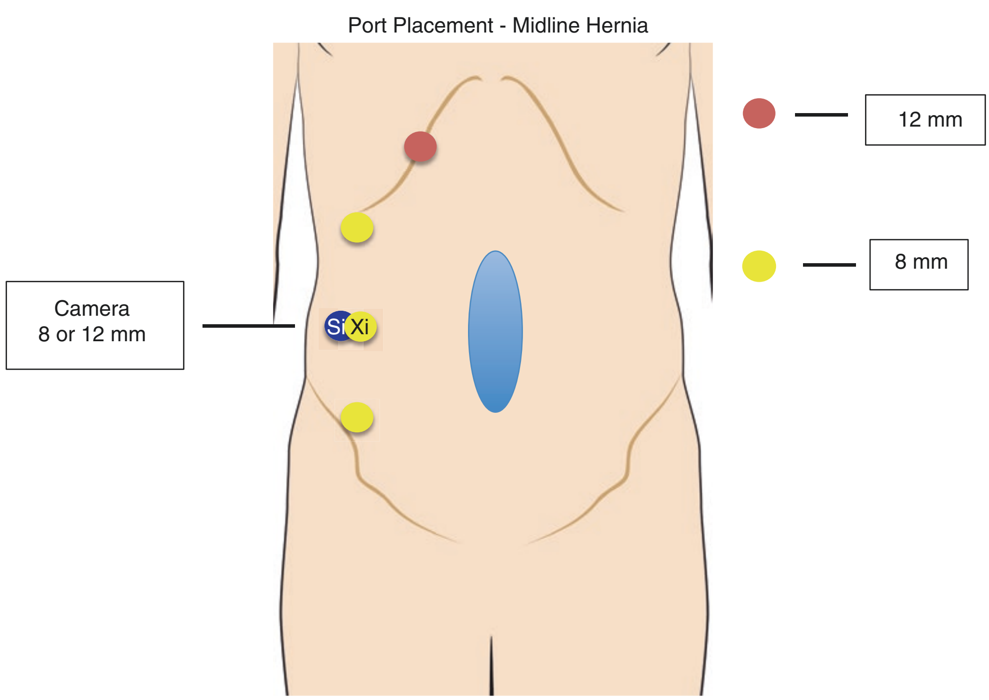

Fig. 30.1 Trocar positions for midline hernia. The robot will be on the left side of the patient

The laparoscope is inserted into the 5 mm trocar to assess the extent of the adhesions. If safe access is understood, the robotic trocars will be placed under direct vision via this trocar site. After this is complete, the 5 mm trocar will be replaced with a 12 mm trocar. Through this, location will be passed the sutures and mesh. If a very large mesh will be required or mesh is excised as part of the operation, this may have to be a 15 mm trocar. Occasionally, these three robotic trocars will be placed in the lower abdomen (subxiphoid hernia) or upper abdomen (suprapubic hernia).

Operative Steps

The robot will be steered into position and connected to the trocars (i.e., docked). The camera is first inserted into the middle trocar. This will allow the safe introduction of the other instruments under direct visualization. Most commonly, a fenestrated bipolar instrument and a monopolar scissors will be used. The latter instrument allows safe non-crushing of the tissues while providing bipolar cautery when needed. The scissors provide monopolar cautery. Precise dissection of the adhesions and tissues will then be undertaken.

It is important to remove the fatty tissue from the upper abdomen that is located in the area of the falciform ligament and in the lower abdomen as well. This dissection should be considered complete when the areas that the mesh will contact will be as free from adipose tissue as possible to allow for ingrowth (Fig. 30.2). In the lower abdomen, this may require the creation of a bladder flap. One does not want to place sutures inadvertently into the urinary bladder. If the hernia is in the suprapubic location, exposure of Cooper's ligament must be obtained so that the prosthesis can be fixed to that structure (Fig. 30.3).

Once this has been done, the scissors are generally swapped to a needle holder of some type. A ruler is introduced via the 12 mm trocar. This is then used to measure the

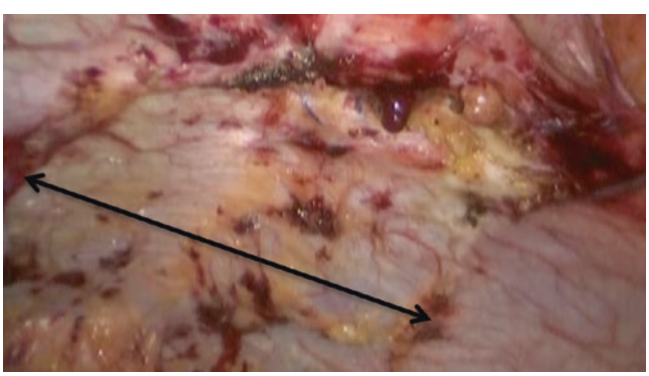

Fig. 30.2 The arrows point to the edges of the falciform ligament that has been dissected

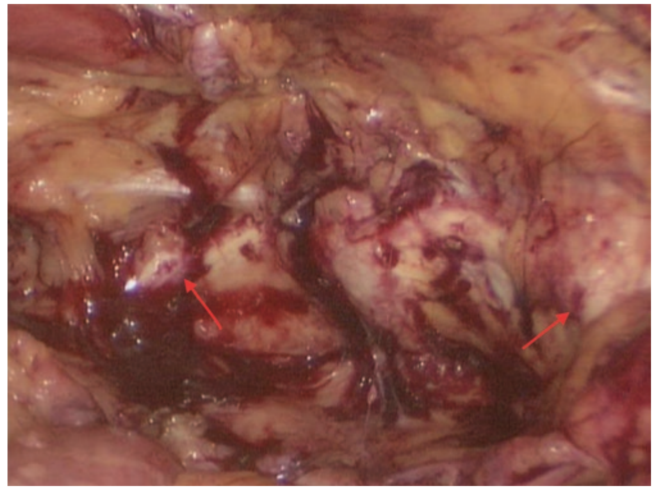

Fig. 30.3 The arrows point to Cooper's ligament

dimensions of the fascial defect(s). When there is more than one defect, these are added together as if they were one defect. This dimension is then chosen to size the mesh. I prefer to use a size that provides at least a 5 cm overlap in all directions. This measurement is taken before the defect is closed, and then 10 cm is added to that measurement to make the mesh selection. This provides the lowest rate of recurrence [3]. Even more recent publications have indicated that the determination of overlap is more complex than simple measurements [4, 5]. These papers indicate that a larger overlap may be needed, but this may be difficult in patients with a smaller internal abdominal diameter.

The mesh is marked to indicate the center of each axis of the material (Fig. 30.4). This will aid greatly in positioning of the product to centrally cover the hernia defect. This is critical because as many as 17% of recurrences have been shown to be due to shifting of the mesh [6]. In other words, rather than a 5 cm overlap in all directions, an improperly placed mesh may have a 7 cm overlap on one side and a 3 cm overlap on the other. Generally some type of suture or device will be used to identify the midpoint of the mesh. This will be placed prior to the rolling of the material. The mesh chosen will be rolled and introduced under direct vision into the abdominal cavity through the 12 (or 15 mm) trocar. If the product used has a soft barrier coating, it is preferred that this surface is place into the interior of the roll to minimize damage to the tissue-separating component (Fig. 30.5).

The prosthesis is unrolled. The central marking suture or device will be pulled through the abdominal wall in the location of the center of the hernia defect (Fig. 30.6). This is best done prior to the closure of the hernia defect. If one elects to close the defect prior to this step, the exact location of the center may be lost, and mesh positioning will be compromised. It is also easier to pass the suture-passing instru-

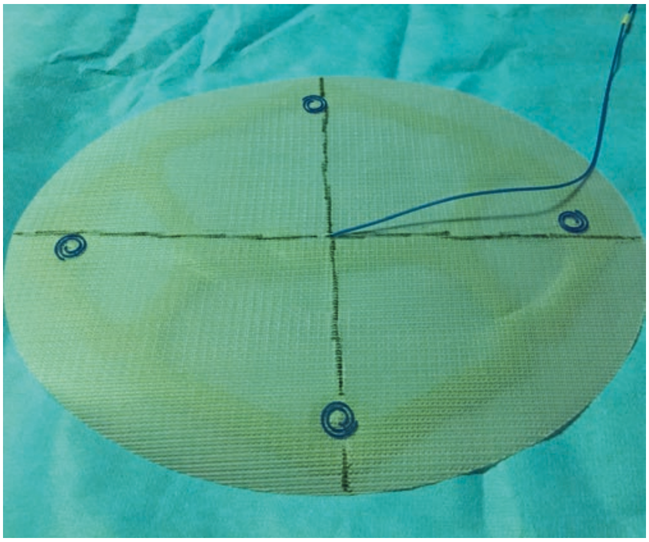

Fig. 30.4 Central lines marked on the mesh

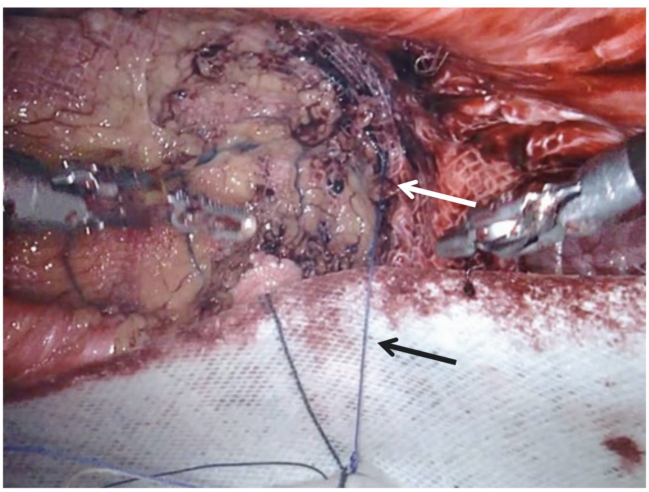

Fig. 30.6 Arrows point to the central positioning suture

ment into the abdominal cavity through the hernia than through the closed fascia of the hernia defect. The mesh may be pulled up to assess the positioning, but then it should be dropped onto the intestine to allow for closure of the hernia defect.

It is at this point that I usually close the defect in most cases. The currently available barbed sutures are ideal for this. There are several options available, but I prefer the double-armed suture. If the defect to be closed is not too large, closure can begin in the middle of the defect. More often than not, however, the defect is too large, and there will be too much tension to begin in the middle. In these cases, closure will begin on either end of the midline. Moving the suturing from side to side will allow closure of defects up to 13 cm. I prefer to lower the intra-abdominal pressure to 6–8 mmHg for this portion of the procedure.

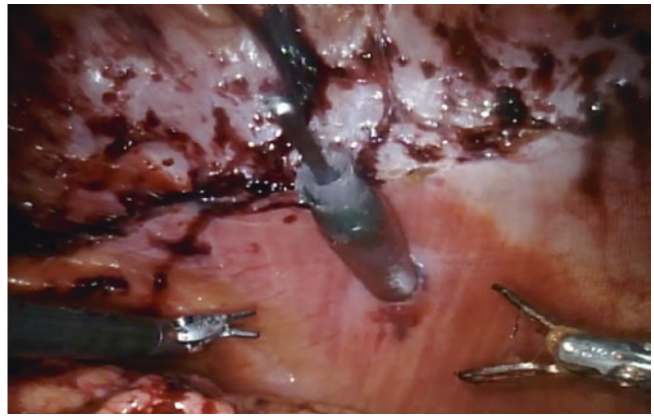

Fig. 30.5 Introduction of the mesh via the larger trocar

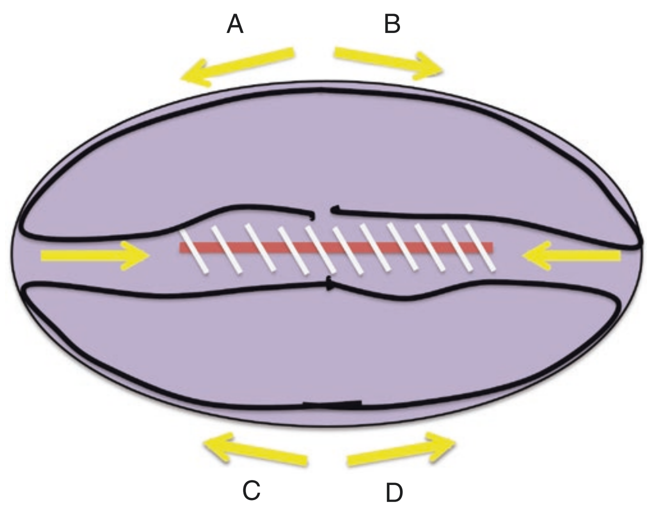

Fig. 30.7 Suture Path indicated by the black line

Once this is accomplished, the mesh will be brought up to the abdominal wall and positioned. The pressure will be returned to 15 mmHg to make the next steps easier. Except for small meshes (i.e., 10 × 15 cm), two double-armed barbed sutures are used. I begin with two throws (A and B) in either direction to the part of the mesh nearest the camera (Fig. 30.7). Next, the second suture will be used, and, again, two throws (C and D) will be placed in either direction on the contralateral side of the mesh. It is critical to pull the mesh into position so that all potential wrinkles are eliminated and the mesh will be taut (Fig. 30.8). Suturing will continue in a sequential fashion by moving from one needle to the next as shown in Fig. 30.7. I will rotate between needle A for 2–3 throws, needle C for 2–3 throws, and then B followed by D for 2–3 throws. In this manner and by making sure the mesh is pulled tight, the material will lay flat against the abdominal. The left over suture will be used to secure the inside surface of the product adjacent to the closed fascial defect (Figs. 30.7 and 30.9). This will provide a total of four rows of suture to secure the mesh and buttress the fascial closure (Fig. 30.9).

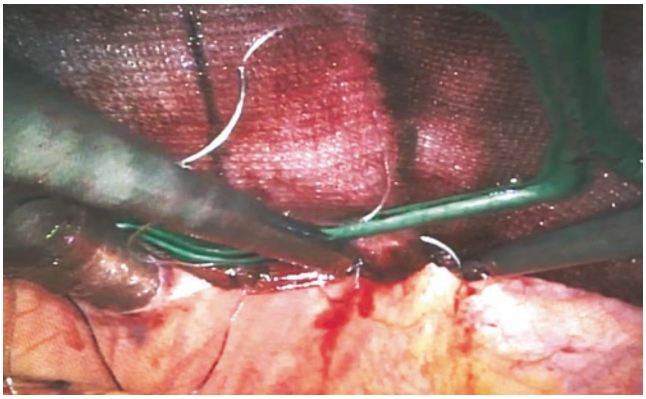

Fig. 30.8 Contralateral suture placement with mesh pulled taut

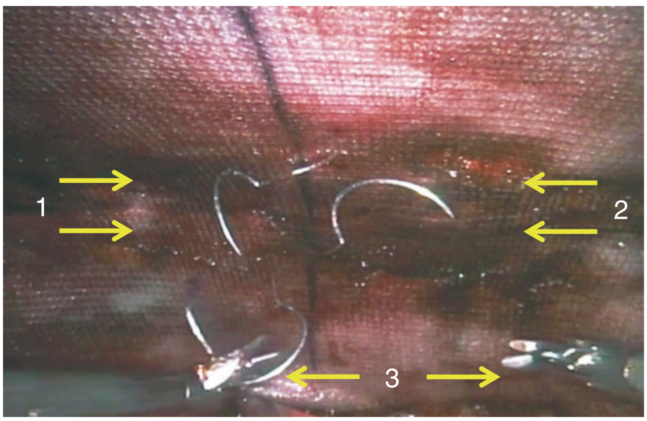

Fig. 30.9 Four rows of sutures (the one nearest the camera is not shown)

Closure

Once the hernia repair is complete, the robot is undocked after a final inspection of the entire abdominal cavity has occurred. The trocars are removed. I do not routinely close the larger trocar site because I choose its position over the ribs prior to insertion. After insufflation is released, these tissues will retract back over the rib margin. For the majority of cases, the robotic trocar sites are not closed because I use the noncutting trocar obturators. The skin incisions are all closed with absorbable poliglecaprone 25 suture and skin tape. This is covered with Band-Aids.

Postoperative Management

In all cases, I prefer to place an abdominal binder to aid in pain control. Additionally, this may decrease seroma rates. This is placed prior to taking the patient off of the operating table. Liberal use of intravenous ketorolac or acetaminophen is beneficial. These outpatients will be sent home with oral narcotics. Resumption of any activity can proceed as they are able to perform them. Enhanced recovery protocols have been shown to help in open surgery and should be used if they are in place even for laparoscopic or robotic surgery as these seem to help [7].

We have found that more patients will be sent home as an outpatient than with even the traditional laparoscopic repair. Many will remain overnight. The patients most likely to remain within the hospital are those that underwent a particularly difficult dissection, experienced more than the usual amount of blood loss, have numerous or high-risk comorbidities, and/or live considerable distances away from the hospital. In most of these instances, these patients do not require intensive care monitoring. General postoperative care is administered, and discharge will occur when surgically appropriate. I do not restrict activities except to tolerance of pain generally. I do not allow the patient to drive an automobile until all sedatives wear off and they feel it is safe to do so.

Tips and Pitfalls

As with all operations, it is best to have a skilled operating room staff to assist in the procedure. This is especially critical for any case that utilizes the robotic technology. Communication between the surgeon and the staff is important especially since the surgeon is seated at the console and not at the bedside of the patient.

The position of the trocars is especially important for the robot and will vary between robots and the hernias that are being treated. One must be cognizant of the arm and leg position of the patient so that the arms of the robot will not strike them. One should strive to place these trocars at least 2 cm away from bony structures also. Patient positioning is important. The use of gel rolls or beanbags will be necessary especially if significant Trendelenburg or reverse Trendelenburg will be required. The patient must be placed in these positions prior to docking of the robot. Unless the facility has the specially designed bed that moves with the robot, the operating table will not be moved unless the robot is undocked. While this can be done, this will cost time.

There are a variety of mesh materials available to the surgeon and the patient. The surgeon should be familiar with these and, ideally, will have the availability of more than one product from which to choose. In this manner, the best material could be used in the situation that it is called upon. From recent findings over the last few years, it appears that the very lightweight products that are particularly macroporous may be unsuitable for use in the repair of ventral and incisional hernias due to high failure rates. Selection of type and size of mesh should not be done until all of the dissection has been completed and an accurate measurement is undertaken. If this is done prior to completion of this dissection, hernias that were unknown may be discovered, and the mesh choice or size will be affected.

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31 Component Separation: Robotic Approach

L.R. Beffa and A.M. Carbonell

Introduction

The optimal management of ventral abdominal wall hernias has undergone significant transformation over the last several decades. Despite this change, modern ventral hernia repair techniques remain founded on the principles and techniques used by Rives and Stoppa [1]. Their concept of placing synthetic mesh in the retrorectus position revolutionized the field of hernia surgery. Furthermore, the component separation techniques (CST) were introduced by Ramirez [2] in 1990, which provided an additional tool for closure of large, complex ventral hernias. Adding to these techniques recently, Novitsky introduced the transversus abdominis release (TAR) as a retromuscular repair, essentially extending the Rives-Stoppa dissection laterally via a posterior component separation [3]. This created a large retromuscular myofascial release and a well-vascularized compartment which is protected from the abdominal viscera. This space allows significant overlap of the defect with synthetic mesh for reinforcement of the repair.

As the field of hernia surgery continues to evolve via technological advancements and increasing use of evidence-based decisions, so will the techniques and platforms that cutting-edge surgeons use today. Since the introduction of robotic surgery, this approach has gained popularity. Surgeons have adapted this approach in a wide array of specialties ranging from cardiac and thoracic surgery to gynecology and urology. The robotic platform was first used to perform a retrorectus Rives-Stoppa hernia repair by Abdalla [4]. Since then, it has become apparent that many of the open techniques can now be performed with robotic assistance but utilizing a minimally invasive approach. This makes robotic ventral hernia repair a great combination of conventional open surgery but with the benefits of minimal access to the abdominal cavity.

While there is a paucity of convincing evidence to support the use of robotics in ventral hernia repair, we believe there are several advantages the robot can provide which are not possible through an open or laparoscopic approach. Robotic assistance makes it possible to perform conventional open hernia repair through minimal incisions that would otherwise be very difficult with standard laparoscopy. This affords several advantages including being able to restore abdominal wall anatomy through a minimally invasive approach, limiting the wound burden to the patient, creating a well-vascularized space in which to place mesh with significant overlap of the defect, improving ergonomics and visualization, and avoiding the placement of intraperitoneal mesh. Disadvantages include cost, time, and training staff specifically for robotic surgery. What little evidence does exist seems to favor robotic ventral hernia repair when compared to open with regard to decreased length of stay and lower incidence of wound infections [5, 6].

In this chapter, we aim to discuss patient selection, our operative approach to robotic CST (or robotic TAR), postoperative management, clinical pearls, and common pitfalls. While we recognize that our approach may differ from others, we aim to provide a broad foundation to which alterations and adjustments can be made to the procedure with ease, should the need arise, given a specific clinical scenario.

Preoperative Considerations

Patient selection is of paramount importance in ensuring hernia repair success. Patients with risk factors for increased wound morbidity, smoking, diabetes, and obesity appear to be well suited for robotic hernia repair. A robotic approach is ideal because the exact same steps for an open repair are performed but with the benefits of decreased wound com-

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plications that are seen with laparoscopic surgery. As with any laparoscopic surgery, the patient must also be able to tolerate pneumoperitoneum, thus making end-stage pulmonary and heart failure comorbidities a relative contraindication.

Large midline defects, up to 20 cm in width, have been closed robotically; however, defects between 6 and 10 cm in widest dimension seem to be best suited for robotic repair with good cosmetic results. Midline defects are ideal, but subcostal, iliac, and flank hernias can also be repaired using the same basic techniques of a robotic retromuscular dissection. Lastly, patients who have thin abdominal wall musculature tend to have more elasticity and compliance to their abdominal wall. This lends itself to defect closure under less tension and better visualization of the layers of the abdominal wall. Additionally, epigastric and suprapubic defects are amendable to robotic repair utilizing a single-dock Rives-Stoppa technique. Both techniques for double-dock robotic TAR and single-dock Rives-Stoppa will be described in this chapter.

All patients are enrolled in an enhanced recovery after surgery protocol. This includes drinking 8 oz of carbohydrate-rich sports drink within 4 h of surgery and preoperative doses of celecoxib and pregabalin. The goal of this program is to avoid the use of narcotics intraoperatively as well as limit postoperative narcotic use as much as possible. Patients receive 5000 units of subcutaneous heparin preoperatively, in addition to mechanical sequential compression devices on the lower extremities for venous thromboembolic prevention.

Double-Dock Robotic TAR Technique

Patient Positioning and Theater Setup

The patient is positioned supine with the arms at 90 degrees. The patient's arms are not tucked since this would interfere with the ability to place the ports lateral and also impair movement of the robotic arms. The bed is flexed so the angle between the patient's costal margin and iliac crest is widened (Fig. 31.1). This step allows for a wider area in the lateral abdomen for horizontal port placement.

The room is set up for docking of the robot on the patient's left side and the side cart of the robot perpendicular to the bed. The center column is aligned over the patient's anterior superior iliac spine (Figs. 31.2 and 31.3). This allows working room for the assistant at the bedside between the side cart and the patient's right arm.

Fig. 31.1 Patient positioning

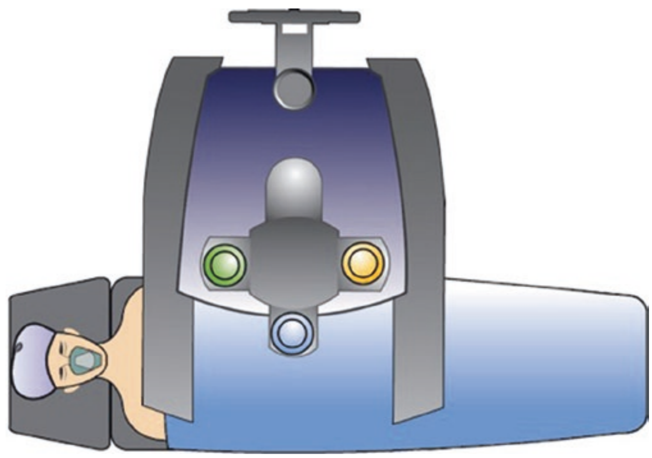

Fig. 31.2 Schematic of robotic docking (Copyright 2017, Intuitive Surgical, Inc. Used with permission)

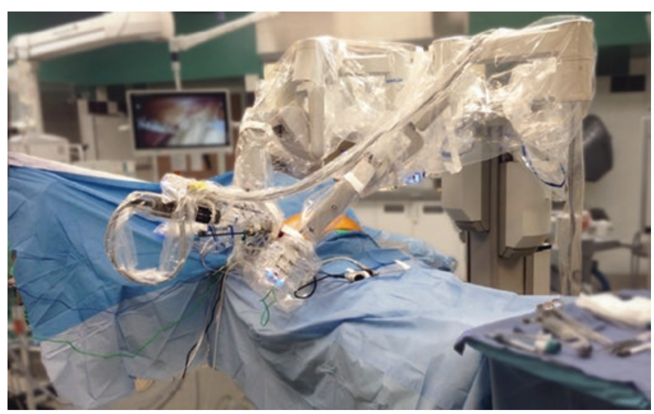

Fig. 31.3 Picture of robot docking

Incision and Access

Intraperitoneal access is obtained using a 5 mm optical view trocar at the right subcostal margin along the inferior border of the 11th rib. Once pneumoperitoneum is established, a 12 × 150 mm balloon tip trocar and 8 mm bariatric-length robotic trocar are placed on the right side, laterally along the midaxillary line. The initial 5 mm entry trocar is switched to a similar 8 mm bariatric-length robotic trocar (Fig. 31.4).

Operative Steps

Lysis of adhesions is first performed, either laparoscopically or robotically, depending on the patient and clinical scenario. Once the robotic ports are free of adhesions, the robot is docked to the right-sided ports, and any additional adhesiolysis is completed. Once the abdominal wall is clear of all adhesions, the abdomen is surveyed (Fig. 31.5).

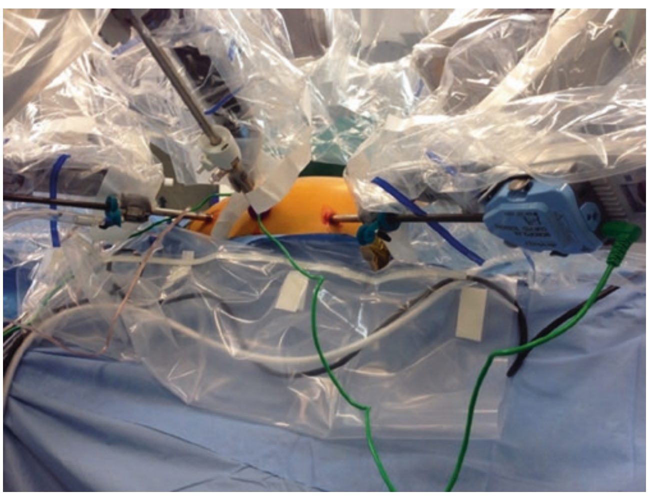

Fig. 31.4 Port placement with robot docked

Fig. 31.5 Hernia defect after adhesiolysis

The next step is to develop the retrorectus plane. This is similar to the open approach where the posterior rectus sheath is incised vertically, immediately lateral to the hernia edge or linea alba. The dissection is extended at least 5–7 cm above and below the hernia to allow for sufficient mesh overlap. The retrorectus dissection commences by peeling the posterior rectus sheath away from the posterior aspect of the rectus muscle (Fig. 31.6). This dissection is then carried laterally until the lateral perforating neurovascular bundles are encountered. Once these perforators are reached, this serves as the landmark for the most lateral extent of retrorectus dissection.

Once the lateral edge of the rectus sheath is reached (again as identified by the perforating vessels and nerves), then the transversus abdominis muscle is exposed by incising the posterior rectus sheath about 1 cm medial to the perforating vessels (Fig. 31.7). This incision is directed posteriorly. Once the posterior sheath is incised, the transversus abdominis muscle is identified and divided down to the transversalis fascia, thus releasing the muscle from its attachments to the posterior sheath. The TAR is most easily begun in the upper

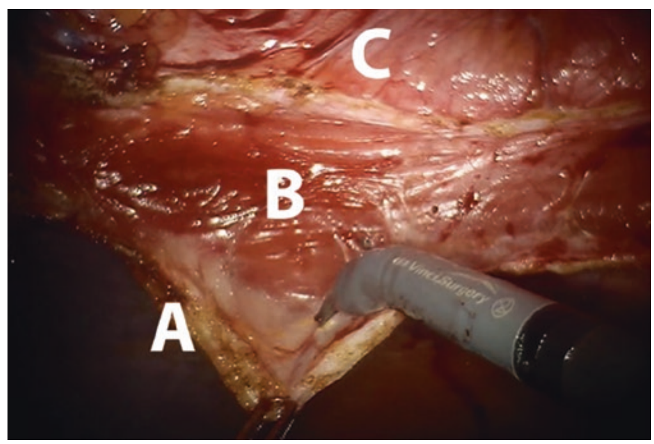

Fig. 31.6 Retrorectus dissection (**A**. cut edge of posterior sheath; **B**. rectus muscle; **C**. hernia defect)

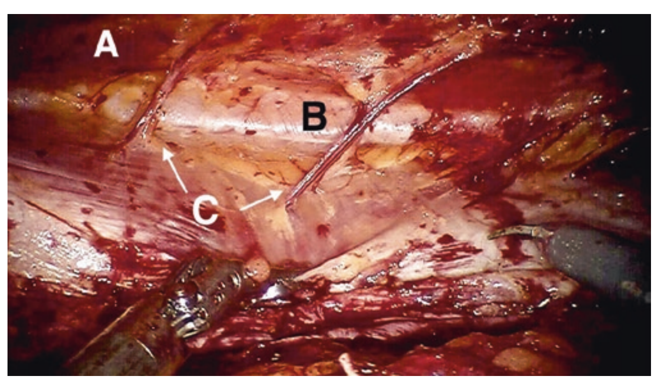

Fig. 31.7 Lateral border of retrorectus dissection (**A**. rectus muscle; **B**. semilunar line; **C**. neurovascular perforators)

abdomen, near the costal margin where the transversus abdominis muscle is more robust; however, the TAR can also be initiated in the lower abdomen. The division of the muscle is then extended inferiorly along the length of the entire dissection where it becomes less muscular and more aponeurotic. Again, it is critical to note that the line of division of the transversus abdominis muscle is medial to the neurovascular perforators (Fig. 31.8).

Once the muscle is divided, the transversalis fascia will be exposed; deep to that layer, lays the peritoneum (Fig. 31.9). Lateral dissection can continue in either of the pre-transversalis fascia or pre-peritoneal planes. The pre-peritoneal plane usually separates more easily, but the peritoneum can be extremely thin. The pre-transversalis plane is more difficult to develop but may be necessary if the peritoneum is too thin. Blunt dissection is performed from medial to lateral, peeling the peritoneum or transversalis fascia away from the posterior aspect of the cut transversus abdominis muscle.

This space is dissected, lateral, until the peritoneal flap, with the attached posterior sheath, rests without tension, upon the visceral contents below. This will create an extensive medialization of the posterior rectus sheath with peritoneum attached, laterally, for visceral sac closure later in the procedure. Small tears in the peritoneum during this dissection may be repaired with absorbable suture.

At this point, a similar configuration of trocars is placed on the contralateral side. Sizing of the retromuscular pocket, and thus the proposed mesh size, is now performed. The entire vertical dimension of the pocket is measured intracorporeally with a metric ruler. This will be the exact vertical dimension of the mesh. The horizontal measurement is made from the lateral most extent of the dissection to the lateral edge of the hernia defect or rectus muscle. The resulting measurement must then be doubled to reflect the similar dissection, which will be performed on the contralateral side.

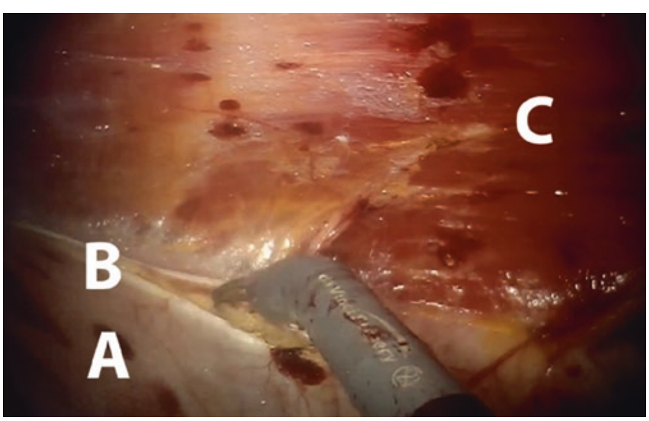

Fig. 31.8 Beginning the TAR with incision of the posterior sheath (**A**. posterior sheath; **B**. incision along posterior sheath; **C**. rectus muscle anteriorly)

A large-pore, mid-weight uncoated polypropylene mesh is cut to the measured size. The mesh is rolled along its vertical axis, leaving a 2 cm portion of mesh unrolled. An absorbable suture is placed into the mesh roll to prevent unrolling of the mesh during positioning. The mesh roll is now introduced into the dissected space through the contralateral 12 mm cannula on the left (Fig. 31.10). The mesh is positioned so that the unrolled edge lies under the contralateral cannula. The edge is secured to the lateral abdominal wall with absorbable suture.

The robot is then undocked from the right-sided trocars, the patient bed is pivoted 180 degrees, and the robot is re-docked with the left-sided trocars. The retrorectus and TAR dissection is carried out, identically, on the contralateral side. As this opposite dissection is carried out, the initial trocars, which were placed intraperitoneally, will need to be pulled back and repositioned pre-peritoneally, as dissection of the peritoneal flap continues lateral to them. The resulting peritoneal defects from these ports are closed with absorbable sutures.

The posterior rectus sheaths are now suture approximated in the midline, utilizing a 23 cm, 2-0, absorbable, self-fixating, barbed suture on a GS-22 needle (V-Loc™ 180, Covidien, Minneapolis, Minnesota, USA) (Fig. 31.11). The

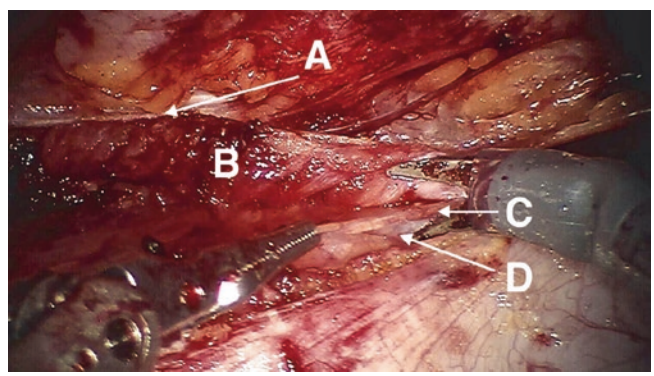

Fig. 31.9 Developing the TAR (**A**. cut edge of transversus abdominis fascia; **B**. cut edge of transversus abdominis muscle; **C**. transversalis fascia; **D**. pre-peritoneal plane)

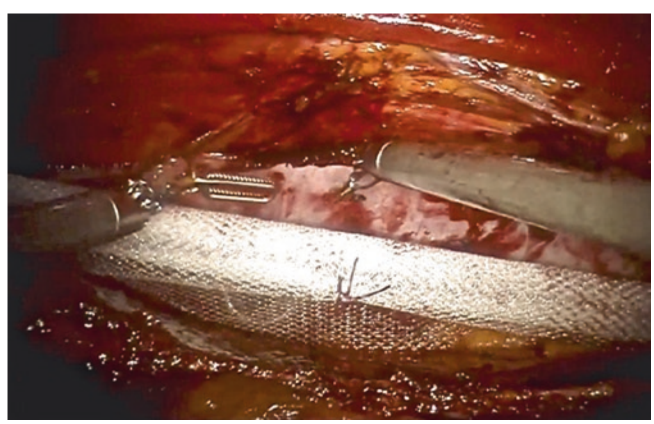

Fig. 31.10 Mesh positioning

posterior sheath and peritoneal flap are inspected a final time to identify any holes that were created or missed during dissection and closed with absorbable suture. At this juncture, the visceral sac is completely closed.

The suture holding the mesh roll is cut, and the mesh is unrolled toward the patient's right side (Fig. 31.12). The mesh should lie flat against the closed posterior sheath and occupy the entire retromuscular dissected space. Similar to the left side, the right edge of the mesh is secured to the lateral abdominal wall with absorbable suture. Additional superior and inferior fixation of the mesh is performed, as needed.

Closure

The anterior rectus sheath and hernia defect are now suture approximated with a 45 cm, #1, absorbable, self-fixating, barbed suture on a CT-1 needle (Stratafix™ Symmetric PDS™ Plus; Ethicon™, Somerville, New Jersey, USA). Every third bite of the fascia should incorporate a bite of the hernia sac to help obliterate the dead space and reduce the size of the resulting seroma. Decreasing the intra-abdominal pressure to 8–10 mmHg

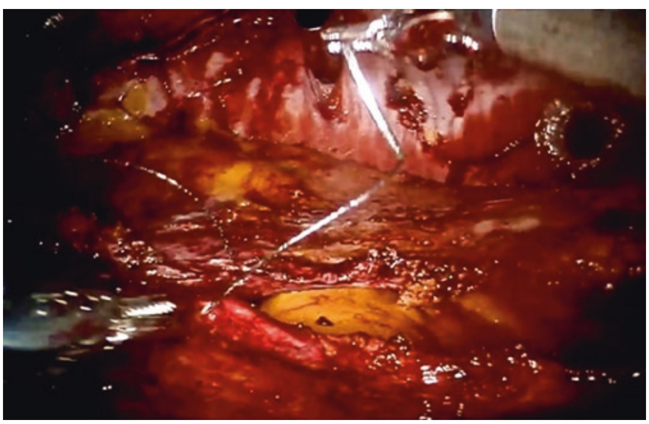

Fig. 31.11 Closing of posterior sheaths and thus visceral sac

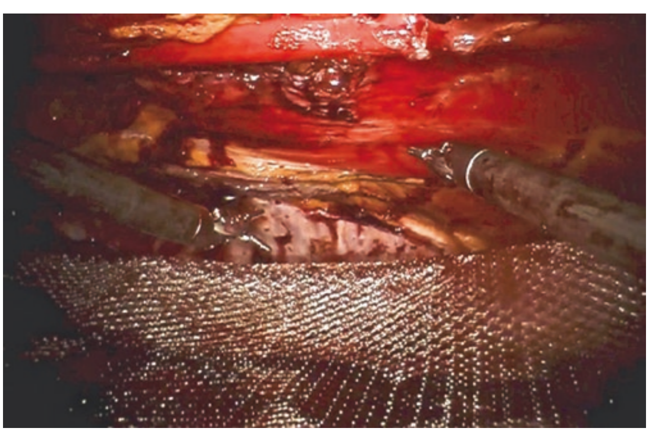

Fig. 31.12 Deployment of mesh

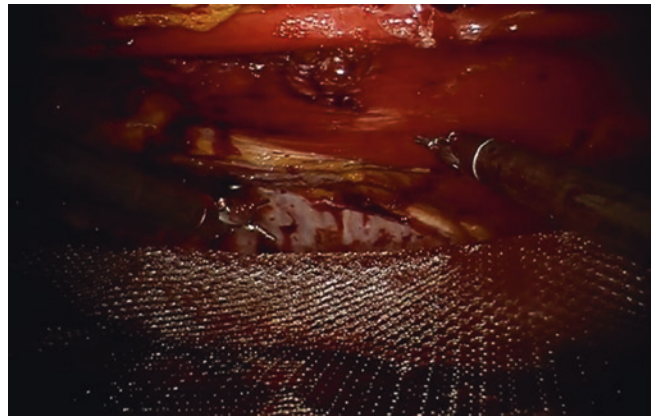

Fig. 31.13 Final mesh position

will help to facilitate fascial closure. Should there be excessive tension, the bedside assistant may place two to three figure-of-eight sutures with a suture passer device to bring the defect together, facilitating the running suture closure.

Once the fascial defect is closed, the robot is undocked, and the laparoscope is inserted to inspect and ensure the mesh is lying flat. The trocars are then removed and the procedure ended. The trocar sites do not require fascial closure, since the mesh extends beyond the fascial incisions in the retromuscular plane (Fig. 31.13). The skin is re-approximated with absorbable sutures and skin glue.

Single-Dock Rives-Stoppa Retromuscular Technique for Epigastric and Suprapubic Hernias

Patient Positioning and Theater Setup

This approach can be used for epigastric or suprapubic defects, which are amenable to a robotic approach. The patient is positioned supine with the arms at 90 degrees. The patient bed is flexed to allow the angle between the rib cage and pelvis to widen. This maneuver will increase the angle between the robotic arms and the patient's body which prevents the robotic arms from colliding with the patient's chest when performing suprapubic hernia repair. For subxiphoid defects, the patient is placed in a split-leg position and also flexed to prevent robotic arm collisions with the legs. The robot is then positioned parallel to the bed, and the arms are swung over the patient to dock to the ports.

Initial Access and Port Placement

For suprapubic defects, the initial port is placed in the right upper quadrant along the costal margin to gain entry into the abdominal cavity. This port is upsized to a 12 mm assistant port. Next, three ports are then placed in a straight line across the upper abdomen: one in the right upper quadrant (8 mm robotic port), one immediately off-midline (12 mm), and one in the left upper quadrant (8 mm robotic port). The 12 mm trocar for the camera is placed off-midline, directly through the rectus muscle, thus avoiding the linea alba, which is the thinnest portion of the abdominal wall (Figs. 31.14 and 31.15). For epigastric defects, the ports are essentially mirrored to go across the lower abdomen except for the assistant port, which is placed in the lower abdomen on the opposite side of the robot (Fig. 31.16). The robot is docked parallel to the patient, and arms are maneuvered to the ports.

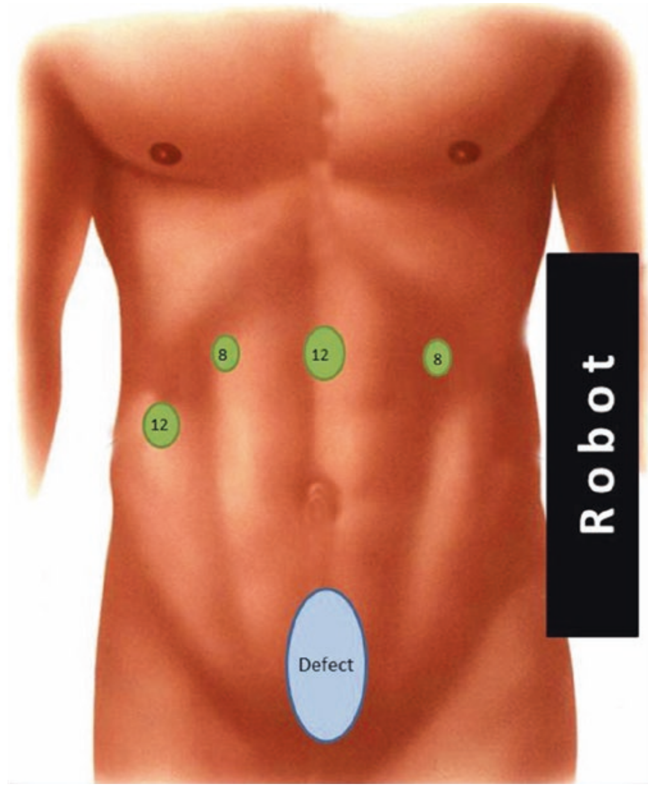

Fig. 31.15 Schematic of port placement and robotic docking for suprapubic defect

Operative Steps

After adhesiolysis is complete and the abdomen surveyed, dissection starts with a transverse incision of the posterior rectus sheath from semilunar line to semilunar line using monopolar scissors. The transverse incision must be made at least 5 cm from the edge of the defect as to allow for adequate mesh overlap. This dissection is carried medially toward the linea alba, and once the linea alba is encountered, the posterior sheath is incised. Dissection then continues within the pre-peritoneal plane. When the contralateral side is reached, the posterior sheath is incised on the contralateral side, and the retrorectus dissection continues toward the lateral border of the rectus (Fig. 31.17). It is important to preserve the linea alba when crossing from the underside of one rectus muscle to the next. The dissection is then carried toward and around the hernia defect. Once the hernia defect is encountered, dissection around the hernia sac begins by pulling the sac down from the abdominal wall and continuing dissection more anteriorly. If dissection becomes too dif-

Fig. 31.14 Suprapubic hernia port placement

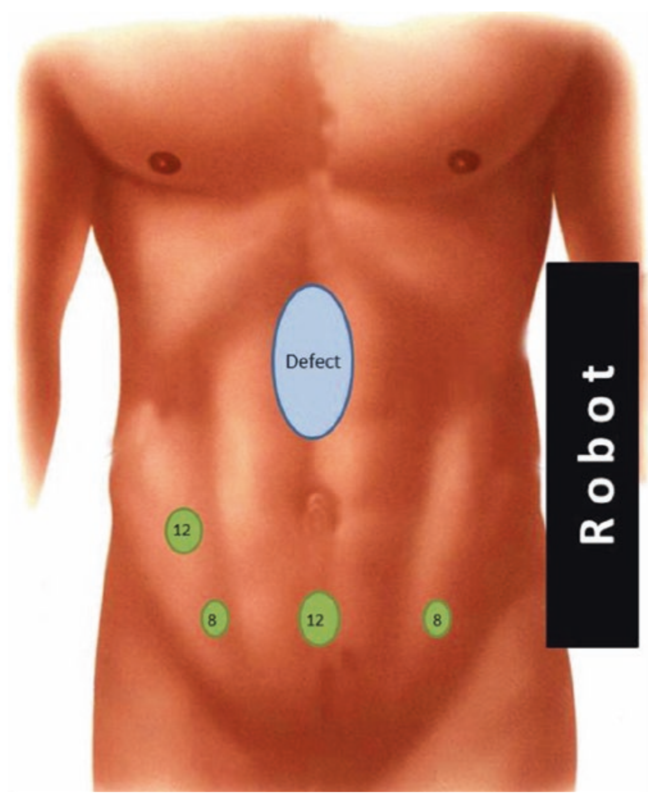

Fig. 31.16 Schematic of port placement and robotic docking for epigastric defect

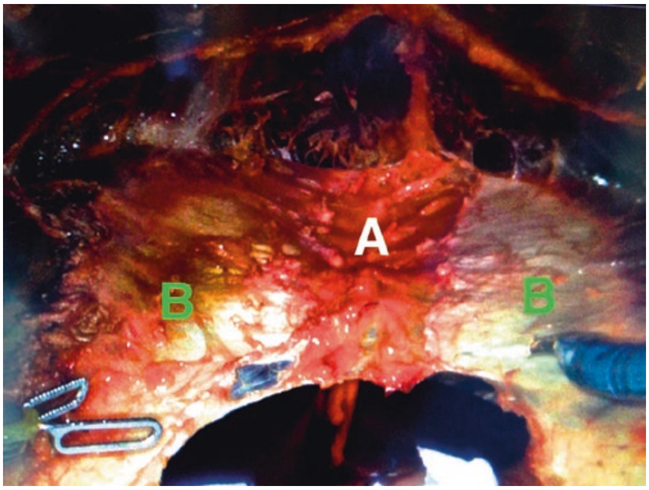

Fig. 31.17 Dissection of both sides of posterior rectus sheath and pre-peritoneal plane (**A**. pre-peritoneal plane; **B**. both sides of posterior rectus sheath mobilized off rectus muscle)

ficult here, the hernia sac can be transected; however, enough redundant hernia sac must be left behind for closure of the posterior sheath later.

After developing the entire retrorectus plane on both sides to the costal margin for epigastric defects or Cooper's ligaments for suprapubic defects, the hernia defect of the anterior abdominal wall is closed in a fashion similar to the double-dock technique. The large retromuscular space is then measured intracorporeally. Any defect in the posterior sheath or bridging peritoneum is closed with absorbable suture. The measurement of the dissected space allows tailoring of the mesh to exact dimensions for maximal mesh overlap. The mesh is brought into the field through the 12 mm assistant port and deployed against the anterior abdominal wall and fixated at its four corners with absorbable suture. Finally, the initial, horizontal flap, created by incising both posterior rectus sheaths, is closed utilizing a 23 cm, 2-0, absorbable, self-fixating, barbed suture on a GS-22 needle (V-Loc™ 180, Covidien, Minneapolis, Minnesota, USA).

Once this is complete, the robot is undocked, and the 12 mm port sites are closed with an absorbable suture utilizing a suture passer device. The skin is re-approximated with absorbable suture and skin glue.

Postoperative Management

All patients who undergo ventral hernia repairs receive the enhanced recovery after surgery protocol. This is a collaborative effort between surgeons, anesthesiologists, nurses, and therapists with the overall goal being to eliminate intraoperative administration of narcotics and significantly limit postoperative narcotic use. Urinary catheters are removed in the operating room. A postoperative, intravenous, low-dose ketamine infusion is utilized, in addition to intravenous acetaminophen and ketorolac. The ketamine infusion is discontinued on postoperative day 1 depending on the patient's level of pain control, and oral analgesics begun.

The patients and floor nursing staff are instructed to ambulate the patient as soon as possible following surgery, typically within a couple hours of arriving to the surgical ward. Diet is advanced as tolerated. Both mechanical and chemical venous thromboembolic prophylaxes are continued through the hospital stay. Most patients achieve adequate oral pain control on either postoperative day 1 or 2, resulting in an average length of stay between 1 and 2 days.

Tips and Pitfalls

- Patient selection is important. Midline defects 10 cm or less are quite amendable to robotic retromuscular ventral hernia repair.
- Patients who have a higher risk of wound complications (i.e., obesity, diabetes, smoking) will benefit from robotic repairs and a minimally invasive approach.
- Patients with wide and dystrophic scars or skin grafts should be repaired in an open fashion to allow for scar revision/removal.
- Proper patient positioning, trocar placement, and robotic docking will avoid situations such as instrument collisions or instrument movement limitations which make completing the repair difficult.
- Identification of the retrorectus neurovascular bundles provides an important landmark during dissection, marking the lateral border of the rectus muscle where the TAR should begin.
- Preservation of the blood supply and innervation to the rectus muscles allow for proper muscle function. If the TAR incision is made lateral to the perforating neurovascular bundle of the rectus muscle, there runs the risk of division of the semilunar line and separation of the oblique muscle attachments to the rectus muscle creating a more dysfunctional abdominal wall and large lateral hernia.
- Tears in the peritoneum and posterior sheath larger than 1 cm should be repaired to avoid intraparietal herniation or mesh exposure to the underlying viscera.
- An extensive lateral dissection should be performed, allowing for significant medialization of the posterior myofascial flap, creating a large space to place mesh in order to encompass the entire visceral sac.
- An enhanced recovery pathway will improve patient satisfaction; allow for a multimodal approach to analgesia, thus decreasing narcotic use; and shorten length of stay.

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Postpartum Divarication Navel-Sparing Treatment by Multidisciplinary Approach

32

Fien Decuypere, Rudolf Vertriest, Iris Kyle-Leinhase, and Filip Muysoms

Introduction

PPAWI (postpartum abdominal wall insufficiency) is an acronym first introduced during the 35th Annual Congress of European Hernia Society in Gdansk, Poland, May 2013. It is a pathological condition induced by abdominal distension during pregnancy. It consists of general laxity of the anterior abdominal wall because of diastasis of the rectus abdominis muscles and of excess skin and panniculus. This has important repercussion on abdominal wall function and its aesthetics. The abdominal wall function is impaired with loss of integrity of myofascial systems with reduced thickness of rectus muscles. Typically, there is an altered angle of attachment.

There is a reported incidence of rectus diastasis of 66% during third trimester [1]. This is induced by the combination of abdominal distension (elevated intra-abdominal pressure) and biomechanical and structural changes of the rectus muscles and linea alba. These are also induced by hormonal influences [2, 3].

Women with severe impaired abdominal wall function often complain about loss of the abdominal muscle strength and endurance. This can also result in low back pain caused by overcompensating of the back muscles. Loss of the pelvic stabilization has also been reported. Aesthetic problems related to the shape of the abdomen are a problem. Women look like they are still pregnant.

The diagnosis is based on physical examination. During the examination, there is a weakness of abdominal wall musculature with prominent diastasis of the rectus abdominis muscles and panniculus of lower abdomen. Imaging can confirm the diagnosis. CT scan and ultrasound are both valid imaging studies to objectify the rectus diastasis.

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We propose our one-step multidisciplinary surgical approach to treat PPAWI. During this surgery, the panniculectomy to address the excess of skin is done by a plastic surgeon. The mesh augmentation of the abdominal wall to treat the rectus diastasis is done by the abdominal wall surgeon.

Indications

Surgery is advised when the impaired abdominal wall function is symptomatic and/or the women have aesthetic problems. We propose a mesh augmentation when the maximum inter-recti distance (IRD) is more than 4 cm in width measured by ultrasound or if there is a concomitant umbilical or epigastric hernia. PPAWI patients with an IRD less than 4 cm and no concomitant hernia are treated with panniculectomy and reeving of the diastasis by the plastic surgeons without mesh augmentation.

Preoperative Considerations

Physical exercise can diminish the excess of skin and panniculus but will never be sufficient to treat the postpartum rectus diastasis. We perform an ultrasound preoperative to measure the IRD and detect umbilical or epigastric hernia. The women should have a clear statement that they have no intention for a subsequent pregnancy. Smoking cessation should be advised to smokers.

Patient Positioning and Theater Setup

Preoperatively the plastic surgeon makes his drawings on the standing patient. The midline and the incision for the horizontal abdominoplasty are marked (Fig. 32.1). When liposuction is indicated, the zones are also denoted.

The patient is brought under general anesthesia. A nasogastric tube and a bladder catheter are placed. Antibiotic pro-

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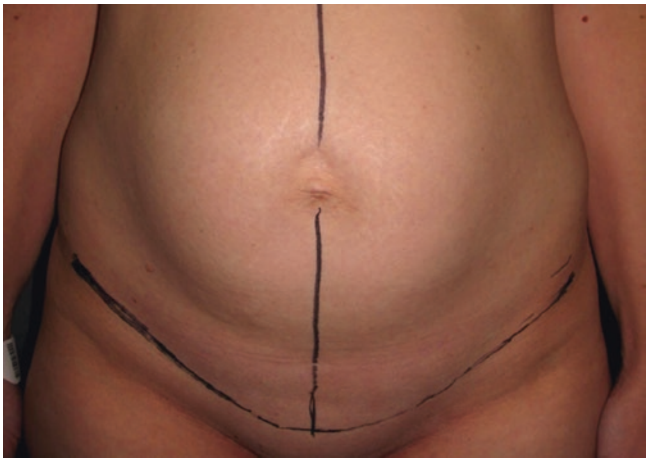

Fig. 32.1 Preoperative markings by the plastic surgeon (AZ Maria Middelares, Ghent, Belgium)

phylaxis with cefazolin is given. The patient is positioned in dorsal decubitus with the arms in 90° abduction. The patient should be positioned on an operating table which can be set in beach chair position. Disinfection and sterile covering of the abdomen are done. This operation will usually take around 180 min. During the surgery, a normal systolic blood pressure is maintained.

Incision and Access

The plastic surgeon starts with a navel sparing horizontal high-tension abdominoplasty following the previous markings. An incision with a 24 blade is made from hip to hip just above the pubic area. Another incision is made vertically on the midline to free the navel from the surrounding skin using a circular incision around the navel. For this circular incision, skin hooks are used to stretch the skin of the navel. The abdominal skin is detached from the abdominal wall using coagulation. Detachment of the skin and subcutis is done up to the xiphoid bone, in order to sufficiently mobilize the skin downward. In this way, a narrow tunnel is made from the navel to the xiphoid bone. This leaves most of the abdominal skin tethered to the muscle and its blood supply (with the perforating arteries). In order to estimate the amount of tissue to be resected, a Lockwood abdominal demarcator is used. Removal of excess skin and subcutis is done with a 24 bladed knife and meticulous control of hemostasis (Fig. 32.2a and b).

The abdominoplasty can also be done with sparing of the perforators in order to prevent flap ischemia. This is done by a discontinuous dissection of the skin and subcutis.

Operative Steps

After the horizontal abdominoplasty, the abdominal wall surgeon starts with the mesh augmentation:

1. Make two separate incisions in the linea alba with coagulation: one beneath the navel (±3 cm beneath) and one above the navel (±3 cm above). This while preserving the vascularization of the navel at maximum (Fig. 32.3).
2. Connect both retro-muscular dissections under in situ umbilicus by making a tunnel (Fig. 32.4).
3. Free the posterior fascia by dissection. Approximate the posterior fascia using a Kocher. Close the posterior layer using running suture with a slowly absorbable suture (Monomax 2.0) using a small bites technique (Fig. 32.5).
4. Mark the middle of the mesh (Parietex Progrip® self-fixating mesh (10 × 30 cm)). Fold the edges of the mesh to the center of the mesh. Place the mesh retro-muscular with the hooks orientated upward. Unfold the mesh. Medialization of rectus muscles on top of self-fixating hooks (Fig. 32.6).
5. Close the anterior fascia using a running slowly absorbable suture (Monomax 2.0) (Fig. 32.7).
6. Tighten the abdominal wall by reefing rectus fascia with nonabsorbable multifilament figure of eight sutures (Mersuture 1.0) (Fig. 32.8).

Closure

Liposuction can be used to refine the transition zones of the abdominal sculpture. The closure is done in beach chair position. The skin is stretched out to the primary incision place. A circular incision is made on the skin in order to reinsert the navel (fixation of the navel using Vicryl 3.0).

Close the subcutis with separate sutures Vicryl 3.0. Two subcutaneous drains are placed and fixated with Ethilon. Control of hemostasis. Closure of the dermis with separate sutures Monocryl 3.0. Closure intradermal of the skin with running sutures Monocryl 4.0 with loops. Application of skin glue (Dermabond). Dressings. An elastic abdominal binder is put immediately after surgery.

Postoperative Management

The gastric tube can be removed immediately after the operation. The patient stays in beach chair position postoperative during the length of the hospital stay. The bladder catheter can be removed the next day. The two

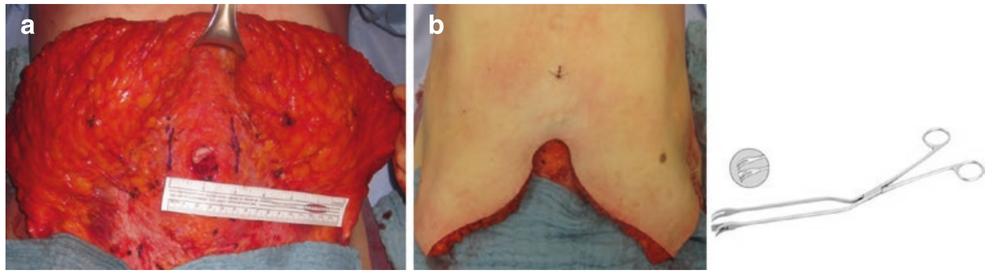

Fig. 32.2 (**a**) Abdominoplasty performed by the plastic surgeon (AZ Maria Middelares, Ghent, Belgium). (**b**) Lockwood abdominal demarcator

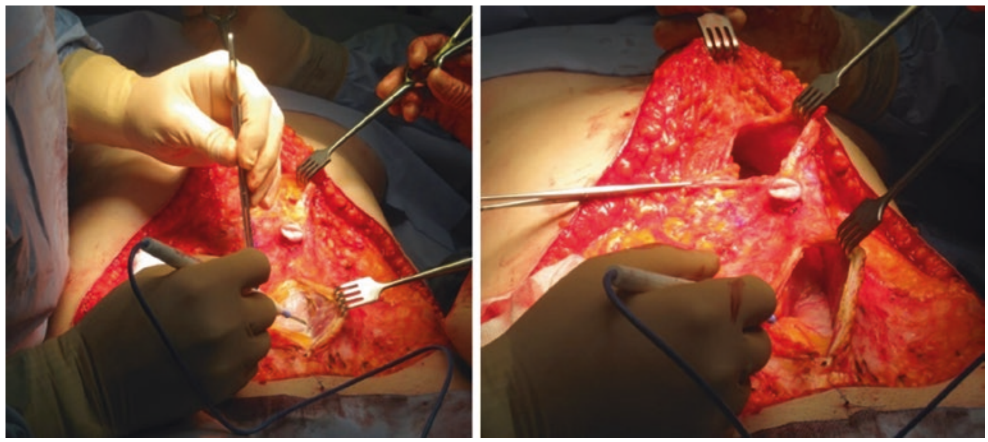

Fig. 32.3 Incision in the linea alba by the abdominal surgeon (AZ Maria Middelares, Ghent, Belgium)

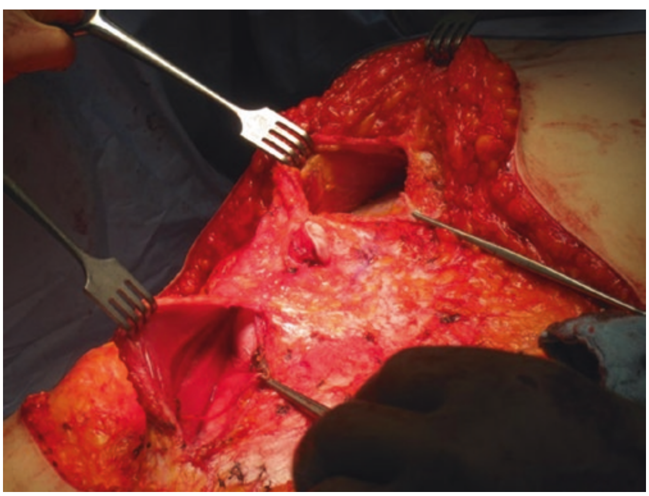

Fig. 32.4 Connecting retro-muscular dissection by the abdominal surgeon (AZ Maria Middelares, Ghent, Belgium)

subcutaneous drains can be removed the next day if the output is less than 30 cc. Most patients stay 2 days in the hospital for adequate analgesia. All women should wear an elastic medical abdominal binder for a minimum of 3 weeks. Postoperative dry and aseptic wound care with removal of the sutures (the loops of the Monocryl 4.0) after 10 days. Pain management with paracetamol, 1 g with a maximum of four times a day. Thrombosis prophylaxis with low molecular weight heparin for 10 days. Most patients are able to return to work in 3 weeks (if the work is not too physically strenuous). A surgery follow-up should be done after 6 weeks. Another is done after 6 months and at 1 year.

Tips and Pitfalls

- Use a self-fixating mesh.
- If there is a concomitant hernia (epigastric or umbilical), they will be treated by the mesh augmentation as well.
- When you free the navel during the abdominoplasty, mark the cranial side of the navel; in that way, the rotation of the navel can be easily preserved.
- When folding the self-fixating mesh, make sure to not fold it too tight in order to easily unfold it retro-muscular.

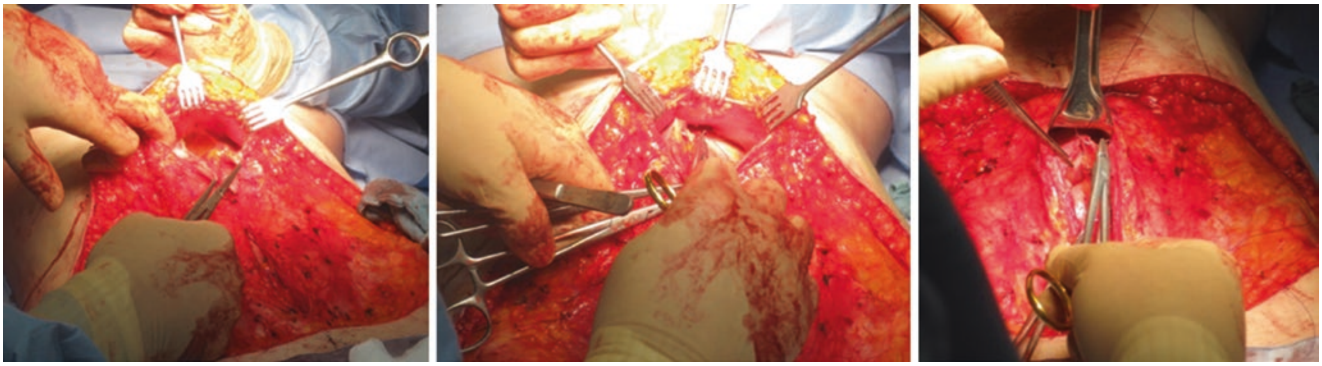

Fig. 32.5 Closure of the posterior fascia by the abdominal surgeon (AZ Maria Middelares, Ghent, Belgium)

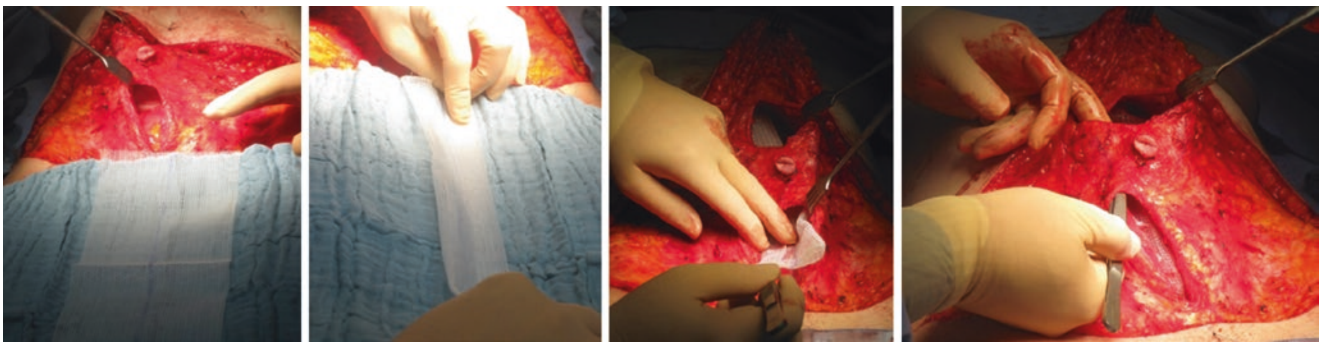

Fig. 32.6 Positioning of the Parietex Progrip self-fixating mesh by the abdominal surgeon (AZ Maria Middelares, Ghent, Belgium)

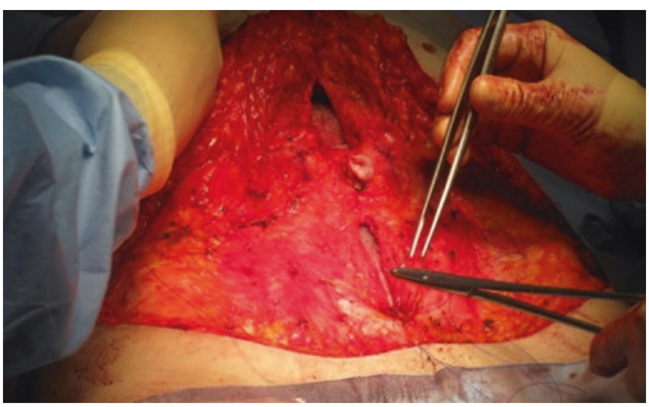

Fig. 32.7 Closure of the anterior fascia by the abdominal surgeon (AZ Maria Middelares, Ghent, Belgium)

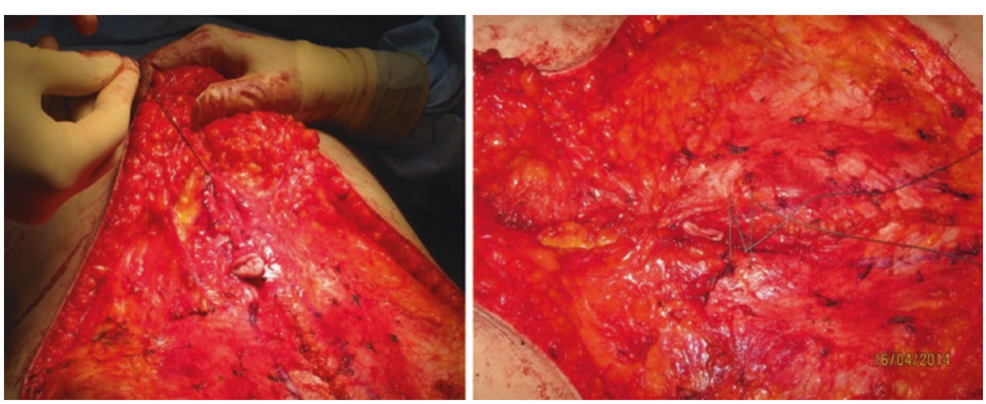

Fig. 32.8 Reefing of the abdominal wall by the plastic surgeon (AZ Maria Middelares, Ghent, Belgium)

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Umbilical, Epigastric, and Spigelian Hernias

33

David L. Webb, Benjamin S. Powell, Nathaniel F. Stoikes, and Guy R. Voeller

Introduction

Primary ventral hernias are hernias that occur spontaneously along fascial defects of the anterior abdominal wall. Inguinal hernias are the most common type of primary ventral hernias and are discussed separately. This chapter focuses on three specific types of primary abdominal wall hernias: Spigelian, epigastric, and umbilical hernias. Though they occur less frequently than their inguinal counterparts, a thorough understanding of the causes and treatment options for these specific types of hernias is important for any practicing general surgeon. These primary abdominal wall hernias can oftentimes prove to be a diagnostic challenge, and one must approach them with a high index of suspicion to prevent a delay in diagnosis and subsequent surgical intervention. This chapter will discuss the typical presentation, etiology, and the various treatment options currently available to manage these specific types of primary ventral hernias.

Embryology

A thorough understanding of the development of the abdominal wall is necessary to appreciate the nature of the hernia defects discussed in this chapter. Abdominal wall and bowel development occur simultaneously during the third through twelfth weeks of intrauterine life. By the third week, the embryo has developed cephalic, caudal, and lateral folds (Fig. 33.1). The cephalic fold is anterior and contains the foregut, stomach, and mediastinal contents. Somatic layer defects in the cephalic fold may result in diaphragmatic, thoracic wall, cardiac, or pericardial defects. The caudal fold contains the hindgut, bladder, and hypogastric abdominal wall. Defects in the caudal fold may result in bladder exstrophy. The lateral folds become the lateral abdominal wall and future umbilical ring. Defects in the lateral fold may result in a congenital umbilical hernia or omphalocele depending on the size of the resultant fascial defect. By the sixth week of intrauterine life, rapid growth of the liver and intestines causes herniation of the midgut through the umbilical ring. By the tenth week, the abdominal cavity has enlarged sufficiently to accommodate the return of the abdominal viscera. The duodenum and proximal colon undergo a counterclockwise rotation as the intestines return intra-abdominally. Congenital defects that result from malformation of the abdominal wall include both omphalocele and gastroschisis. Omphalocele results from failure of the intestines to return to the abdomen and thus remain confined within the umbilical ring. Gastroschisis is a full-thickness abdominal wall defect that results in the intestines herniating into the amniotic cavity without a covering membrane.

Anatomy of the Abdominal Wall

Abdominal wall anatomy is complex, and a thorough understanding of the layers of abdominal wall musculature is key to performing hernia surgery.

The abdominal wall is a hexagonal configuration and is bordered caudally by the pelvic wall and pubic symphysis, cranially by the costal margin and xiphoid, and laterally by the midaxillary line. The rectus abdominis muscle fibers run vertically from the costal margin to the pubis paralleling the linea alba at the midline (Fig. 33.2). Each rectus muscle has its origin on the fifth, sixth, and seventh rib and the xiphoid process cranially and inserts onto the pubic bone caudally. The three-layer lateral portion of the abdominal wall is composed of the external oblique, internal oblique, and the transversus abdominis. The fibers of each muscle layer run in different directions. The fibers of the external oblique run inferior and anterior, the internal oblique fibers run superior

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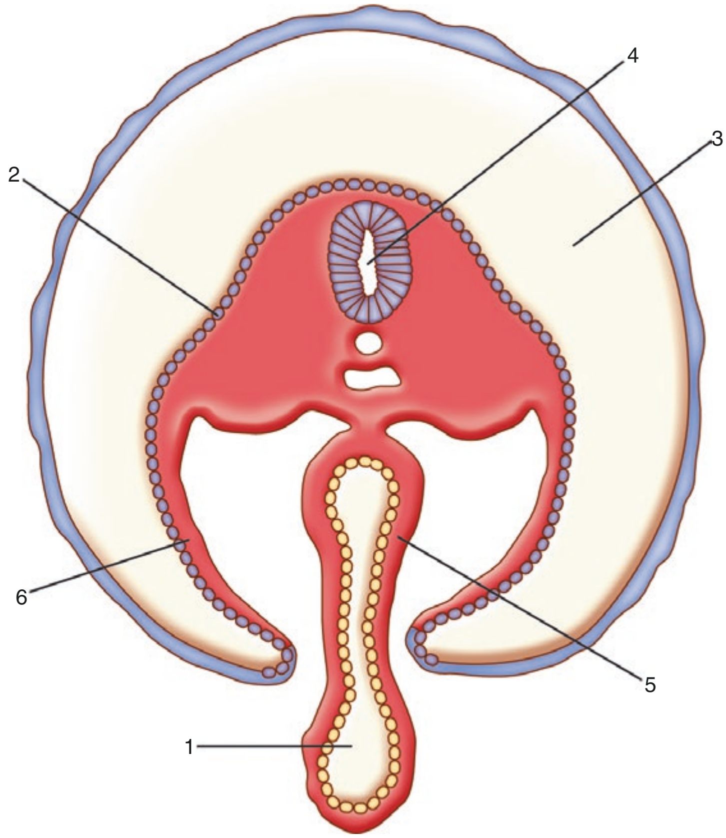
Fig. 33.1 Formation of ventral abdominal wall. *1*. Yolk sac. *2*. Surface endoderm. *3*. Amniotic cavity. *4*. Neural tube. *5*. Splanchnic mesoderm. *6*. Somatic mesoderm



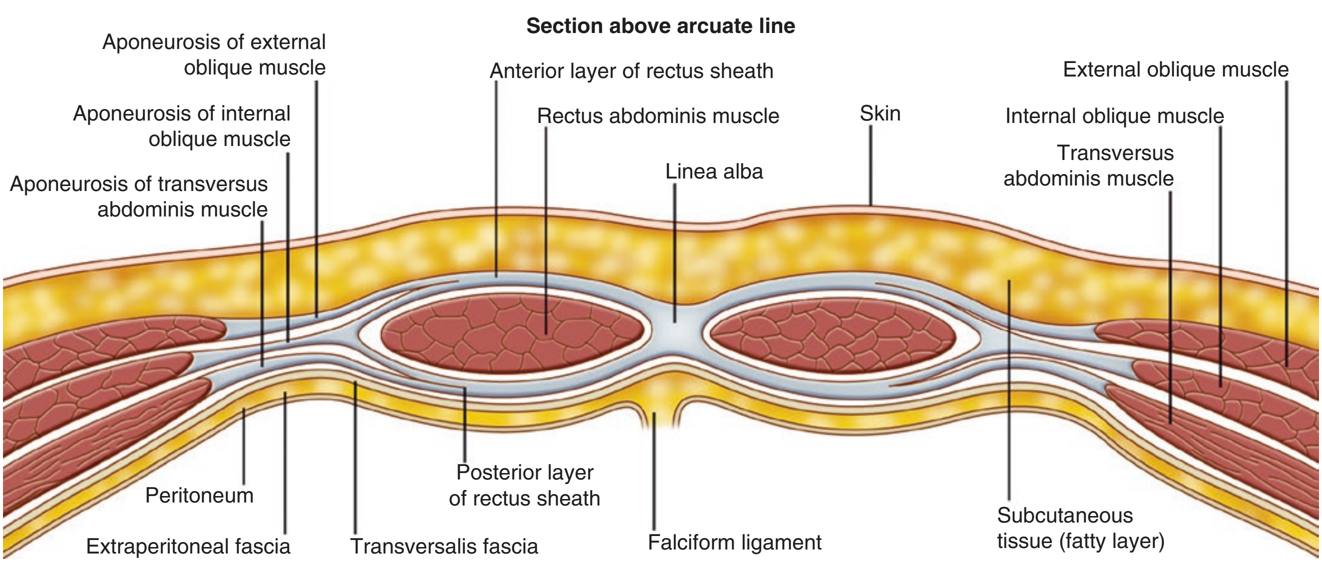


Fig. 33.2 The rectus abdominis surrounding the linea alba in the midline where epigastric and umbilical hernias arise

and anterior, and the transversus abdominis fibers run transversely (Fig. 33.3). Primary ventral hernias rarely form through the lateral abdominal wall muscle group and typically occur through defects in the linea alba or the semilunar lines.

The linea alba is formed from the fusion of the aponeuroses of the rectus sheaths and lateral abdominal wall muscles at the midline and runs from xiphoid process to pubic symphysis. The linea alba is the most common location for both primary and incisional hernias on the anterior abdominal wall. The linea alba is typically wider above the umbilicus than it is below. In cadaver studies, the average width of the linea alba above the umbilicus measured approximately 1.7 cm compared to 0.7 cm below. This accounts for the higher incidence of primary ventral hernias along the linea alba above the umbilicus.

The semilunar line (Spigelian line) is formed by the musculoaponeurotic junction of the transversus abdominis

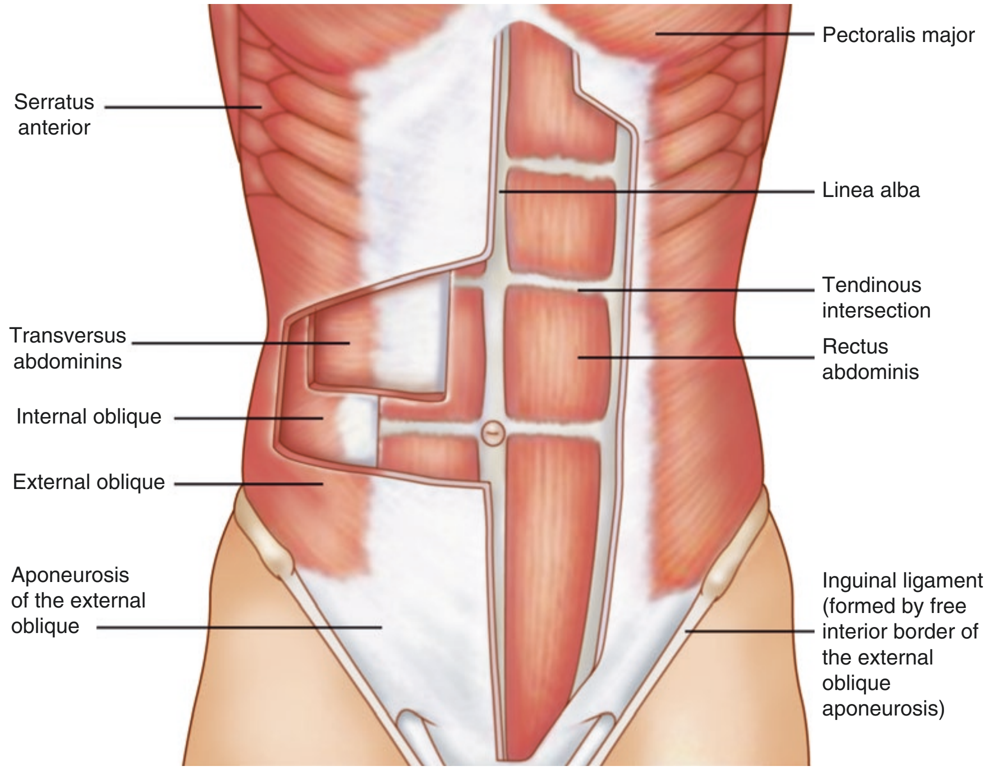


Fig. 33.3 Orientation of the internal oblique, external oblique fibers, and the transversus abdominis of the abdominal wall

muscle and runs in a gentle curve from the costal margin to the groin lateral to the rectus muscle on either side of the abdomen. The lateral edge of the rectus muscle runs from the costal margin to pubic symphysis following a similar curve as the semilunar line. The Spigelian fascia runs between these two lines and consists of the fused aponeuroses of the transversus abdominis and internal oblique muscles. The arcuate line (line of Douglas) runs transversely across the lower abdomen and marks the inferior margin of the posterior rectus sheath. Below the arcuate line, all three lateral abdominal wall muscle aponeuroses cross anterior to the rectus muscle. The intersection of the Spigelian line and the arcuate line is a point of weakness in the abdominal wall and is often referred to as the Spigelian hernia belt (Fig. 33.4). The inferior epigastric vessels run in the lateral rectus sheath at this point in the abdominal wall, and many anatomists propose that this contributes to the relative weakness. A triangle is formed by the inferior epigastric vessels medially, the Spigelian line laterally, and the arcuate line superiorly.

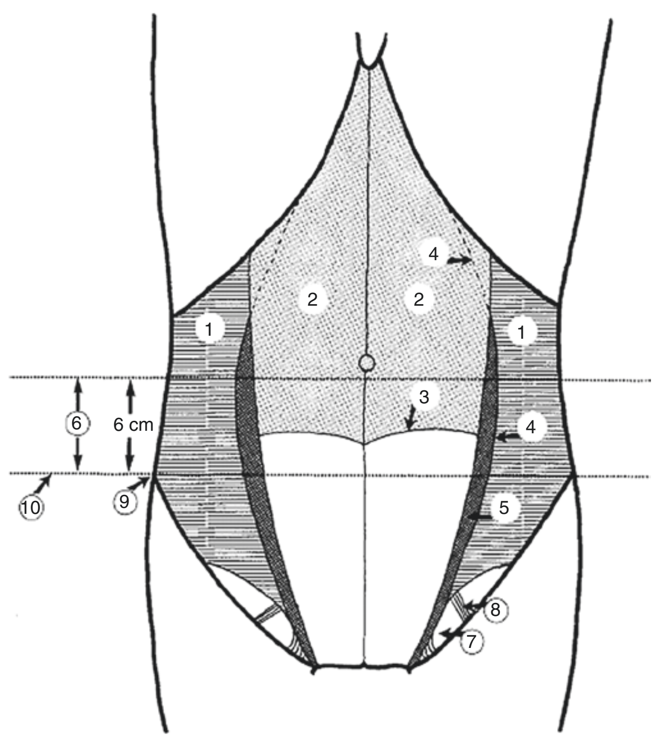


Fig. 33.4 Spigelian hernia belt. External and internal obliques are cut away in this figure. *1*. Transversus abdominis. *2*. Dorsal lamella of the rectus sheath. *3*. Semicircular line of Douglas. *4*. The semilunar line. *5*. Spigelian aponeurosis. *6*. Spigelian hernia belt. *7*. Hesselbach's triangle. *8*. Inferior epigastric vessels. *9*. Anterior superior iliac spine. *10*. Interspinal plane

Spigelian Hernia

Definition and Epidemiology

Spigelian hernias occur through defects in the Spigelian fascia between the semilunar line laterally and edge of rectus sheath medially. These hernias typically form below the arcuate line because of the relative weakness that exists due to the absence of the posterior sheath [1, 2]. The defect typically involves both the transversus abdominis and internal oblique fasciae, with the external oblique fascia remaining intact. As a result, Spigelian hernias may be difficult to appreciate on physical exam and can be missed at the time of an open operation until the external oblique fascia is opened [3].

The incidence of Spigelian hernias in the pediatric population is low. It has been theorized that the hernia may result from a congenital defect in fusion of the mesenchymal layers and is often associated with cryptorchidism [4]. Spigelian hernias in the adult population are typically acquired. It has been theorized that these hernias may be related to the stretching of the abdominal wall caused by previous surgery, collagen disorders, obesity, COPD, or pregnancy. For whatever cause, the acquired weakness in the Spigelian fascia allows interdigitation of fat that acts as a lead point for the hernia. The male to female ratio is 1:1.8, and some authors estimate that it comprises about 0.12% of all abdominal wall hernias. Ultrasound and CT scan are useful aids in diagnosis, but as shown by the Mayo study below, there are false negatives with these tests.

History

Adriaan van den Spieghel first described the Spigelian or semilunar line in the seventeenth century as the medial concave line that is the boundary between the muscle and the anterior aponeurosis of the transversus abdominis. Klinkosch first described the Spigelian hernia in 1764. In the early nineteenth century, Sir Astley Cooper published a series of 23 hernias that occurred along the Spigelian line [5, 6].

Current Literature

Literature specific to repair of Spigelian hernias tends to be limited to small case series and date back as far as the 1930s. Louis River published one of the first case series in which he described his management of five patients with Spigelian hernias. He reviewed the anatomic defects present in each of his patients and described his method of primary tissue repair. Watson, Read, and Weiss followed by publishing their personal experiences in managing Spigelian hernias. These publications all predated the routine use of synthetic mesh reinforcement for hernia repair and, therefore, all advocated for a primary tissue repair.

The current literature specific to this type of primary ventral hernia is still limited to small cases series but now includes discussion regarding the ideal method of repair for these types of hernias. Some authors still favor a primary tissue repair, despite the growing majority advocating a mesh-based repair performed via either an open or laparoscopic approach. Hsieh published a case series of 11 patients with Spigelian hernias. Seven patients received an open primary tissue repair with the remaining four patients receiving an open preperitoneal repair with mesh [7]. Mean follow-up was 8.5 years for the primary repair group versus 6.7 years for the mesh repair group. They found no recurrences in either group with similar complication rates. The paper unfortunately illustrates the low number of these hernias repaired by any one group, making it difficult to judge one method of repair being superior to another.

Larson et al. published the largest case series to date from their experience at the Mayo Clinic. They described a total of 81 hernia repairs over a 20-year time period. Mass, pain, or bowel obstruction were the most common symptoms on presentation. Preoperative imaging was done in 21 patients and was positive in 15. Open primary tissue repair was performed in 75 patients, open mesh repair in 5 patients, and laparoscopic mesh onlay repair in 1. Mean follow-up for 76 patients was 8 years with 3 reported hernia recurrences, all in the primary suture repair group [8].

In 2006, Malazgirt published a prospective multicenter study consisting of 34 patients with Spigelian hernias [9]. Twenty-three patients underwent an open intraperitoneal mesh repair, six patients received an open preperitoneal mesh repair, three received a laparoscopic intraperitoneal onlay mesh repair, and two patients received an open primary tissue repair. Mean follow-up was 30 months, and overall postoperative complication and recurrence rates were low. The authors concluded the type of repair is surgeon dependent but that preperitoneal repairs, either open or laparoscopic, yield shorter hospital stays and better patient compliance.

Spigelian hernia does lend itself to a laparoscopic extraperitoneal hernia repair as published by Koksal et al. [10]. They described an approach in which the trocar setup is virtually identical to a traditional TEP inguinal hernia repair. The preperitoneal space is dissected and used to allow space for mesh placement. The mesh is placed a little more cephalad than when done for an inguinal hernia. The authors of this chapter have performed a similar type of laparoscopic preperitoneal mesh repair on 24 patients with Spigelian hernias diagnosed incidentally during TEP inguinal hernia repairs with no known recurrences to date.

Moreno-Egea et al. showed that laparoscopic repair might be more beneficial to patients in regard to morbidity and hospital length of stay [11]. Twenty-two patients in their study underwent elective repair of Spigelian hernia; eleven had open preperitoneal repair, while the other 11 had laparoscopic repair. In the laparoscopic group, eight were performed via the TEP method, while the other three underwent a laparoscopic intraperitoneal onlay mesh placement. Average length of stay in the open group was 5 days, while the laparoscopic approach was 1 day, with a p value <0.001. There were no postoperative complications in the laparoscopic approach, but the conventional method had four patients with hematomas.

An approach the authors of this chapter have also used is a hybrid laparoscopic and open approach. We first perform a diagnostic laparoscopy, placing a 5 mm laparoscope intra-abdominally to evaluate the exact location of the Spigelian hernia. After proper identification of the hernia defect, we then make a small incision over the hernia and repair the defect with a Ventralex ST-type patch via an open anterior approach. This allows complete excision of the hernia sac and closure of the fascia over the patch. This approach is excellent for managing larger hernia sacs that may lead to seromas and skin bulging if not excised.

Epigastric Hernia

Definition and Epidemiology

An epigastric hernia is primary abdominal wall hernia that forms through a defect in the linea alba between the xiphoid process and umbilicus [12]. The exact incidence of epigastric hernias is largely unknown owning to a variety of different factors. They are diagnosed infrequently in the children and are typically found in the adult population with a male to female ratio of approximately 3:1.

Several theories regarding the etiology of epigastric hernias have been put forward since the early 1900s. In 1914, Moschcowitz described the vascular lacunae hypothesis. He theorized that vascular lacunae formed when small blood vessels penetrated the linea alba [13]. These points of penetration were felt to result in a small space through which preperitoneal fat from the falciform ligament could begin to herniate through and enlarge over time. Alternatively, Askar proposed the decussation theory for the formation of epigastric hernias in 1978. Askar dissected a large number of cadavers and emphasized the importance that fibers crossing the midline play in reinforcing the linea alba. He found individuals who did not have triple lines of fiber decussation reinforcing the linea alba were more likely to form epigastric hernias [14]. Most likely, the etiology of epigastric hernias is multifactorial and results from a combination of these anatomic hypotheses coupled with inherited collagen disorders and environmental factors including increased intra-abdominal pressure.

The presentation of epigastric hernias is widely variable and patient dependent. Symptoms may be out of proportion to their relative size of the hernia defect, and patients often present with pain with physical activity, upper abdominal discomfort, or an enlarging bulge in the upper abdomen. In cases of diagnostic uncertainty, patients require a complete physical examination and work-up to rule out other causes of abdominal pain as epigastric hernias can mimic other intra-abdominal pathology such as symptomatic cholelithiasis and peptic ulcer disease.

History

Arnaud de Villeneuve of France first described epigastric hernias in 1285. In 1742, Rene' de Garengeot more clearly defined this type of hernia and attributed its symptoms pathology of the underlying intra-abdominal organs. Maunior described with the first repair of an epigastric hernia in 1802, but the procedure quickly fell out of favor because of complications probably due to the iatrogenic injury of intra-abdominal viscera at the time of repair. In 1885, Terrier published his account of a successful epigastric hernia repair and helped bring renewed attention to treatment of these types of hernias.

Literature

There is a relative paucity of randomized controlled trials devoted solely to the repair of epigastric hernia. Despite this, a number of case series detailing repair methods for epigastric hernias have been published over the years. Ponten recently published the largest case series report to date devoted solely to epigastric hernias. His series included 235 epigastric hernia repairs over a 5-year period; 68 patients received a mesh-based repair versus 167 patients with a primary suture repair. Hernia recurrence rate was lower in the mesh-based repair group compared to the primary repair group (10.9% vs. 14.9%). Incidence of chronic pain was equivalent in both groups [15]. Similarly, Stabilini published a retrospective series comparing suture repair versus open preperitoneal mesh placement with polypropylene mesh [16]. The mean hernia defect size was 2.5 cm (range of 0.5–10 cm). Recurrence rate was 14.7% in the suture repair group vs. 3.1% in the mesh group. There were more local wound complications with the mesh group; however, this does not seem to offset the recurrence risk in the suture group. Unfortunately, most other data on epigastric hernias in the last 20 years is isolated to smaller case reports [17, 18]. Most studies on the topic combine epigastric hernias into the broader category of primary ventral hernias, and these will be discussed later in this chapter [19].

Umbilical Hernia

Definition and Epidemiology

An umbilical hernia is a primary ventral hernia located at or near the umbilicus and is seen frequently in surgical practice. Congenital umbilical hernias result from failure of the umbilical ring to close properly during embryological development. The formation of the umbilicus occurs early in gestation as a result of the fusion of the body stalk containing the umbilical vessels and allantois with the extracoelomic yolk stalk containing the vitelline duct and vessels. As described previously, the fetal midgut typically returns to the abdominal cavity by the twelfth week gestation, and the abdominal wall closes as the celomic sac obliterates. Failure of this process can result in formation of an umbilical hernia.

Umbilical hernias in infants are quite common, and the vast majority will close spontaneously by the age of 2 years. Hernias that persist after the age of 5 years will typically require surgical repair. Umbilical hernias in the adult population are most commonly acquired defects. They occur more frequently in women and in patients with conditions that result in increased intra-abdominal pressure, such as pregnancy, obesity, ascites or abdominal distention, and chronic pulmonary disease.

Small asymptomatic umbilical hernias barely detectable on physical exam may be managed with observation. Patients presenting with symptoms (typically periumbilical pain with physical activity), an enlarging hernia defect, incarceration, thinning of the overlying skin, or recurrent ascites should undergo prompt surgical repair.

History

The first reported umbilical hernia repair in the United States was performed by Stoser in 1894. A few years later in 1898, Mayo proposed his “vest-over-pants” repair that quickly gained wide acceptance in the surgical community [20]. This technique employed the imbrication of the superior and inferior fascial edges during the repair and was seen as a technical breakthrough since it significantly reduced the morbidity over earlier approaches. Now, small hernia defects (<2 cm) in low-risk patients are typically repaired with primary fascial reapproximation. Larger umbilical hernia defects are typically repaired with prosthetic mesh reinforcement.

Umbilical Hernia and Cirrhosis

Umbilical hernia in the setting of cirrhosis and recurrent ascites bears special mention. Umbilical hernia occurs in up to 20% of patients with liver cirrhosis complicated by ascites, a significantly higher incidence rate compared to the general population [21]. As depicted in Fig. 33.5, hernias in this setting also tend to enlarge quickly and become symptomatic. The etiology of umbilical hernia in cirrhotics is multifactorial. Increased intra-abdominal pressure secondary to ascites, abdominal wall muscle weakness secondary to hypoalbuminemia, and recanalization and varices formation of the umbilical vein at the umbilicus secondary to portal hypertension all play a role in umbilical hernia formation in this patient population [21]. Further, tense ascites may also cause pressure necrosis and perforation of the overlying umbilical skin that may lead to evisceration, ascites drainage, and bacterial peritonitis [22–26].

The treatment of cirrhotic patients with umbilical hernia remains somewhat controversial. Historically, cirrhotics were treated nonoperatively secondary to the exceedingly high rate of perioperative complications and hernia recurrences [27–29]. Expectant management, however, often leads to progression of disease and subjected patients to

Fig. 33.5 Umbilical hernia in a cirrhotic patient with ascites

complications associated with the hernia. Operating in this setting further increases the risks associated with a potential surgical repair. As medical care for cirrhotic patients has improved over the years, a number of studies have shown a significant decrease in perioperative complications in regard to umbilical hernia repair in this patient population.

Marsman et al. reported their experience of cirrhotic patients with an umbilical hernia and ascites who underwent elective hernia repair ($n = 17$) versus expectant management ($n = 13$) [30]. They found expectant management was associated with a higher rate of both morbidity and mortality. Ten of thirteen patients (77%) required hospitalization for incarceration with six patients requiring emergent operations. Two patients died from hernia-related complications. In the treatment group, complication rate was low, and only 4 recurrences were encountered in the 17 patients who underwent elective hernia repair.

A number of other studies have also reported favorable outcomes and have suggested elective umbilical hernia repair in cirrhotic patients in order to avoid complications associated with expectant management [24, 31–33].

Most studies indicate that preoperative medical management of ascites is essential in cirrhotic patients undergoing elective umbilical hernia repair in order to prevent postoperative complications and hernia recurrences. The treatment of ascites usually combines sodium restriction, diuretics, and paracentesis [34, 35]. If ascites can be adequately medically managed preoperatively, elective umbilical hernia repair in cirrhotic patients is now usually indicated. The method of repair, open primary repair, open mesh repair, and laparoscopic repair with intraperitoneal onlay mesh, is still debated in the literature, with each approach offering its own potential benefits and risks [35]. No high-quality randomized control trials have been performed to date to advocate one repair over the others. For patients scheduled for liver transplantation, umbilical herniorrhaphy should be done during transplantation.

Current Literature

Repair options for umbilical hernia include open primary suture repairs and mesh-based repairs. Mesh repairs can be performed via either an open approach or with laparoscopic assistance. Most of the data currently available indicate lower recurrence rates with mesh-based repairs when compared to primary suture repairs. This has to be balanced with the potential complications of mesh placement.

Asolati published a retrospective review analyzing predictors of recurrence in patients undergoing elective umbilical hernia repair in single-center VA hospital over a 6-year span [36]. Two hundred and twenty-nine patients were included in the study with 97 patients receiving a primary suture repair (43%) versus 132 patients receiving a mesh repair (57%). Seven recurrences in the suture repair group were identified vs. four in the mesh repair group (7.7% vs. 3%). In their patient population, African-American gender, diabetes, and hyperlipidemia were found to be the factors that were significant for recurrence. Smoking, obesity, and type of hernia nor size was found to be insignificant in their study.

Eryilmaz looked at their experience of repairing umbilical hernias with either mesh or suture repair [37]. Over a 5-year span, they performed suture repair on any hernia less than 3 cm and polypropylene mesh repair on any hernia larger than 3 cm. Primary repair was performed in 63 patients, with mesh repair in 48 patients. The recurrence rate in the suture repair group was 14% vs. 2% in the mesh group. They concluded that mesh should be used in all umbilical hernia repairs. Arroyo in 2001 and Sanjay in 2005 [38, 39] both showed lower recurrence rates with the use of mesh for repair of umbilical hernia. Sanjay had a follow-up of 4.5 years. Schumacher [39] in 2003 found that in patients with a BMI >30, the recurrence rate of umbilical hernia was 32% vs. only 8% in those with a BMI < 30. He also found that the larger the hernia, the higher chance of recurrence if the repair was done without mesh.

More recently, Christoffersen et al. published their findings from a prospective cohort study based on patients from the Danish Ventral Hernia Database [40]. They compared outcomes of patients undergoing elective open mesh and sutured repair for small (<2 cm) umbilical and epigastric hernias. Over a 4-year period, 4786 patients met inclusion criteria and included 3438 patients receiving primary suture repair vs. 1348 patients receiving a mesh repair with a mean follow-up of 21 months. Reoperation rates for hernia recurrence were significantly lower for the mesh repair group compared to the primary suture repair group (2.2% vs. 5.6%). They concluded that even small (<2 cm) primary umbilical and epigastric hernias should be repaired with mesh reinforcement.

In 2008, the authors of this chapter published our initial experience with use of the Bard Davol Ventralex hernia patch in primary umbilical and epigastric hernia repairs [41]. The retrospective review included 88 patients with average BMI of 32. Average OR time was 52 min, and postoperative follow-up ranged from 8 days to 3 years. No hernia recurrences were found in follow-up. Two patients developed mesh infection requiring subsequent mesh explantation. From our experience with this composite patch, we concluded it has a valuable role in primary umbilical and epigastric hernia repairs. In addition, we performed a cost comparison of umbilical hernias being repaired via an open approach with the Ventralex patch compared to a laparoscopic approach. The laparoscopic group had no recurrences and no mesh infections but at a significantly higher cost. The laparoscopic repair was on average $1200 more expensive per case compared to the open approach using the Ventralex hernia patch. Since Davol introduced the Ventralex patch for repair of small ventral hernias, other companies have followed suit and introduced similar mesh products for the same indication. They work in a similar fashion to the Ventralex patch (Fig. 33.6).

Since publication of our initial experience with the original Ventralex hernia patch, the patch itself has undergone significant refinement by the manufacturer. The initial version of the Ventralex hernia patch was a composite mesh patch composed of both polypropylene and ePTFE. Some concern existed regarding the use of composite mesh products for implantation during hernia repair because the two synthetic materials may contract at different rates following placement. This could result in “taco-ing” or “cupping” of the patch and potentially expose the abdominal viscera to the polypropylene component of the patch and possibly result in clinical morbidity. To address this concern, Bard Davol introduced a newer version of the patch, the Ventralex ST hernia patch. The Ventralex ST patch is composed entirely of polypropylene mesh with its visceral side coated with a proprietary hydrogel coating to allow for safe intraperitoneal placement. The hydrogel layer (Sepramesh) swells after placement to minimize tissue attachment to the visceral side of the mesh acting as an adhesion barrier to minimize potential visceral adhesion formation during mesh incorporation and re-peritonealization of the mesh patch.

We converted to the newer version of the mesh patch immediately after it was commercially available and are currently analyzing our results in over 200 placements. In addition, we have been active participants in the American Hernia Society Quality Collaborative (AHSQC) since its inception in 2013. The AHSQC is a quality improvement database designed to track patient outcomes following hernia repair. To date, we have over 140 patients who have undergone primary umbilical and epigastric hernia repairs with the Ventralex ST patch being followed longitudinally in the AHSQC database. Preliminary analysis shows excellent results with very low complications and recurrence rates.

Presentation and Diagnosis of Anterior Abdominal Wall Hernias

Patients can present with a variety of different symptoms when they have primary anterior abdominal wall hernias depending on hernia location and hernia contents. Umbilical hernias tend to be the most common anterior abdominal wall hernias and often are easier to diagnose than their Spigelian and epigastric hernia counterparts. Typically they present with a reducible bulge at the umbilicus that can at times be tender. If patients have an acute incarceration/strangulation of omentum, they can present with pain and erythema, but more frequently it is a chronic incarceration without signs of strangulation. Incarcerated small intestine can present as a bowel obstruction or perforation. If the hernia is very large, it can contain multiple viscera with a variety of related symptoms.

Epigastric hernias can at times be difficult. Often a thorough history is the best clue with patients complaining of a

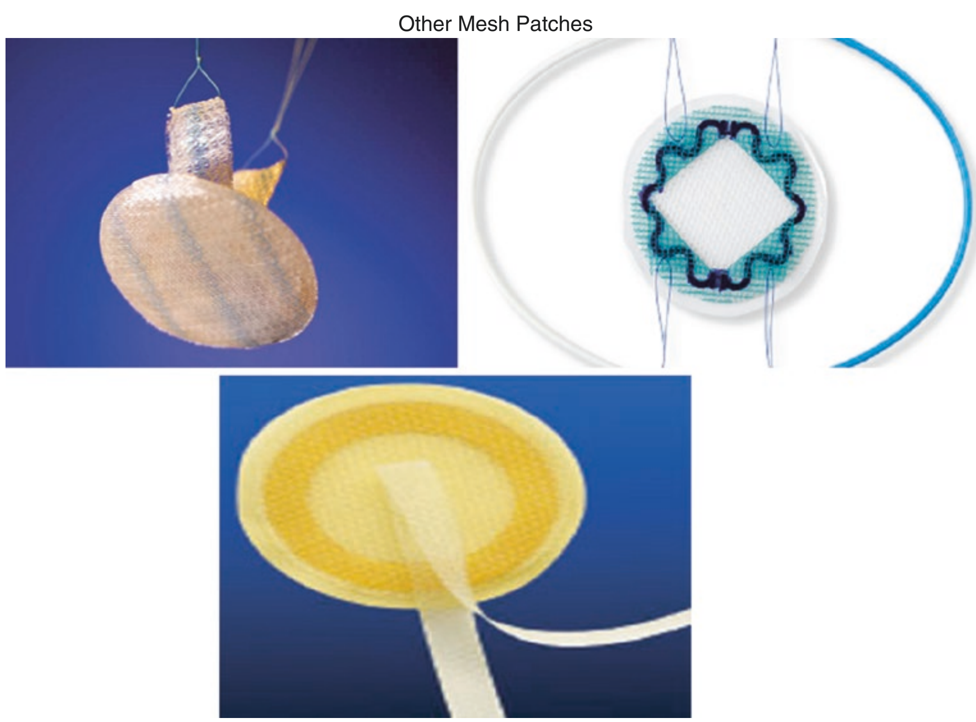


Fig. 33.6 Other commercially available mesh patches for use in repair of small ventral hernias

bulge and/or pain in the epigastrium. Physical exam is helpful if the defect is large enough to palpate and confirms the diagnosis. If there is still concern about the true etiology of the pain, an abdominal ultrasound or CT scan can be helpful in the diagnosis [1, 42, 43]. Most epigastric hernias are small in nature and often only have preperitoneal fat in the hernia. However, the size of the hernia can vary widely and contain a variety of tissues including preperitoneal fat, omentum, stomach [44], liver [45], colon, or small intestine. There have even been reported epigastric hernias causing pancreatitis [46]. Due to this fact, a variety of symptoms can be present.

Spigelian hernias are often difficult to diagnose due to their relative rarity and low clinical suspicion, especially in obese patients. Presentation is often similar to the above-mentioned hernias except they are found along the Spigelian line and not in the midline. Patients' presentations will be different depending on hernia sac contents as well. Once again ultrasound and CT scan have aided in the diagnosis, but there are false negatives with these methods, and diagnostic laparoscopy is an excellent diagnostic tool in the patient with pain in this area and a negative work-up.

Preoperative Planning

Most primary anterior abdominal wall hernias can be repaired in a similar fashion regardless of defect location. The method of repair, open vs. laparoscopic, is mostly dependent on surgeon preference, but one should tailor the surgical approach to the individual patient. Hernia defect size along with patient factors such as body habitus, tobacco use, and diabetes mellitus may influence the approach that is best suited in each individual case. As with most hernias, a tension-free repair is ideal so mesh is usually used unless there is a clear contraindication to doing so. We tend to recommend open repair in most primary anterior abdominal wall defects due to our success using the Ventralex ST-type patch with most of these hernias. The patients have similar or less pain than their laparoscopic counterparts; it is less expensive, and it is an easy repair to perform. These patches allow a sublay repair through a small incision with minimal morbidity. For larger hernias and in patients at increased risk for wound complications, we typically favor the laparoscopic approach to allow for wider overlap of the hernia defect and decreased wound infection and mesh infection rates.

Open Repair of Primary Anterior Abdominal Wall Hernias

Open hernia repair has long been the mainstay of treatment for anterior abdominal wall hernias. The method of repair, either a sutured primary fascial closure or a mesh-based repair, should be tailored to the individual patient and take into account hernia defect size and patient factors such as body habitus, smoking status, and other medical comorbidities that may influence the risk of hernia recurrence. For smaller defects less than 2 centimeters in low-risk patients, a sutured repair may be ideal. Because of the increased risk of hernia recurrence associated with a sutured primary fascial closure, most authors now advocate a mesh-based repair for hernia defects larger than 2 centimeters. Some feel all primary ventral hernia defects should be repaired with mesh reinforcement.

Patient Positioning and Theater Setup

Patients undergoing open ventral hernia repair are typically positioned in the supine position. Arms may be tucked depending on surgeon preference. All patients undergoing an open anterior ventral hernia repair should receive appropriate prophylactic antibiotic coverage prior to skin incision. We also advocate the use of a barrier dressing, such as an Ioban incise drape, to help minimize potential contamination from skin flora.

Incision and Access

A vertical midline incision is typically used for epigastric hernias directly overlying the hernia defect. A curved, infraumbilical incision is used when repairing primary umbilical hernias.

Operative Steps

Dissection is continued down through the subcutaneous tissues until the hernia sac is identified. The redundant hernia sac is dissected away from the subcutaneous tissues and transected at the level of the fascia. The subcutaneous fat is then elevated off circumferentially from the underlying fascia for 2–3 cm to get back into good, healthy non-attenuated fascia (Fig. 33.7). The appropriate-sized mesh prosthetic is then selected to provide adequate overlap of the hernia defect. The mesh prosthetic is then placed through the hernia defect intraperitoneally in the sublay position. Care must be taken to ensure the mesh prosthetic lays flush against the anterior abdominal wall circumferentially without interposition of any abdominal viscera or omentum between the mesh prosthetic and the visceral surface of the abdominal wall. We fixate the mesh patch to the abdominal wall fascia using permanent suture. The total number of points of fixation is dependent on mesh size, and the sutures include purchase of both the polypropylene skirt of the Ventralex ST patch and overlying fascia (Fig. 33.8). For a medium-sized

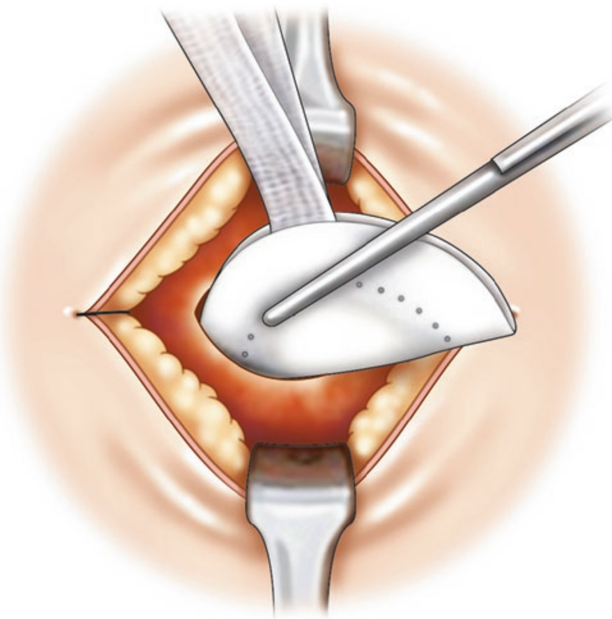


Fig. 33.7 Placement of the Ventralex patch into the hernia defect

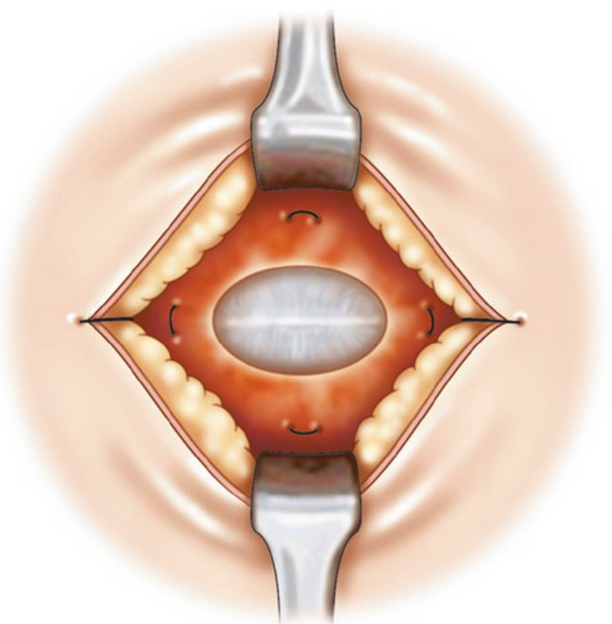


Fig. 33.8 After the Ventralex patch has been placed with four Prolene U-stitches securing it in place

Ventralex ST patch (6.4 cm circle), we typically place four 2.0 Prolene U-stitches at the 12, 3, 6, and 9 o'clock positions. For the small patch (4 cm circle), we fixate at the 12 and 6 o'clock positions only. The fascia is then closed over the mesh to add another barrier of protection from possible wound infections (Fig. 33.9). If there is evidence of ischemic bowel at any point of the procedure, synthetic mesh should be used with caution given the risk of possible mesh infection.

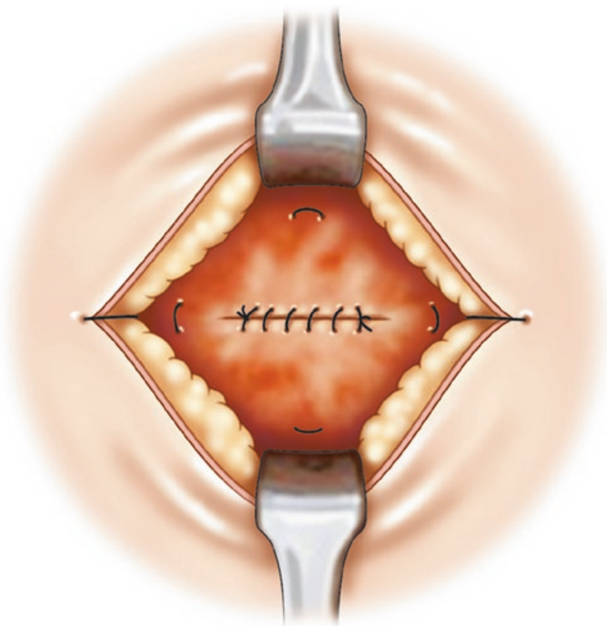


Fig. 33.9 Fascial closure over the mesh to reinforce repair and separate mesh from subcutaneous fluid collection

Closure

We typically tack the umbilical stalk down to the fascial closure when repairing umbilical hernias to achieve a satisfactory cosmetic appearance of the umbilicus postoperatively. The skin is closed in layers with buried absorbable suture, and the incision is typically dressed with skin glue.

Laparoscopic Repair of Primary Anterior Abdominal Wall Hernias

Patient Positioning and Theater Setup

Laparoscopic repair of epigastric and umbilical hernias is performed in the same fashion as the laparoscopic intraperitoneal onlay mesh (IPOM) ventral hernia repair discussed in previous chapters. Patients are typically positioned in the supine position with bilateral arms tucked, and laparoscopic towers are positioned on both sides of the bed. All patients should receive appropriate prophylactic antibiotics prior to skin incision.

Incision and Access

A Veress needle inserted in the left upper quadrant at the costal margin (Palmer's point) is an ideal way to insufflate the abdomen safely. Alternatively, one can use a Hasson trocar, but this makes a large hole that can lead to hernia formation. Most of the primary abdominal wall hernias can be repaired using all 5 mm trocars, and we place two of these laterally on each side of the abdomen (Fig. 33.10).

Operative Steps

The contents within the hernia sac are reduced intra-abdominally. It is important to also take down the peritoneum and reduce all preperitoneal fat that may be incarcerated within the hernia defect as well. For epigastric hernias, it is important to mobilize the falciform ligament from the peritoneal surface of the abdominal wall in order to obtain adequate mesh overlap and allow the prosthesis to lie flush against the anterior abdominal wall. Once the fascial defect is clearly delineated, mesh selection is performed and should provide at least 5 cm of overlap circumferentially around the hernia defect. Mesh fixation is often debated, but we advocate placing at least four transfascial sutures to fixate the mesh superiorly, inferiorly, and laterally on each side. A laparoscopic tacker can then be used to fixate the edges of the mesh circumferentially using the double-crown technique. If the hernia is large, additional transfascial sutures should be used accordingly.

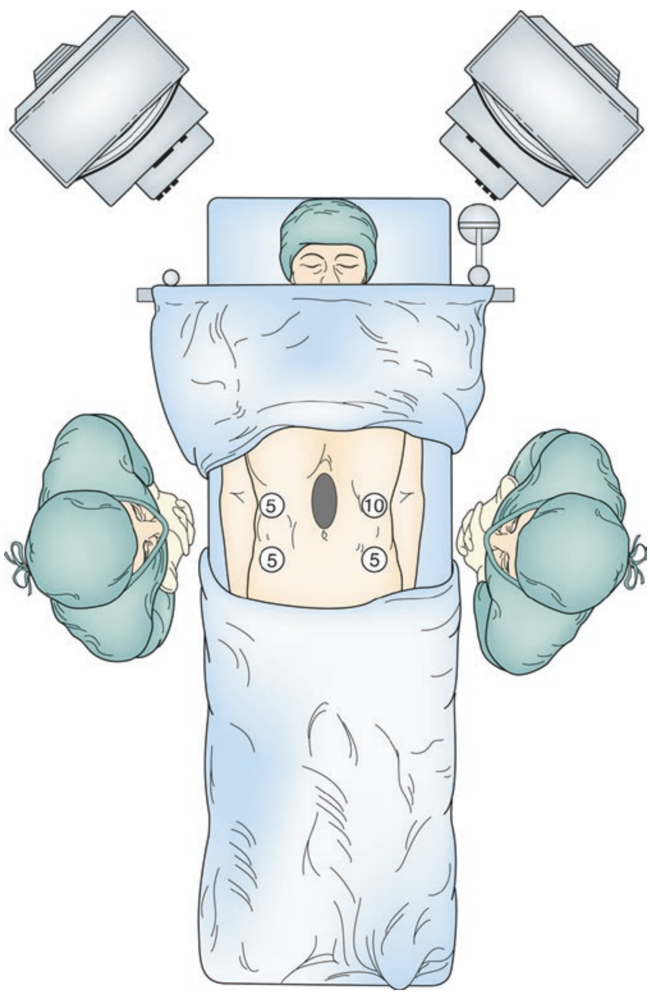


Fig. 33.10 Trocar placement and tower setup for most laparoscopic anterior abdominal wall hernia repairs. Four trocars are placed, two in either flank laterally with video towers at both sides at the head of the bed

Closure

The fascia is closed on any trocar sites greater than 5 mm with interrupted absorbable sutures. The skin at all trocar sites is closed with absorbable suture and dressed with skin glue.

Postoperative Management

We place a compression dressing over the repair to help aid with hemostasis and decrease seroma formation and also recommend use of an abdominal binder postoperatively. We do not routinely leave subcutaneous drains unless there is a large dead space present. Patients are typically discharged immediately postoperatively and prescribed a short course of oral narcotics for postoperative analgesia. We do not restrict the patient's activity postoperatively. They will limit any strenuous activity for a while due to discomfort from the repair. This policy can be adjusted to each individual patient depending on body habitus, age, type of repair, and job requirements. Patients receive follow-up in an outpatient setting at 2-week and 6-week intervals postoperatively.

Tips and Pitfalls

Postoperative complications are similar for all types of primary ventral hernias discussed in this chapter. Small hematomas and ecchymosis can occur, and most will resolve spontaneously with expectant observation. Seromas are more common following larger hernia repairs and will also typically resolve spontaneously with expectant management. Aspiration of persistent seromas with or without radiographic guidance can be performed, but one must weigh the potential risk of infection prior to performing this intervention. Surgical site infections when encountered should be treated promptly with empiric antibiotic coverage and possible drainage. If chronic mesh infection develops, the decision to perform mesh explantation will depend on the judgment of the practitioner.

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Parastomal Hernia

34

Leif A. Israelsson and Alfred Janson

Today creating an ostomy is utilized in both elective and emergent situations as well as by an open or a laparoscopic technique. In about one-third of the patients with colorectal cancer, the ostomy is permanent [1]. The improvement of modern stoma bandages enables an easy and reliable stoma care making the daily life easier for the patient. Unfortunately the development of parastomal hernia is a frequent complication, and Goligher even considered some degree of herniation as almost inevitable after colostomy formation [1].

Parastomal hernia may present as problems of stoma care, difficulty with appliances or with irrigation, and a significant cosmetic deformity—or as straightforward complications of a hernia with intestinal obstruction or strangulation. The presence of a large protrusion may make repair a necessity irrespective of its other side effects (Fig. 34.1).

Fig. 34.1 A large parastomal hernia presenting problems of stoma care, difficulty with appliances, and a significant cosmetic deformity

Parastomal hernia is more common than previously thought. It develops in 30–50% of patients supplied with an ostomy, and one-third of these demand repairs. The methods of repair have not always been successful, and after suture repair or relocation of the stoma, recurrence rates are unacceptably high. The introduction of mesh repair has increased the proportion of successful repairs. With open or laparoscopic mesh repairs, fairly low recurrence rates are reported. However, no randomized trial and few long-term follow-up studies are available reporting the results with the various techniques for parastomal hernia repair.

In randomized trials a prophylactic prosthetic mesh placed in a sublay position reduces the rate of parastomal hernia. In nonrandomized studies, a prophylactic onlay, sublay, or intraperitoneal onlay mesh (IPOM) has also been associated with low herniation rates.

Definition of Parastomal Hernia

Pearl defined parastomal hernia as an incisional hernia related to an abdominal wall stoma [2]. In studies on parastomal hernia, the definition used has not been consistent. Before 2004 the definition used at follow-up examination was given in only one report, and then parastomal hernia was defined as a palpable cough impulse at the ostomy site [3].

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Beginning in 2004, authors generally report the definition used and then regard any protrusion in the vicinity of the stoma with the patient straining in a supine position and in an erect position as herniation [4–11]. Studies have shown that patients with a parastomal hernia according to this definition have a poorer quality of life than others [9].

A CT scan in the supine position has sometimes been added to the clinical examination at follow-up but does not seem to be a reliable tool detecting parastomal hernia [5, 10, 11]. The correlation between different methods of detecting parastomal hernia has now been studied [12]. The correlation between clinical examination, CT scan in the supine position, and CT scan in the prone position, with the ostomy placed over an inflatable ring, was studied. The radiological definition of parastomal hernia used was that of any intra-abdominal contents protruding beyond the peritoneum or the presence of a hernia sac. The correlation between clinical examination and CT scan in the prone position was very strong between methods and between raters. CT scan in the supine position was not as accurate since several parastomal hernias detected by clinical examination and with CT scan in the prone position could not be detected in the supine position.

Parastomal hernia has by Kingsnorth been classified into four subtypes related to the anatomy of the herniation [13] (Fig. 34.2):

1. An interstitial type with a hernia sac within the muscle/aponeurotic layers of the abdomen
2. A subcutaneous type with a subcutaneous hernia sac
3. An intrastomal type in ileostomies with a hernia sac between the intestinal wall and the everted intestinal layer
4. A perstomal type or prolapse with the bowel prolapsing through a circumferential hernia sac enclosing the stoma.

This classification defines the type of parastomal hernia according to the position of the hernia sac. The classification has not been used in clinical studies as it is difficult to distinguish these types of parastomal hernias by physical examination [8].

By the definition given by Kingsnorth, a prolapse is a parastomal hernia of the perstomal type with a circumferential hernia sac within the stoma. In a Cochrane report, parastomal hernia was defined as a hernia beside the stoma and stoma prolapse as an eversion of the stoma through the abdominal wall [14]. In some studies stoma prolapse has been regarded as a separate entity, although it is not clear how to differentiate between a prolapse and the other types of parastomal hernia at clinical examination [15–21]. Most authors have probably included all types of parastomal hernia according to the definition given by Kingsnorth. This seems reasonable since all entities include the presence of a hernial sac and certainly represent undesired complications after stoma formation.

Without a uniform definition used, it is difficult to compare parastomal hernia rates between different clinical reports. Also, since the herniation rate increases with time, results cannot be compared between reports with different time to follow-up. Follow-up examination should be no less than 12 months after the index operation, although parastomal hernias still develop after 5–10 years following ostomy formation [22].

Currently the practice is that parastomal hernia at clinical examination is defined as any protrusion or bulge adjacent to the stoma—detected with the patient supine with elevated legs or while coughing or straining when erect. The radiological definition of parastomal hernia is any intra-abdominal contents protruding beyond the peritoneum or the presence of a hernia sac at CT scan in the prone position, with the ostomy placed over an inflatable ring. A uniform classification of parastomal hernia to be used in future studies has been suggested by the European Hernia Society (EHS) based on hernia size and the presence of a concomitant incisional hernia [23].

Incidence of Parastomal Hernias

Due to different definition of herniation being used as well as differences in time between the index operation and follow-up examination, the rate of parastomal hernia is reported to occur within the very wide range of 4–81% [3, 15–18, 20, 22, 24–30]. With a more uniform definition used during the last decade, the rate of parastomal hernia reported after 12 months has been close to 50%. Current data indicate that 1 year after stoma formation, the rate of parastomal hernia is at least 30% and probably close to 50% in general surgical practice. The rate increases during the following 5–10 years. Thus, parastomal hernia is a major clinical problem.

The rate of herniation has been suggested to be lower after an ileostomy than after a colostomy, and this was supported in a recent meta-analysis [31]. The proportion of parastomal hernias occurring after ileostomy at a Bricker diversion is similar to the rates reported for other ostomies [32–38].

Loop ileostomies and loop colostomies probably produce similar high rates of parastomal herniation [14, 39, 40]. Hernia rates with loop stomas cannot easily be compared with end stomas since follow-up time is often shorter with loop stomas partly due to the often temporary nature of the stoma. A loop stoma may also be utilized as a palliative means in patients with malignant disease with a short survival time after stoma formation.

Current practice is to place the stoma through a separate incision laterally of the midline. Many different methods have however been used, with mixed results. Ostomies brought out through the laparotomy wound have produced disastrous results in terms of infection, wound dehiscence,

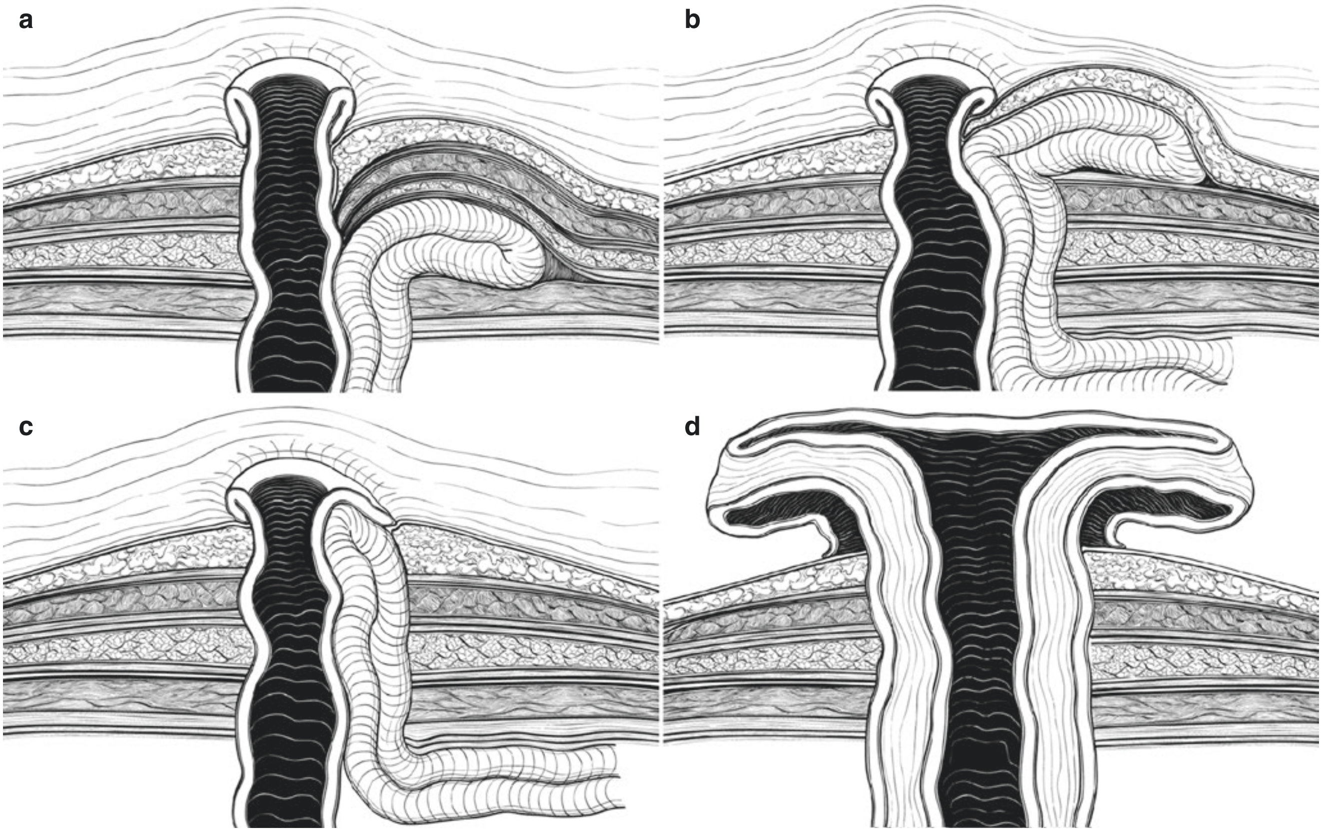

Fig. 34.2 There are four subtypes of parastomal hernia. (**a**) Interstitial. With a hernial sac lying within the muscle/aponeurotic layers of the abdominal wall. This may contain omentum and small or large intestine. In these cases, the stoma is asymmetrical and is edematous and cyanotic if its vascular supply is compromised. (**b**) Subcutaneous. With herniation alongside the stoma with a subcutaneous sac containing omentum or bowel. This is the commonest form of paracolostomy hernia, and not infrequently, the colon situated just proximal to the stoma is found in the sac. (**c**) Intrastomal. This is a problem of spout ileostomies only. A loop of the intestine may herniate alongside the stoma and lie between the emergent and the everted layer of the stoma. (**d**) Perstomal or prolapse. A prolapsed stoma contains a hernial sac within itself; other viscera, especially small gut, can enter this sac and even become strangulated

and herniation [1, 41–43]. An extraperitoneal construction of the stoma has been tried in order to reduce the rate of herniation [1, 27]. This was in two retrospective studies associated with a lower rate of parastomal herniation than the conventional route. These results have been challenged by others though, and the technique does not seem to have become widely used [13, 44].

To bring out the stoma through the rectus abdominis muscle has in two retrospective studies been associated with a lower rate of parastomal hernia than if brought out lateral to the muscle [24, 45]. Four other retrospective studies did not confirm these findings [3, 27, 28, 46]. There are no randomized studies available to settle this matter, but it is nevertheless probably wise to bring out enterostomas through the rectus muscle. This is obviously not associated with any disadvantages, and placing the stoma as close to the midline as possible facilitates patients' stoma care.

Risk factors for parastomal hernia formation are wound infection, old age, obesity, corticosteroid use, chronic respiratory disorders, and malnutrition [1, 13, 46–48].

Making a too large opening in the abdominal wall for the enterostoma has been suggested as a risk factor for herniation. A large opening and hence a possibly higher proportion of herniation may however be related to a bulky bowel necessitating a large opening. Clinical data is sparse, but it nevertheless appears wise to make the opening just large enough to allow the bowel to pass through.

Fixating the mesentery or suturing the bowel to the aponeurosis has been attempted as means to lower herniation rates. Such measures can be disregarded as they have not had any effect on the rate of parastomal hernia developing [18, 26, 27, 29].

Prevention of Parastomal Hernias

The high occurrence of parastomal hernia makes it important to search effective prophylactic measures. Since a large proportion of stomas intended to be temporary are never reversed, preventive measures should be sought for all types of ostomies [49]. The most promising results in the attempt to prevent parastomal hernia developing have been with a prophylactic prosthetic mesh placed at stoma formation. During the last decade, several studies with this approach have been published. There are now four trials randomizing about 300 patients between a conventional ostomy with the same procedure with the addition of a prophylactic mesh placed in a sublay position [4, 11, 50, 51]. These trials pooled together report a rate of parastomal hernia of 36% without a mesh reduced to 7% with a prophylactic mesh. Long-term follow-up is yet not available to any extent, but one trial has reported results after 5 years, and at that time, the herniation rate was 81% without a mesh and 13% with a prophylactic mesh [22]. This encouraging effect on the rate of parastomal hernia with a prophylactic mesh has in all studies been achieved without any increased rate of infection or complications related to the mesh.

One might regard an ostomy as an intentionally created hernia. Therefore, it seems logical that parastomal herniation can be prevented in the same way as incisional hernias are repaired, i.e., with a mesh. An incisional hernia is defined as intra-abdominal contents protruding through a defect in the abdominal wall. In constructing an ostomy, the surgeon creates a defect in the abdominal wall for the bowel to pass through, which according to the definition produces a hernia. Therefore, the high rates of parastomal hernia encountered without a prophylactic mesh are not surprising.

In the first randomized trial employing a prophylactic mesh in open surgery, the abdominal cavity was accessed through the midline (Fig. 34.3) [4, 52]. The skin at the stoma site was grasped with a clamp, and a circular excision of the skin was made. After dissection through the subcutaneous tissue, a cross was cut in the anterior rectus sheath.

Corresponding to the intended stoma site, the peritoneum and the posterior rectus sheath were opened along the midline for a length appropriate to contain a mesh of 10 by 10 cm. Dissection was continued in the avascular plane dorsal to the rectus muscle until the lateral border of the muscle was reached.

A partly absorbable low-weight large-pore mesh was cut to 10 by 10 cm, and a cross was cut in its center—just large enough to let the bowel pass through. The mesh was placed in the retromuscular plane created, and the upper and lower lateral corners were anchored to the dorsal rectus sheath with single absorbable stitches.

Peritoneum and the dorsal rectus sheath were then opened by a cross incision at the intended stoma site. The stapled bowel end was first brought out through the opening in the dorsal rectus sheath and then through the opening in the mesh. The length of the bowel and the size of the opening in the mesh could then be checked and adjusted. Lastly the bowel was brought out through a split made in the center of the rectus muscle and through the openings previously made in the anterior aponeurosis and skin. The bowel was opened and sutured with a running absorbable monofilament suture with stitches placed 2–3 mm from the skin edge and with seromuscular bites in the bowel.

The medial corners of the prophylactic mesh were anchored, and measures were taken to prevent the mesh unnecessarily coming into contact with abdominal contents.

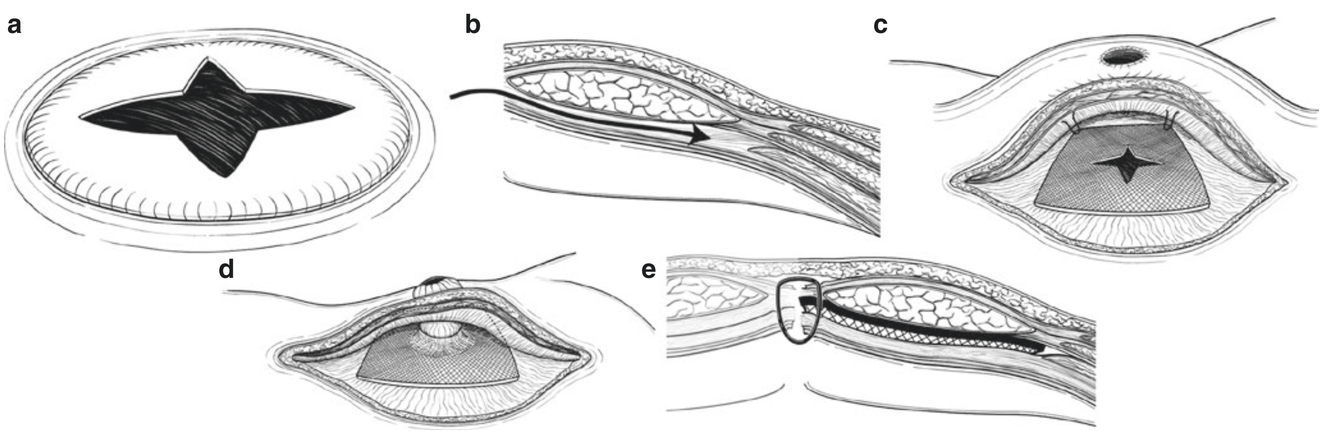

Fig. 34.3 Steps taken when placing a prophylactic mesh at stoma formation. (**a**) A circular excision of the skin is made, and it is dissected through the subcutaneous tissue down to the anterior rectus aponeurosis. A cross is cut in the aponeurosis above the center of the rectus abdominis muscle. (**b**) Corresponding to the stoma site, the peritoneum and the posterior rectus sheath are opened along the midline for a length of more than 10 cm. Dissection is continued to the lateral border of the rectus muscle in the avascular plane dorsal to the rectus muscle. (**c**) A mesh 10 by 10 cm with a crosscut in its center is placed in the plane created. The lateral corners of the mesh are anchored to the dorsal rectus sheath with single stitches. (**d**) The bowel is brought out through the opening in the dorsal rectus sheath, the crosscut in the mesh, the split in the rectus muscle, the crosscut in the anterior rectus sheath, and the skin opening. (**e**) The medial corners of the mesh are anchored as the running suture in the anterior rectus aponeurosis incorporates also the peritoneum and the mesh. Along the mesh every other stitch in the aponeurosis includes peritoneum, thereby averting bowel coming into contact with the mesh

This was accomplished when closing the midline incision with a continuous suture technique using a slowly absorbable or nonabsorbable monofilament suture in the anterior rectus aponeurosis. Then the medial upper and lower corners of the prosthetic mesh were anchored as the running suture in the aponeurosis incorporated also the mesh and peritoneum. Along the length of the mesh, every second or third stitch in the aponeurosis also included peritoneum—thereby preventing bowel from coming into contact with the mesh.

Experiences with a prophylactic mesh used in routine surgical practice have also been reported by Jänes. In 93 consecutive ostomies, most patients could be provided with a prophylactic mesh in a sublay position. In less than 10% of patients, a mesh could not be utilized due to severe scarring of peritoneum or the abdominal wall after previous surgery. In dirty wounds with fecal peritonitis, a prophylactic mesh was used in 19 patients, and no infection of the mesh occurred in these patients. The rate of surgical site infection was actually lower in the group of patients provided with a mesh than in others. The higher rate of wound infection when a mesh was omitted was probably an effect of patient selection or some other bias, but it seems safe to conclude that a prophylactic low-weight large-pore mesh can be placed in severely contaminated environments.

In the randomized trials, several different types of meshes have been used with similar results. Thus, the particular choice among the low-weight large-pore meshes available seems not to be of relevance as long as sound surgical principles are followed.

Ostomies formed by laparoscopic approach have become more and more common. Dissection and division of the bowel are then performed laparoscopically, and the bowel is brought out through an opening made in the abdominal wall with an open technique. There is no reason to assume the rate of parastomal hernia to be lower with a laparoscopic technique than with an open [53]. Thus, there is an indication for a prophylactic mesh to be used also when stomas are created with a laparoscopic technique.

The laparoscopic dissection starts by mobilizing the bowel and creating an appropriate length of the bowel before it is divided with a cutting linear stapler (Fig. 34.4). With an open technique, the skin at the stoma site is grasped with a clamp, and a circular excision of the skin is made. After dissection through the subcutaneous tissue, a cross is cut in the anterior rectus sheath, and muscle fibers are split in the center of the rectus muscle. With the index finger through this opening, blunt dissection creates a space in the avascular plane dorsal to the rectus muscle. A low-weight large-pore mesh is cut to a 10 by 10 cm and is pushed through the skin opening with the index finger positioning it in the retromuscular space created. A cross is cut in the center of the mesh and peritoneum. As peritoneum is opened, the abdomen will exsufflate. The bowel end that is held close to the opening with a laparoscopic clamp is then extracted through the mesh with a clamp inserted through the skin opening. This method has produced similar rates of parastomal hernia (15%) in 25 consecutive patients as with a prophylactic mesh utilized in open surgery [54].

There are also a number of clinical reports including more than 1000 patients with the use of a prophylactic mesh in nonrandomized studies. They all report a virtually nonexisting risk of mesh infection or of the mesh eroding into the bowel. Similar results have been reported with a prophylactic mesh used for the ileal conduit at a Bricker diversion [55].

Principles of Surgical Management of Parastomal Hernias

Surgical repair has been reported to be indicated in about 30% (11–70%) of patients with a parastomal hernia [8]. An accurate diagnosis and assessment of the anatomy of the hernia are essential. Therefore, the patient must be examined (a) recumbent and relaxed; (b) recumbent with the muscles tense—most easily achieved by elevating their legs; (c) in the erect position; and (d) in the erect position with the muscles tense. A CT scan with the patient in the prone position with the stoma over an inflatable ring is often useful to delineate the defect in the abdominal wall and its relation to any concomitant incisional hernia.

Alternative stoma sites should be considered if relocation of the stoma is needed and the help of a stoma care nurse (enterostomal therapist) is valuable. An optimal stoma site is of great importance for patient bandaging and prevention of future complications.

The patient who has had cancer surgery must be screened for recurrence before surgery is advised. It is also prudent to exclude recrudescent inflammatory bowel disease before undertaking operation in patients with ileostomies. A consideration that has become more commonplace is the life expectancy of the patient. An increasing number of patients of an advanced age are being seen with multiple medical problems that add to the risk of general anesthesia. If these illnesses will considerably shorten the remaining lifetime of the patient (e.g., less than 2–3 years) or if these prohibit anesthesia, then one may not wish to proceed if there is no immediate need for surgical intervention.

Surgery is imperative in all cases of intestinal obstruction or strangulation related to parastomal hernia. Urgent emergency surgery is also necessary in all cases of paracolostomy hernia where perforation has occurred during irrigation.

When a parastomal hernia causes abdominal wall distortion and difficulties with fitting an appliance or irrigating a stoma, surgery is the treatment of choice. Surgery should be considered if the stoma has become out of the patient's

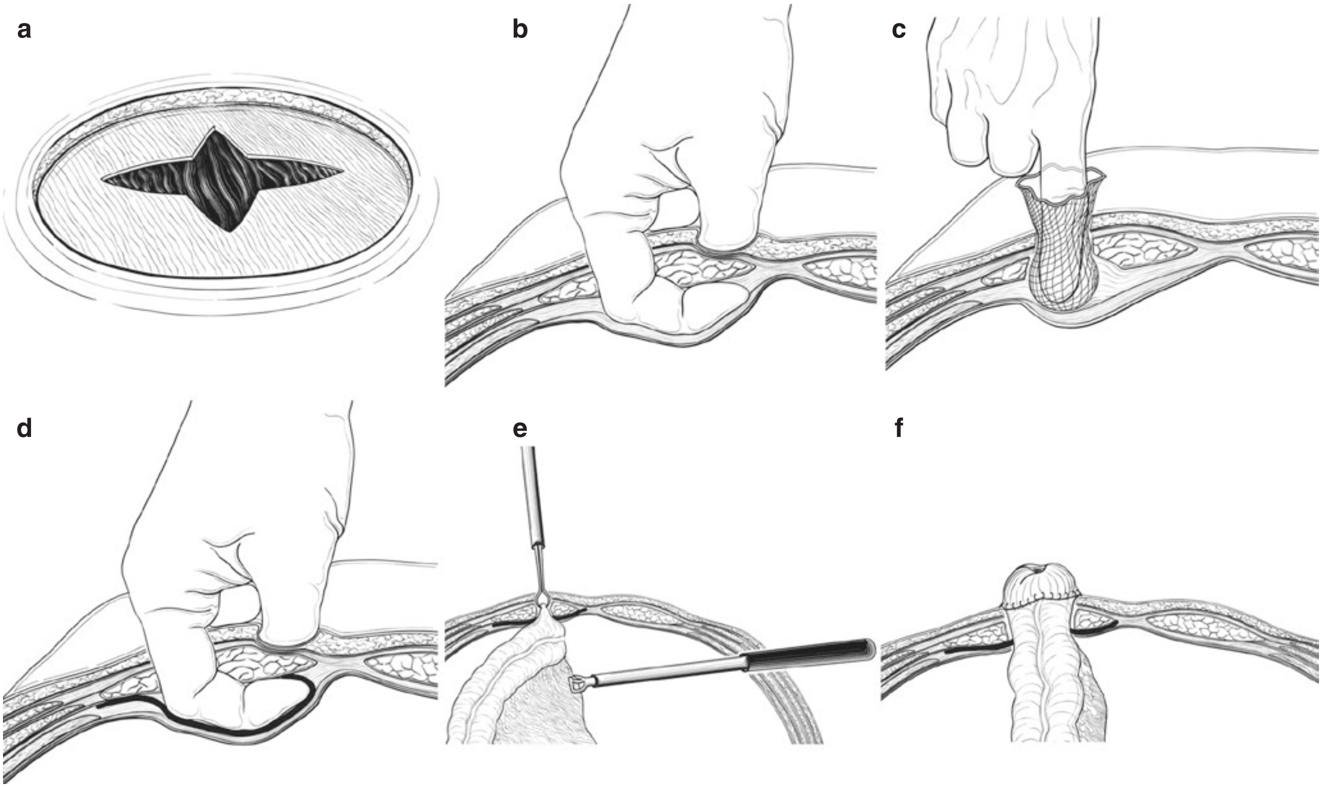

Fig. 34.4 Steps taken when placing a prophylactic mesh at laparoscopic stoma formation. (**a**) A circular excision of the skin is made, and it is dissected through the subcutaneous tissue down to the anterior rectus aponeurosis. A cross is cut in the aponeurosis above the center of the rectus abdominis muscle. (**b**) The rectus muscle is split, and with the index finger, a space is created bluntly in the avascular plane dorsal to the rectus muscle. (**c**) A mesh 10 by 10 cm is inserted via the skin opening. (**d**) The mesh is with the index finger spread out and positioned into the sublay position in the retromuscular space. (**e**) The sigmoid colon is held with a laparoscopic clamp close to the peritoneum at the intended stoma site. The peritoneum is then opened, and as the abdomen exsufflates, the colon is grabbed with a clamp inserted through the skin opening. The sigmoid colon is gently pulled through the mesh and the layers of the abdominal wall. (**f**) A running monofilament absorbable suture attached the bowel to the skin

range of vision (even with the help of a mirror) or if its site on a hernia bulge makes it unmanageable. The disfigurement caused by a bulging parastomal hernia may warrant surgery for cosmetic reasons. In special circumstances, the repair may need to be accompanied by an abdominoplasty to permit a good fit of the appliance. In some instances local liposuction at the stoma site may reduce problems with stoma care.

Preoperative cleansing of the colon is not indicated when repairing parastomal hernias. Randomized trials have shown that in colonic surgery, there is nothing to be gained by subjecting patients to exhausting preoperative colonic cleansing [56]. There is no similar trial available concerning parastomal hernia repair specifically, but it seems reasonable to extrapolate findings in general bowel surgery into this field. Similarly there are no specific studies at hand concerning the use of antibiotic prophylaxis, but it is probably wise to administer prophylactic antibiotics adhering to the same principles that have been shown to be beneficial for bowel surgery in general.

Repairing Parastomal Hernias

Hernia repair is still associated with a high recurrence rate [57]. It has been attempted to repair parastomal hernias by a local procedure. Then the stoma is mobilized locally, the peritoneal sac is identified, and its contents are reduced before closing the peritoneum. The musculoaponeurotic defect is closed with nonabsorbable sutures in an attempt to narrow the aperture. Such local aponeurotic repair should not be performed since it produces an unacceptable high recurrence rate reported in the range of 50–76% [44, 48, 58–61].

Stoma relocation either with formal laparotomy or with limited transperitoneal transfer of the stoma has also been tried when treating parastomal hernias. However, relocation of the stoma into another quadrant produces a recurrence rate at the new site that is at least as high as after the primary enterostomy and recurrence rates of 24–86% are reported [48, 59, 61–63]. If the stoma is relocated a second time, the recurrence rates are further increased [48]. Caution should be exercised when considering relocation of a stoma into a quadrant on the same side of the abdominal wall since this is associated with a higher risk of recurrence [59].

A matter of concern after relocation of an ostomy is that the defect in the abdominal wall at the parastomal hernia site may be very large. Suture repair of the defect has produced a high rate of incisional hernia, and 23–36% of patients having a suture repair develop hernias, but only 3–6% of those having a mesh repair [30, 64–67]. Thus, the abdominal wall defect at a parastomal hernia site must—as with all other large abdominal wall defects—be repaired with a mesh technique.

Relocating the stoma into another quadrant is possibly a better option if a prophylactic sublay mesh is placed at the new site. This can be done in combination with a sublay mesh repair of the abdominal wall defect at the primary stoma site and of any concomitant incisional hernia. This method has been reported in a nonrandomized series [68].

Mesh Repair of Parastomal Hernias

Mesh repair has for many years been the golden standard for incisional hernia. Mesh repair is now also evolving as the method of choice for surgical treatment of parastomal hernias.

Meshes can be placed in an onlay, an inlay, a sublay, or an intraperitoneal onlay position (IPOM) (Fig. 34.5). The size and placement of the mesh are crucial, and the mesh must be placed with considerable overlap and in all directions extend at least 5 cm beyond the edge of the abdominal wall defect. Clinical reports consistently state better results with mesh repair than with suture repair or relocation of the stoma without a prophylactic mesh.

For mesh repair of parastomal hernias, most available types of meshes have been tried, and results have been reported. This includes nonabsorbable, absorbable, partly absorbable, and acellular collagen matrix (biological) meshes. Polypropylene meshes and low-weight large-pore meshes can be placed in a contaminated environment without major complications [4, 69, 70]. It seems likely that low-weight meshes induce fewer infections than the heavyweight meshes [71]. There is a risk of inducing an inflammatory tissue response when placing mesh in contact with bowel, and this may cause fistula formation, adhesions, and septic complications. With the IPOM technique, a mesh constructed in two layers is therefore usually used. The surface facing the abdominal contents is of a nonreactive material so that adhesions are not formed. When ePTFE is used for this nonadhesive surface, there is a high risk of infection in contaminated areas, and if an infection occurs, the mesh must be removed.

Placement of an onlay mesh in the subcutaneous plane involves mobilization of the stoma and fixation of the prosthesis to the external oblique, after threading the stoma through a window in the prosthesis. The advantage of subcutaneous placement is that a laparotomy may not be required. The disadvantage of this and other local techniques is the risk of contamination if the stoma has to be sealed and repositioned. No matter how the stoma is sealed, there is a risk of contamination and of subsequent sepsis. If a septic complication occurs, troublesome sinuses may follow and warrant removal of the mesh. However, modern polypropylene mesh is tolerant of sepsis, and simple local infection will usually settle with the prosthesis remaining in place.

The sublay technique places the mesh around the stoma in the plane between the posterior rectus sheath or peritoneum and the parietal muscles.

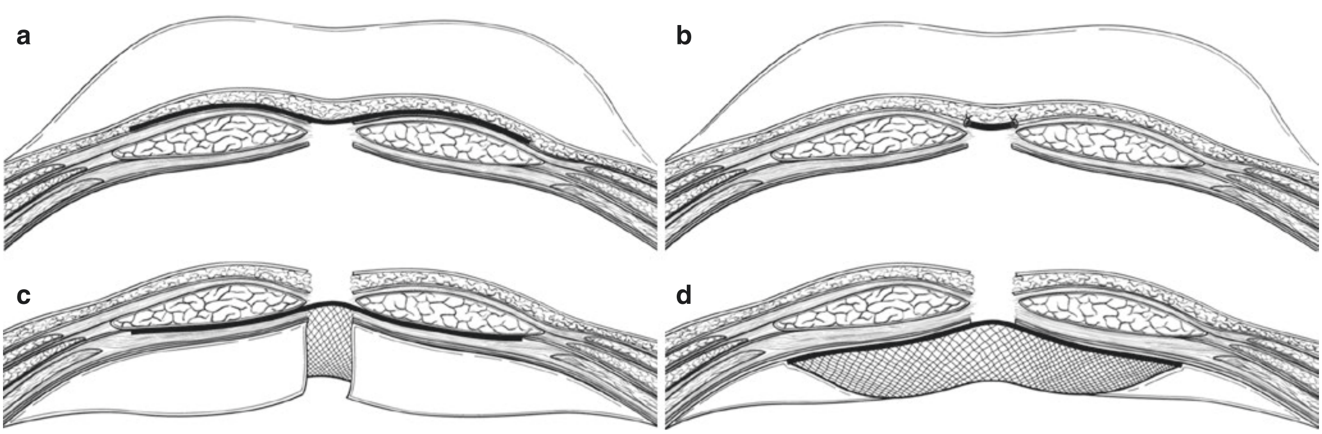

Fig. 34.5 Repairing parastomal, the mesh can be placed in an onlay, an inlay, a sublay, or an intraperitoneal onlay position. (**a**) An onlay mesh is placed anterior to the anterior rectus aponeurosis. The mesh overlap must be considerable (5–10 cm) and the mesh firmly fixated to the aponeurosis. (**b**) An inlay mesh fits the abdominal wall defect and is sutured to wound edges. This method produces inferior results. (**c**) A sublay mesh is placed dorsal to the rectus muscle and anterior to the posterior rectus sheath. The mesh overlap must be at least 5 cm. (**d**) An intraperitoneal onlay mesh (IPOM) is placed on the peritoneum from within the abdominal cavity. The overlap must be more than 5 cm, and the mesh surface facing the abdominal cavity must not cause adhesions

An IPOM can be placed with either an open or a laparoscopic technique. Then the surface facing abdominal contents should be of a nonreactive material so that adhesions are not formed. There are today several meshes available that allegedly provide a nonadhesive surface toward the intestines.

The laparoscopic approach offers the surgeon the ability to visualize the entire abdominal wall so that any incisional hernias may also be repaired at the same time. This technique requires that the prosthetic material be placed in the intraperitoneal position. The laparoscopic approach is described into detail in Chap. 24.

Technique of Extraperitoneal Prosthetic Repair

The patient is prepared with the stoma sealed with an adherent plastic film. The original laparotomy scar is reopened. A plane of dissection is opened between the posterior sheath or peritoneum and the parietal muscles lateral to the stoma. During this dissection, the hernial contents are reduced, if possible without opening the hernia sac. This may not be possible (Fig. 34.6).

A sheet of polypropylene mesh is prepared, to repair the defect, with a hole in it to allow the egress of the stoma. A cut is made in the mesh so that it can be positioned. The polypropylene should fit snugly around the efferent bowel and should overlap the margins of the defect by at least 5 cm. The polypropylene is quilted into place. The mesh is at its corners fixed to the dorsal rectus sheath by single stitches, and the cut made in the mesh is closed with nonabsorbable sutures. If there is any defect in the main wound, the margin of the mesh is extended medially to overlap and repair this defect.

The Sugarbaker Technique of Open IPOM Repair

Repair in this fashion has been described by Sugarbaker and utilizes the old laparotomy incision for access to the abdominal cavity [72, 73]. Berger has developed a modified version of this method in laparoscopic repair of parastomal hernias [74, 75]. The ostomy is covered by a plastic adhesive drape to seal this site and minimize the potential for contamination. The abdomen is entered, and the contents of the hernia are dissected free from the edges of the aponeurotic defect. Care must be taken to preserve the vascular supply to the bowel during this dissection. It is not necessary to dissect or remove the peritoneal sac of the hernia itself. An accurate measurement of the defect will allow the appropriate sizing of the biomaterial. A minimum of a 5-cm overlap is mandatory (Fig. 34.7).

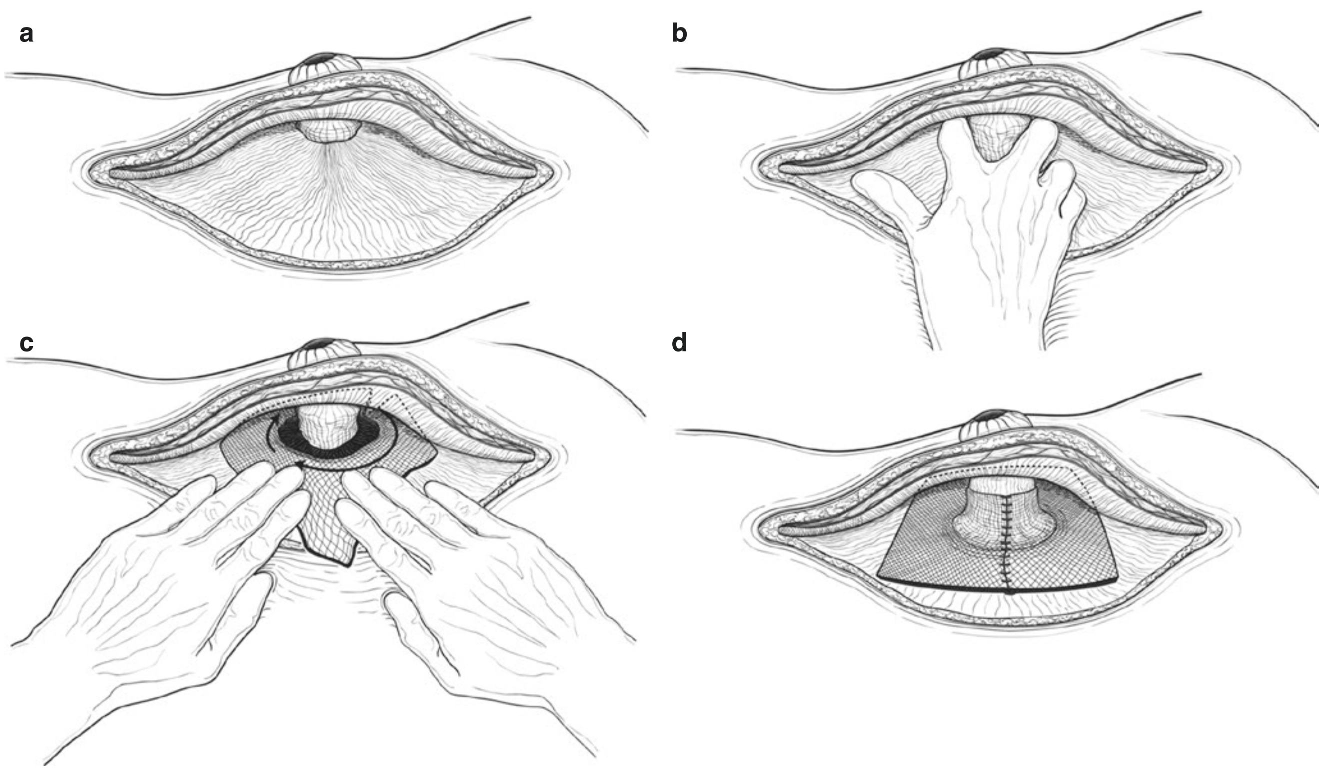

Fig. 34.6 Technique of extraperitoneal prosthetic repair. (**a**) Reopening the laparotomy incision. (**b**) Developing the extraperitoneal plane to the stoma. (**c**) Preparing the mesh to make the repair. (**d**) Placing the polypropylene in place to the muscle layer and superficial to the peritoneum—in the extraperitoneal plane again like "ham in a sandwich"

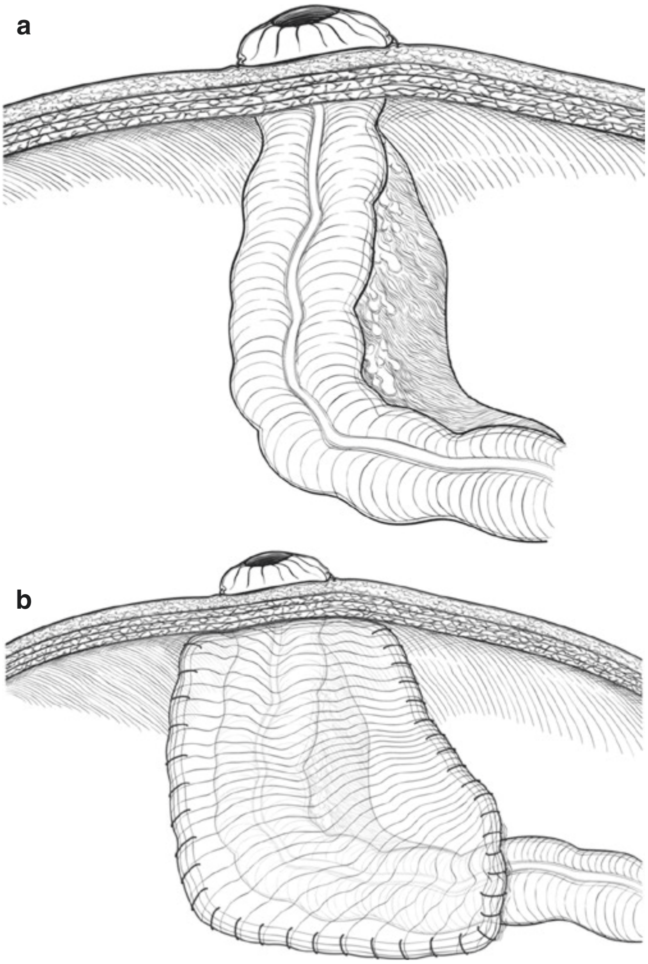

Fig. 34.7 The Sugarbaker technique of open IPOM repair. (**a**) Position of the lateralized colon onto the sidewall of the abdomen prior to the placement of the biomaterial. This must usually be sutured into place to maintain this position. (**b**) Completed repair of the parastomal hernia. Note that the biomaterial covers the hernia defect as well as the lateralized intestine

The prosthesis can be fixed to the abdominal wall in a variety of methods. It may be helpful if the colon is sutured to the lateral abdominal wall by either permanent or absorbable sutures. The mesh should be positioned to provide the necessary amount of overlap so that the intestine is "lateralized" in relation to the exit of the stoma.

The results reported by this technique in the limited number of seven patients were favorable [73]. There were no recurrences or complications after 4–7 years of follow-up. The importance of this technique today is its impact on the development of recent laparoscopic techniques.

Technique of Stoma Relocation

The new stoma site must be precise and careful. One in the lower abdomen overlying the contralateral rectus muscle and away from old incisions and skin creases is preferred. Commonly the location will be at the precise contralateral abdominal location. Preoperative consultation with the enterostomal nurse is valuable to the identification of the ideal location.

A problem, which should be foreseen, is distortion of the abdominal wall by surgery after the operation has begun. The laxity of the musculature caused by anesthetic paralysis and the positioning of the patient on the operating table can result in a significant change in the habitus of the patient. Additionally the operative manipulation of the skin and muscle can result in lateral undermining of the tissues, which can eventuate in a poorly constructed stoma.

The ostomy is covered by a plastic adhesive drape to seal this site and minimize the potential for contamination. Approaching the operation via a midline laparotomy incision greatly facilitates the operation. The stoma is straightened out from the abdominal cavity; an everted ileostomy is uneverted and then closed. The easiest way of closing the bowel is using one of the linear stapling devices available. This will avoid any contamination and generally results in a closed ostomy that is easy to manipulate.

The following steps are then taken (Fig. 34.8):

1. An adequate length of the intestine—ileum for ileostomy and colon for colostomy—is mobilized so that the new ostomy can be constructed with no degree of tension.
2. The low-weight, large-pore mesh is placed in a sublay position at the new stoma site according to the principles for a prophylactic mesh. Without a prophylactic mesh, recurrence rates are uncomfortably high.
3. The mesh is placed in a sublay position covering the midline incision, thereby treating a possible concomitant

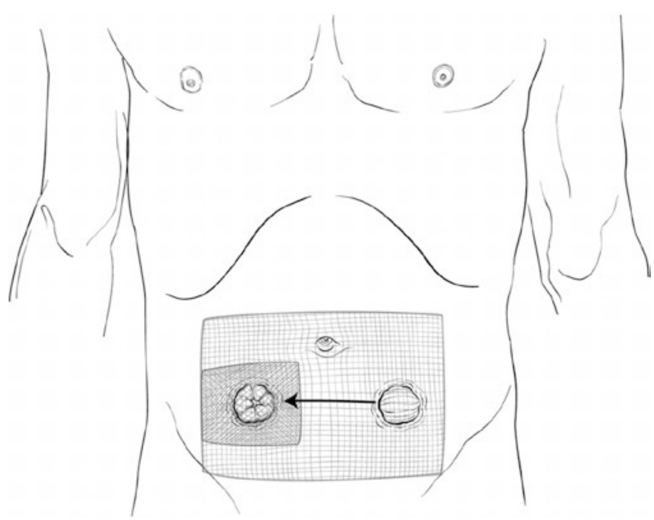

Fig. 34.8 A parastomal hernia is relocated from the left lower quadrant to the right quadrant. A large low-weight large-pore mesh is placed as a prophylactic mesh at the new stoma site and also covering the midline and the defect at the parastomal hernia site

incision hernia or working as a prophylactic mesh against an incisional hernia developing.

4. The mesh is placed in a sublay position at the original stoma site. A defect in the abdominal wall with a diameter of more than 2 cm cannot be closed by simply suturing it without a high proportion of incisional hernias developing. As the defect after a parastomal hernia is always larger than 2 cm, a mesh repair is warranted.

The midline is closed with a running monofilament nonabsorbable or slowly absorbable suture. This suture must be with a suture length to wound length ratio of more than 4. To minimize the risk of wound infection and incisional hernia, the high suture length to wound length ratio should be achieved with many small tissue bites placed 5–8 mm from the wound edge [76, 77]. The skin is closed with a continuous subcuticular suture of a monofilament absorbable suture.

When the operation is completed with wounds closed and draped, the short cutoff bowel end distal to the staple line is excised through the stoma opening. This part of the bowel is most often expendable as scarring and distortion make it useless for a new ostomy. The circular skin defect after the stoma is narrowed with a subcuticular absorbable monofilament purse-string suture. Although this leaves a skin defect with a diameter of several centimeters, late cosmetic results are very good as activated dermatomyofibrils within days will contract and markedly lessen the size of the defect. As the skin opening allows the wound to drain, wound infection will be rare.

Postoperatively appropriate stoma care should be instituted. The general principles for fast-track abdominal surgery should be utilized with swift resumption of meals and activity together with adequate nonmorphine-based analgesics [78]. If despite these measures being taken some degree of postoperative adynamic ileus appears, it may be followed by hyperactivity of the stoma, which may necessitate intravenous fluid replacement after the operation.

Conclusions

Creating an ostomy is a common surgical procedure utilized in both elective and emergent situations. This development has been greatly facilitated by the improvement of modern stoma bandages that now enable an easy and reliable stoma care.

Parastomal hernia develops in 30–50% of patients supplied with an ostomy, and one-third of these demand repairs.

In randomized trials a prophylactic prosthetic mesh placed in a sublay position has reduced the rate of parastomal hernia. This has been achieved without any increase in the rate of complications. Also in nonrandomized studies, a prophylactic onlay, sublay, or IPOM has been associated with low herniation rates.

After suture repair or relocation of the stoma, recurrence rates are unacceptably high. With open or laparoscopic mesh repairs, considerably lower recurrence rates are reported. There are no randomized trials or long-term follow-up available comparing results with these various techniques for parastomal hernia repair.

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35 Laparoscopic and Robotic Repair of Parastomal Hernias

Karl A. LeBlanc

Introduction

The creation of a stoma is necessary to treat many different conditions. It is well known that this will predispose to the development of a hernia due to the fact that the intestine must traverse the abdominal wall. This topic is excellently covered in the prior chapter on parastomal hernia. This chapter will focus on the technical aspects and results of the laparoscopic- and robotic-assisted repair of these hernias. The reader is referred to Chap. 34 for in-depth discussions of the incidence and diagnosis of these problematic hernias. The basic concept of these methods of repair does not differ significantly from the open repair.

Laparoscopic Technique

This approach can be used for all types of primary or recurrent parastomal hernias as classified by the European Hernia Society [1]. Once such approach is the "keyhole approach." In this technique, the mesh is cut with either a "T" or a true circle to allow for the exit of the intestine from the mesh to the abdominal wall. Basically, the mesh mimics the defect in the abdominal wall to allow egress of the intestine. This has proven to be problematic because of the keyhole approach due to the recurrence rates as high as 56% [2, 3]. I had modified this technique to use two overlapping meshes with favorable results but have also abandoned that method in favor of the onlay repair [4]. This Sugarbaker repair is the same as that described in the prior chapter except for the laparoscopic approach.

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Preoperative preparation will include a first generation cephalosporin or an appropriate broad-spectrum antibiotic relative to local hospital policy and antithrombotic prophylaxis. A Foley catheter is occasionally used for any stomal hernia repair but is always used for a urostomy. I prefer to close all ostomies except for the urostomy hernias with silk suture to prevent extrusion of intestinal contents during the operation. Additionally, the location of the ostomy appliance is marked with a skin-marking pen (to assure no sutures are placed in that area) and covered with a sponge. An Ioban drape (3M Company, St. Paul, MN) is applied onto the skin (Fig. 35.1).

The overall procedure is similar to the laparoscopic incisional hernia repair described in Chap. 28. A noncutting optical trocar is used to enter the abdomen in the upper quadrant opposite the site of the ostomy. This will be followed by three additional trocars. The camera port is usually in the upper midline (Fig. 35.2). These are all usually 5 mm trocars but occasionally one of them will be replaced with a 12 mm to ease insertion of the meshes. The presence of additional hernias, which are not uncommon, can alter the final number and location of the trocars. Adhesiolysis will be done with or

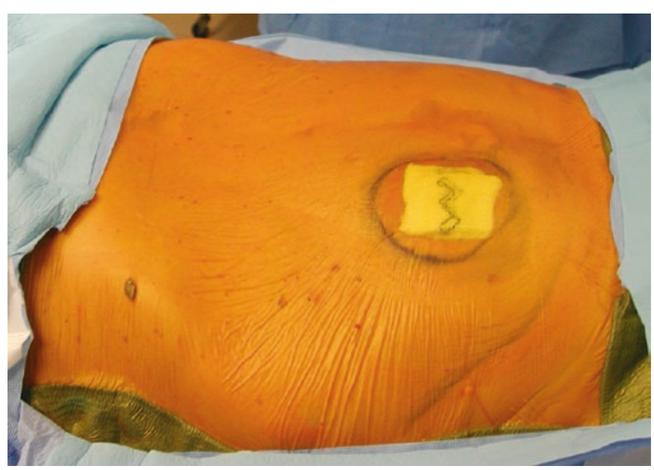

Fig. 35.1 Fully draped ileostomy hernia

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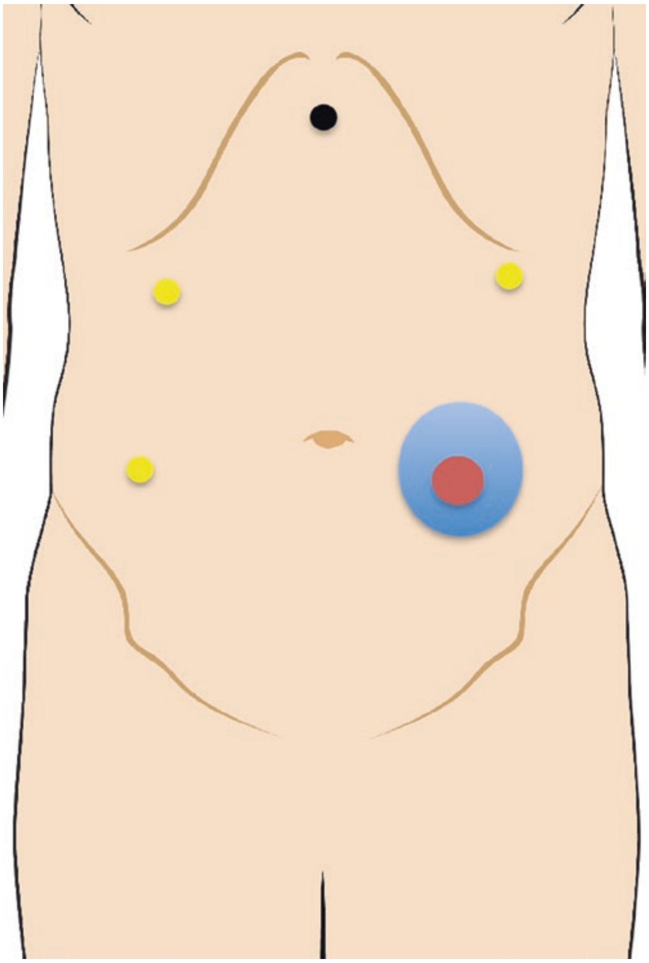

Fig. 35.2 Typical trocar site locations (*yellow* are working trocars, *black* is camera port, *red* is ostomy, *blue* is hernia)

without the use of an energy source based upon the type of tissue that is adhesed to the abdominal wall.

Once the entire area that will be covered by the meshes has been freed of both adhesions and preperitoneal fat (i.e., preparation of the "landing zone"), a ruler is inserted into the abdominal cavity. The dimensions of the defect will be measured but it is important to measure the overlap of 5 cm that will cover the defect. This size has been shown to reduce recurrence rates in incisional hernia repair [5]. It has been my preference to repair these hernias with a threefold approach. As part of this, I use two different mesh materials. After the measurements have been made, a 5 × 7 cm Bio-A (W. L. Gore & Associates, Elkhart, DE, USA) that has been shaped for hiatal hernia repair is cut to enlarge the "U"-shaped opening and the edges rounded (Fig. 35.3). An appropriately sized DualMesh PLUS (W. L. Gore & Associates, Elkhart, DE, USA) is chosen. Three permanent sutures are placed. On the portion that will be positioned lateral to the hernia defect, two are placed 8–10 cm apart to allow the creation of a tube through which the intestine will pass (Fig. 35.3).

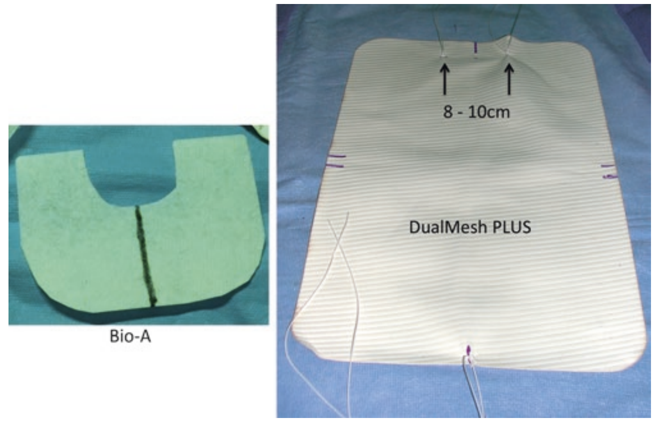

Fig. 35.3 Mesh and suture configurations

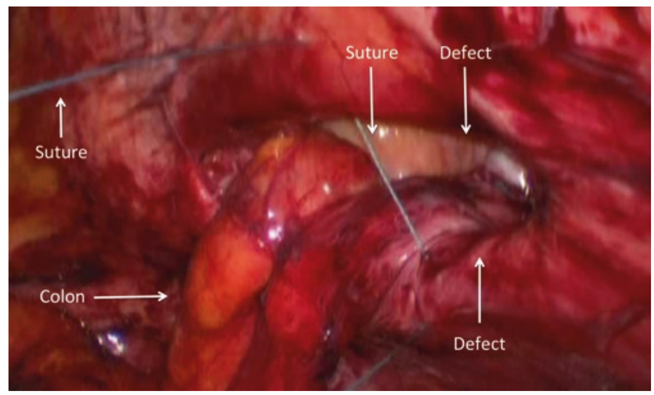

Fig. 35.4 Closure of the defect with permanent suture

These should not be spaced closer than together due to the real risk of obstructing the intestine once these are tied into place. The single suture will allow the other side of the mesh to be located accurately and held in place during fixation.

The first step in the repair will be the closure of the defect itself (Fig. 35.4). Any suture can be used but I prefer the Ti-Knot device (LSI Solutions, Victor, NY, USA). This will serve to allow placement of the absorbable product onto intact tissue, which will facilitate ingrowth (Fig. 35.5). Following this, the Bio-A is brought into the abdominal cavity, positioned to cover the closure, and then fixed with an absorbable fixation device (Fig. 35.6a, b).

The DualMesh PLUS is then introduced into the abdominal cavity. In most cases, it can be rolled tightly and pulled into the abdomen via a 5 mm trocar site (Fig. 35.7). Once positioned correctly, the lower of the two sutures will be pulled through the abdominal wall lateral to the lateralized intestine from a skin incision using a suture-passing device (Fig. 35.8). Through that same incision, another pass of the suture-passing device approximately 1 cm above the site of the other suture will allow the formation of the "tube" through which the intestine will pass. The location of these sutures is critically impor-

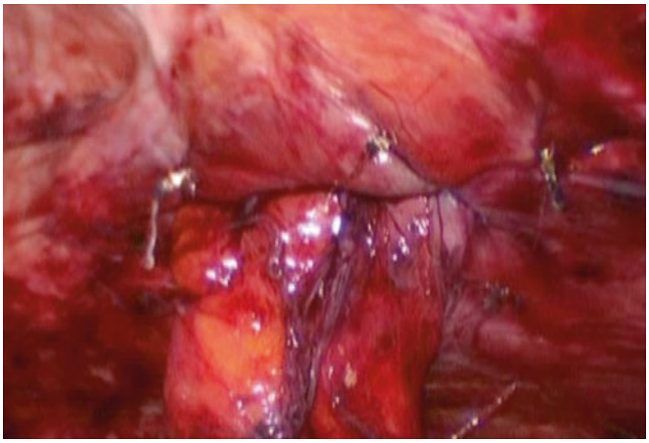

Fig. 35.5 Closed defect

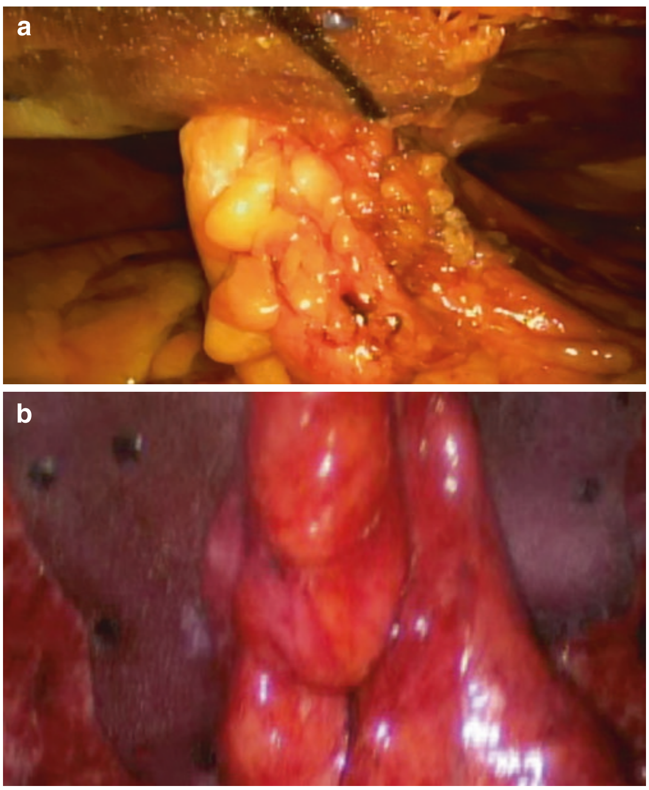

Fig. 35.6 (**a**, **b**) Bio-A in place and fixed to the anterior abdominal wall

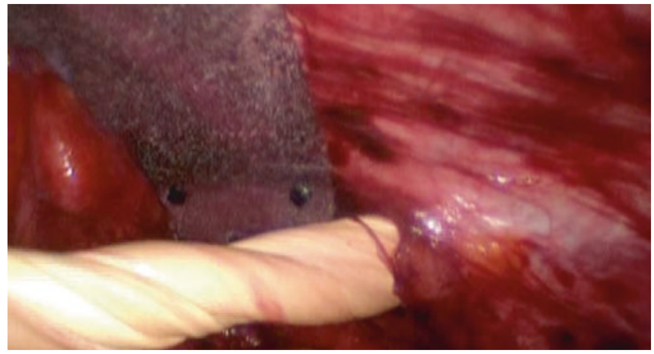

Fig. 35.7 DualMesh PLUS being pulled into the abdomen via a 5 mm trocar site

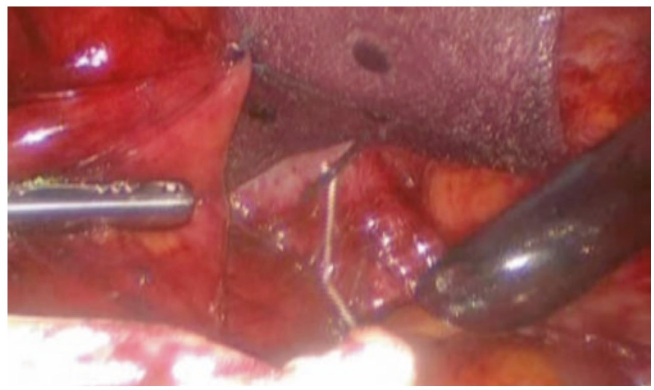

Fig. 35.8 Suture-passing device grasping the lower transfascial suture

tant. If they are put too far apart, the mesh might be pulled too tightly and act as a bowstring resulting in obstruction of the intestine or creating an erosion and fistula [6].

After assurance that these two sutures are correctly placed, the single suture will be brought through the anterior abdominal wall. It is frequently helpful to move the camera to the lower trocar on the opposite side of the abdomen to place this and the other two sutures. Once the correct position of all three sutures is confirmed, they are tied. The mesh will be pulled tightly in all directions and fixed with an absorbable fixation device, although a permanent one could be used depending on the selection of the surgeon. These are placed 2–3 cm apart along the periphery and adjacent to the bowel underneath the mesh.

Once this has been done, additional transfascial sutures are placed approximately 5–10 cm apart (Fig. 35.9). These sutures are placed by using a "suture-passing" device, of which there are many different varieties. An incision in the skin is made through which the device is inserted to traverse the entire abdominal wall and the mesh. It will initially contain the suture, which is "handed off" to a laparoscopic instrument. The device is then removed and reintroduced through the same skin incision but directed to be at least 1 cm apart from where the other end penetrates the mesh. It is then caught by the suture-passing device and withdrawn outside of the abdomen and tied. The decision of how many additional sutures is based upon the location of the hernia, the prior number of repairs, the presence of prior mesh (although it is best to excise them), and associated comorbidities of the patient.

To prevent the possibility of any organ from slipping into the entry point of the intestine under the mesh, I prefer to sew the intestine to the mesh with a permanent suture (Fig. 35.10).

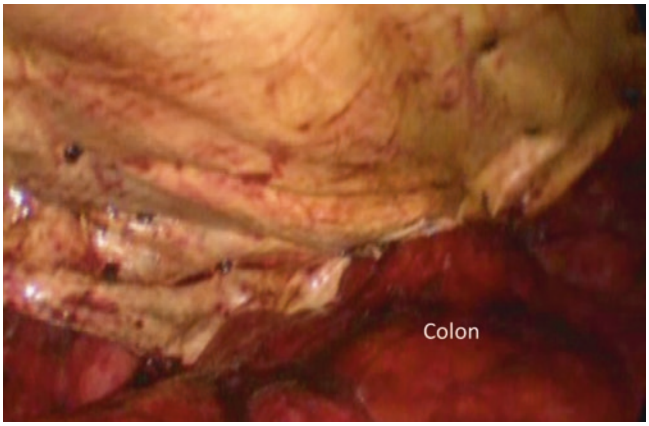

Fig. 35.9 Nearly completed fixation of the DualMesh PLUS

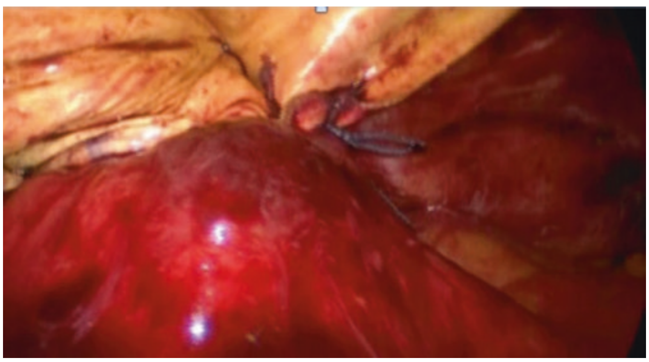

Fig. 35.10 Intestine sutured to the mesh

Once this is complete, the abdomen is deflated, trocars are removed, and the site of all transfascial suture incisions is inspected. In many cases, there will be dimpling due to the fact that the subcutaneous tissue has been caught by the knots of the suture. A hemostat must be used to lift up at these sites to remove the dimpling at that time, as these will be a permanent cosmetic deformity. The skin incisions are closed with an absorbable suture.

Drains are not generally used but will be needed if the contents of the hernia are very large. These patients will be fed the next day and will be discharged from the hospital once there is ostomy function. This is necessary to assure that the stomal opening has not been compromised.

Results of Laparoscopic Technique

In my own experience with the above technique with 18 patients laparoscopically, I have had 2 recurrences with an average follow up of 30 months. Both of these were recurrent when the operations were performed. One of these patients gained 50 pounds, and the intestine slipped into the entry site of the ileostomy. I had not sutured the mesh to the intestine in this patient and began to do this in every case after that. The other patient developed a mesh infection of a mesh that was placed prior to the parastomal hernia repair that I had performed. When I removed that material, I also excised the parastomal mesh. Not surprisingly, the hernia recurred and I have since repaired it robotically without evidence of another failure. Two additional patients had to be returned to the operating room to loosen the lateral transfascial sutures as these were too tight. Consequently, I have required the 8–10 cm gap between them and the method of placement described above.

Others have reported favorable results with the laparoscopic method. It was noted above that the use of a keyhole is associated with an unacceptably high recurrence rate. Favorable results with a product specifically designed for these hernias but incorporating a keyhole within it were initially reported [7]. They had only a 4.2% rate of recurrence. Wara and Anderson also reported a low rate of recurrence (3%) but did incur a complication rate of 22% with 4.2% infection rate [6]. Recently, however, Mizrahi et al. reported their experience with this same product. Their recurrence rate was 46.4% [8]. That product is no longer available.

Berger and Bientzle reported on two different methods, the pure Sugarbaker and the keyhole plus Sugarbaker (sandwich method) on 66 patients. The combined recurrence rate was 12% [9]. They later utilized only the sandwich method with polyvinylidene fluoride in 47 patients with a 2% recurrence rate [10]. Others have reported similar results, with a recurrence rate from 4 to 10.5% [11–13]. This is a very similar methodology to that described in this chapter except that both of the meshes were permanent and a keyhole was used rather than the shape described herein.

Hansson et al. performed an extensive meta-analysis on the topic of parastomal hernia repair methods (Table 35.1) [14]. They concluded that the primary sutured repair should not be done and that a mesh repair in any location was preferred. It appeared that the sublay (retromuscular) location is the best location in the open repair. They also analyzed the method of use of the mesh as either the onlay (Sugarbaker or keyhole) but open or laparoscopic (Table 35.2). They concluded that the laparoscopic keyhole had too high a rate of recurrence to be recommended. The sandwich repair was preferred by the laparoscopic technique.

An even more recent meta-analysis regarding only laparoscopic methodology provided similar results [15]. Fifteen articles were eligible for review with a total number of 469 patients. There were favorable outcomes overall, but the recurrence rate was much better with the Sugarbaker repair (Table 35.3).

An extensive analysis of evidence-based medicine has found that that there is level 3 evidence that the laparoscopic repair of parastomal hernias can be performed safely and level 4 evidence that the recurrence rate after laparoscopic

Table 35.1 Meta-analysis of different repairs (numbers are percentages; *IPOM* intraperitoneal onlay mesh)

Repair type	Infection	Other complications	Mortality	Recurrence rate
Suture only	11.8	10.8	3.8	69.4
Open onlay mesh	4.5	8.3	0	17.2
Open sublay mesh	4.8–8.4	7.1	0–8.4	6.9
Open IPOM	4.4	17.8	0	22.2
Laparoscopic IPOM	6.0	12.7	1.2	14.2

Table 35.2 Meta-analysis of mesh repairs (numbers are percentages)

Mesh repair type	Recurrence rate
Open Sugarbaker	15.0
Open keyhole	14.2
Laparoscopic keyhole	34.6
Laparoscopic Sugarbaker	11.6
Laparoscopic sandwich (Sugarbaker and keyhole)	2.1

Table 35.3 Outcomes of laparoscopic parastomal hernia repair

Outcome	Percentage
Postoperative morbidity overall	1.8
Surgical site infection	3.8
Mesh infection	1.7
Obstruction requiring reoperation	1.7
Other complication	16.6
Recurrence rate overall	17.4
Sugarbaker repair	10.2
Keyhole repair	27.9

repair is lower than the open approach [16]. Based upon these findings, the group concluded that the recommendations are as follows: Laparoscopic repair of parastomal hernias should be considered a safe alternative to the open approach (grade B). Additionally, the laparoscopic repair is a valid alternative option to open repair because the rate of recurrence is lower than the open approach (grade C).

Robotic Technique

The robotic repair of these hernias is very similar to the laparoscopic method. This should not be surprising given the fact that this still represents a laparoscopic technique. The position of the trocars will be similar to the laparoscopic locations. Four trocars and three robotic arms are generally used. Three trocars are for the robot arms, and a fourth one is used for introduction of sutures and mesh as well as removal of the needles (Fig. 35.11). Note there are two different locations of the camera trocar for the different robots. Currently only the Si robot (Intuitive Surgical, Sunnyvale CA, USA) is FDA approved for hernia repair. The adhesiolysis and exposure of the intestine and fascial defect are similar to the laparoscopic approach. I prefer to repair this type of hernia with three different methods exactly like the laparoscopic repair above with specific modifications that will be noted below. I do not choose the size of either of these until I have assessed and measured the defect and the areas to be covered by them.

The DualMesh PLUS will be sized to provide at least a 5 cm overlap of the product to the fascial defect. The ultimate choice of size will also be significantly influenced by the presence of an additional incisional hernia (which will occur in at least 25% or more of cases). The location of any incisional hernia will also dictate not only the size of this mesh but if an additional mesh should be used solely to cover the incisional defect itself. The mesh will be marked on both sides to delineate the center of both axes of the product. At least three absorbable (rather than the permanent sutures used laparoscopically) sutures will be placed into the mesh (Fig. 35.12). These are used for positioning of the mesh only and will be cut after their purpose is served. Two purple polyglactic acid (#0) sutures are placed one side approximately 10 cm apart as shown on the mesh on the right in the figure. These will sometimes be placed closer if the hernia is from an ileostomy or urostomy. Instead of using all three sutures of the same color, it is sometimes helpful for identification inside the abdomen to use a different color, such as a white polyglactic acid (#0) suture for the single one. The mesh on the right in Fig. 35.12 would be used if an associated incisional hernia is also found that will not be covered by the parastomal mesh. It has a centrally located polyglactic acid suture for placement and positioning. The third mesh is the Bio-A that would be used similarly to the laparoscopic repair discussed earlier in this chapter.

Once the dissection of adhesions and the reduction of the hernia contents are complete, the sidewall of the abdomen is inspected to evaluate the amount of adipose tissue that could lie between the mesh and the fascia. It is important that this is dissected away from the tissues so that the mesh is approximated to firm fascia rather than fat to assure rapid and adequate tissue ingrowth. After this is completed, the fascial defect and the area that is to be covered with the DualMesh PLUS is measured intracorporeally with a ruler that is inserted into the abdominal cavity through the fourth trocar that was placed earlier. The measurement is done on both the transverse and vertical directions (Fig. 35.13). Ten centimeters is added in all directions and this is the mesh chosen. In some cases, this may need to be modified such as

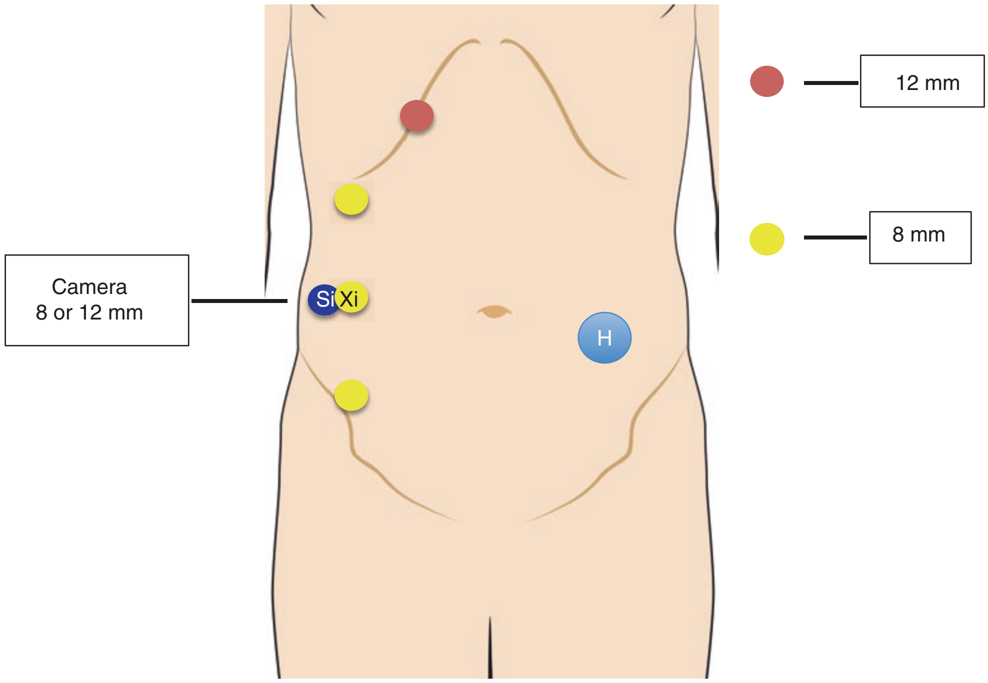

Fig. 35.11 Typical trocar placement for LLQ hernia

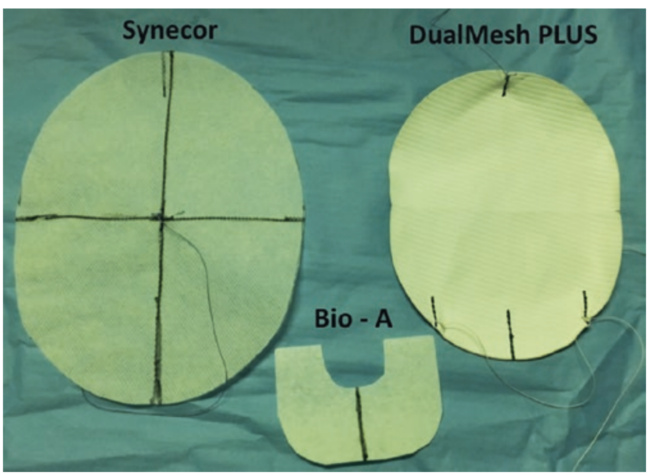

Fig. 35.12 Various meshes that are used; all of the sutures are absorbable

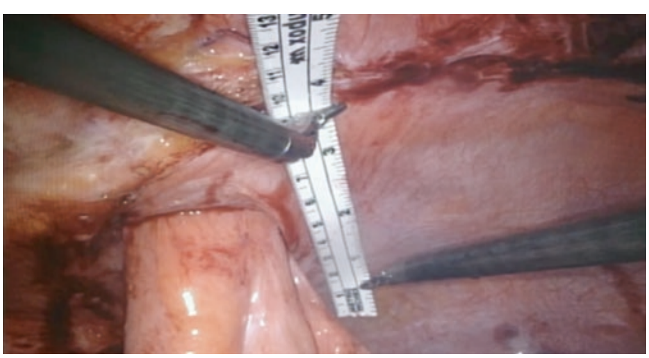

Fig. 35.13 Measurement of the area to be covered by the onlay mesh

if there is an existing mesh already or if there is an associated incisional hernia that will also be repaired with the same prosthetic. It is preferable to remove any other mesh in place, if possible.

The fascial defect will then be re-approximated with barbed sutures (Fig. 35.14). The Bio-A will be introduced and placed onto the abdominal wall. The closure described above will be covered with the material, and the side with the cutout will face the intestine. This will then be secured with an absorbable tacking device similar to the laparoscopic repair (Fig. 35.15). To accomplish this, one of the robotic instruments will be removed and the device placed. It is usually necessary to undock the arm to complete this maneuver.

The DualMesh PLUS will now be introduced and positioned (Fig. 35.16). The location of the exact middle of intestine is located on the lateral abdominal wall and an incision is made there, as is done laparoscopically. The sutures will be pulled tight to assess mesh position and to note any constriction of the bowel (Fig. 35.17). Due to the location of these sutures on the mesh, this will create a small flap of mesh. This is generally used to suture the mesh to the bowel or mesentery to eliminate the risk of herniation through this potential site.

Next the white (if used) suture is pulled through the wall of the abdomen at the site that confirms that the mesh is centered and positioned properly (Fig. 35.18). The previously placed lines on the DualMesh PLUS are helpful at this time. The mesh is drawn tight (Fig. 35.19). If it is loose, the suture should be moved to assure that the mesh

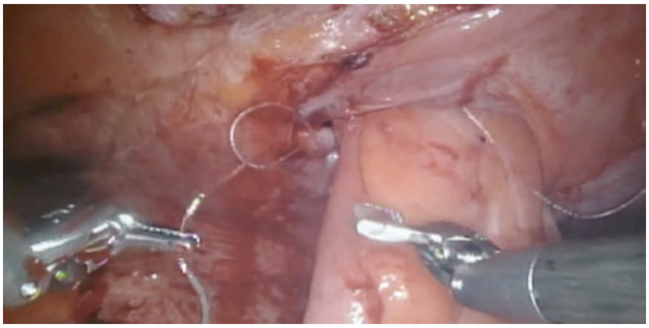

Fig. 35.14 Partial closure of the parastomal fascia defect

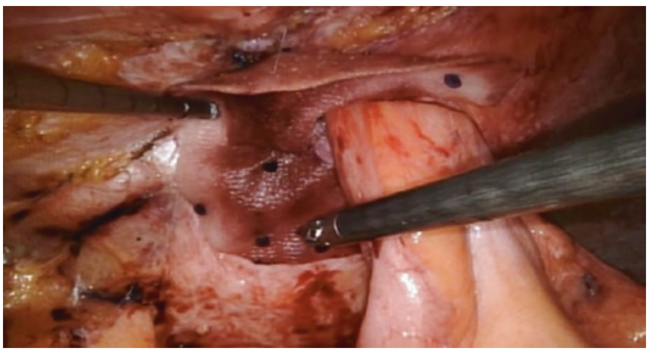

Fig. 35.15 Placement and fixation of the Bio-A. The tacking device on the left is used with an undocked robotic trocar. The instrument on the right is a robotic needle holder

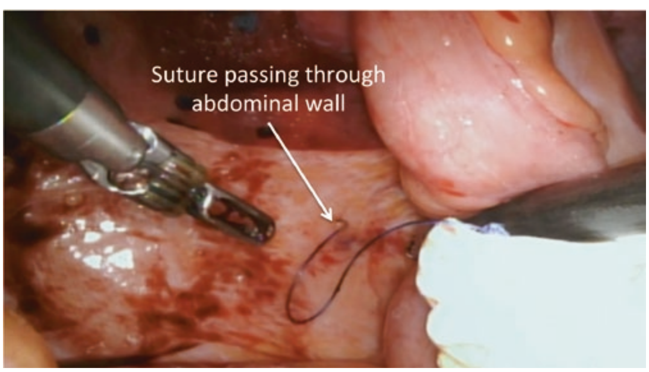

Fig. 35.16 Lateral transfascial suture pulled through the abdominal wall

is snug. Another barbed polypropylene suture (#2) is used to secure one side of the mesh. This is a double-armed suture. One will run adjacent to the intestine and the other near the edge of the mesh. A separate suture will be used to also suture next to the intestine and the other arm on the lateral aspect of the mesh. This will create the tunnel for the intestine to enter typical of the Sugarbaker repair (Fig. 35.20). The final step will be to suture the mesh to the intestine with a smaller barbed permanent suture (Fig. 35.21).

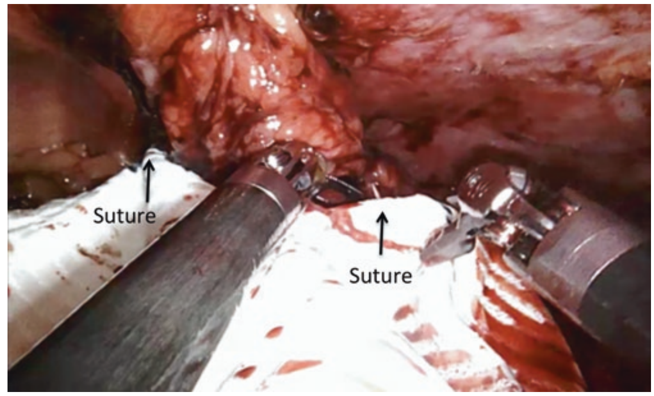

Fig. 35.17 The two lateral sutures are pulled tight to assess placement

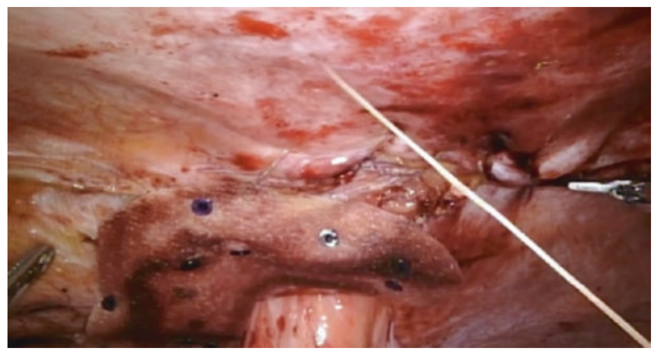

Fig. 35.18 The *white* polyglactic suture is pulled through the abdominal wall to position the medial side of the mesh

Fig. 35.19 The DualMesh PLUS is drawn tight against the abdominal wall

Postoperative Management

Abdominal binders are generally not used, as this seems to interfere with ostomy function. The NGT and urinary catheter are removed on postoperative day one. Meals are advanced as appropriate. Patients are usually discharged on the third or fourth postoperative day.

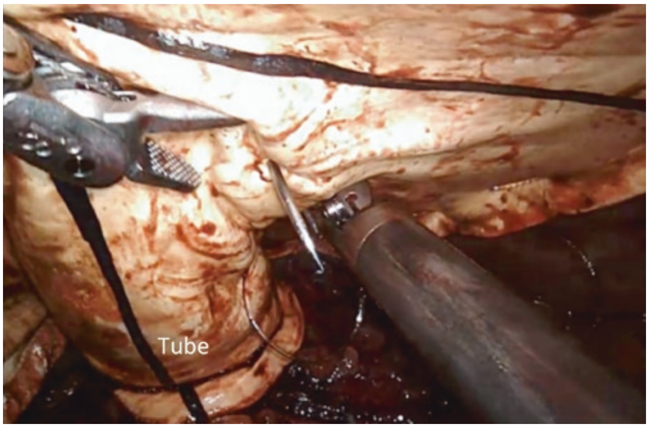

Fig. 35.20 Fixation with barbed suture to complete creation of a tube for the intestine to pass

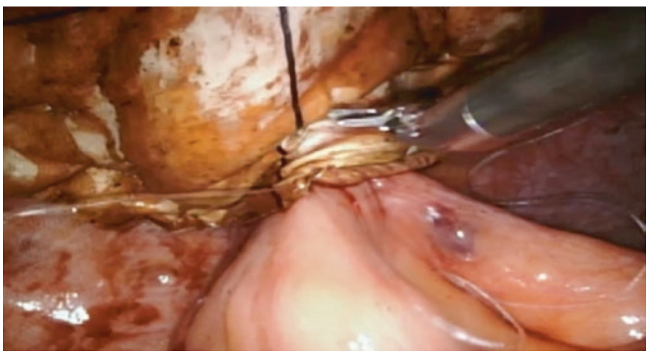

Fig. 35.21 Securing the intestine to the mesh with barbed suture

Most of these hernias will develop a seroma. Generally they are small unless the hernia contents were long standing and of large amount. Patients should be informed of such preoperatively. Unless very symptomatic no treatment is necessary. If needed, aspiration or drainage via interventional radiology could be done.

Results

To date, we have performed 16 parastomal hernias using the robotic assistance. At the time of this writing, the follow-up ranged from 2 to 36 months. One patient did have to be returned to the operating room due to an obstruction that was caused by too tight of a suture that fixed the mesh to the anterior abdominal wall. The mesh was slit and re-sutured to the intestine. There have been no other adverse events or recurrence during this time frame.

Conclusion

The laparoscopic repair of parastomal hernias is a preferred technique over the open method. This can be done in a safe and effective manner with the Sugarbaker or this modified Sugarbaker, as described here. The robotic repair is an extension of that repair and should provide similar, if not, superior results.

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Lumbar Hernia

36

Maciej Śmetański and Karl A. LeBlanc

Anatomy

The lumbar area is bounded above the 12th rib, below the iliac crest, behind the erector spinae (sacrospinalis), and in front the posterior border of the external oblique (a line passing from the tip of the 12th rib to the iliac crest). Within this area two triangles are described: the superior lumbar triangle (of Grynfeltt) and the inferior lumbar triangle (of Petit). The superior lumbar triangle is an inverted triangle, its base is the 12th rib, its posterior border is the erector spinae and its anterior border the posterior margin of the external oblique, and its apex is at the iliac crest inferiorly. The base of the inferior lumbar triangle is the iliac crest, its anterior border is the posterior margin of the external oblique muscle, its posterior border is the anterior edge of the latissimus dorsi muscle, and its apex is the superior triangle. Both the superior and the inferior lumbar triangles vary in size depending on the attachments of muscles to the iliac crest (Fig. 36.1). The floor of both triangles is the thoracolumbar fascia incorporating the internal oblique and the transversus abdominis to a variable degree.

The T12 and L1 nerves both cross the superior lumbar triangle. The abdominal wall musculature (rectus abdominis, external and internal oblique, and transversus abdominis) and overlying skin are supplied by the 7th through 11th intercostal nerves and subcostal nerve (12th intercostal equivalent). It is described that the 11th intercostal nerve divides into two branches (at the tip of the 11th rib). The posterior branch supplies motor innervation of the transversus abdominis and internal oblique muscles, and the anterior branch supplies motor innervation of the external oblique and sensory innervation of the overlying skin [1]. This is important to mention that if the nerve is injured proximal to its division (e.g., intraoperatively), motor innervation for the entire segment of the muscles would be compromised.

The cutaneous sensory nerves of the abdomen overlap with adjacent sensory nerves to provide the innervation in the dermatomal distribution. In contrast, minimal overlap exists between adjacent motor nerves. Segments of each abdominal muscle are innervated by a single intercostal nerve. So loss of a single spinal level of motor nerves results in paralysis of a full-thickness segment of the abdominal musculature, what can lead to postoperative flank bulging, often diagnosed as a type of lumbar herniation [2].

Another important finding for the surgical anatomy is that the segmental nerves and vessels are situated between the internal oblique and transverse muscle. This is important to understand because this layer should not be used for surgical procedures to avoid possible nerve irritation or injury. Surgical injury and/or division of the nerves in this layer can potentially lead to pain and functional impairment of the lateral abdominal wall.

Clinical Features

Congenital lumbar hernia does occur and can be bilateral [3]. Such congenital hernias present as a bulge in the loin and may be associated with intestinal symptoms. Lumbar hernias may be acquired, following sepsis in the retroperitoneal tissues [4] as a result of osteomyelitis or tuberculosis of the vertebral bodies or iliac crest which disrupts the lumbodorsal fascia [5], or following surgical operations on the kidneys [6], aortic aneurysm, and also iliac bone harvest and latissimus dorsi myocutaneous flap [7, 8]. Traumatic lumbar hernias occur following direct blunt trauma [9] and seat belt injuries in vehicle accidents [10, 11]. During the vehicle

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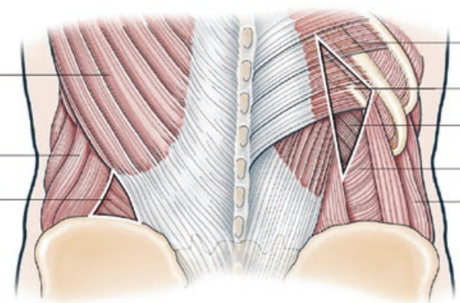

Fig. 36.1 Dissection of the lumbar region to illustrate the anatomy of the inferior lumbar triangle (*left*) and the superior lumbar triangle (*right*)

crash, poorly applied seat belt tends to migrate above the iliac crest exposing the full abdominal musculature to the forces of deceleration. This results in anterior rotation of the pelvis with a shearing action that predisposes the patient to disruption of the musculofascial structures [12]. In some cases even large disruption of the posterolateral abdominal wall from the level of T12 vertebra to the iliac crest can occur, causing large lumbar hernia involving sigmoid and descending colon and/or the kidney [13].

Lumbar hernia is also described following the anterior approach to the lumbar spine for vertebral interbody fusion for lumbar disk disease or nephrectomy. These are usually not true hernias as there is no true fascial defect. In some cases a true fascial defect (i.e., hernia) may be demonstrable, but, in the majority, this is not the case. These abdominal wall deformities result from the injury to the nerves that innervate the upper portions of the external oblique, internal oblique, transversus abdominis, and rectus muscles. The path of the T11 and T12 nerves can be traversed during the dissection of open space for the above operation. The development of a permanent flank bulge as a consequence of flank incision for radical nephrectomy is underestimated and can occur in almost half of the patients [14]. The deformity can be progressive as the protrusion of the upper portions of the paralyzed muscles will cause an outward protrusion of the normal portions of these muscles (Fig. 36.2). This bulge can increase in the time causing pain and discomfort especially during the Valsalva maneuver and walking [2].

Lumbar hernias may contain a variety of intra-abdominal organs; hernias containing the colon are most frequent, but small intestine, stomach, and spleen are also likely candidates for herniation. A particular curiosity is the sliding hernia of the colon, which causes intermittent obstructive symptoms.

The differential diagnosis must include tumors of the muscles, lipoma, hematoma associated with blunt trauma, abscess, and adrenal tumors. Small fatty protrusions of retroperitoneal fat through the lumbodorsal fascia have been implicated as a cause of low back pain [15, 16].

Back pain radiating to the groin, presumably due to irritation of lateral cutaneous branches of the 10th, 11th, and 12th intercostal nerves, has been recorded. Tiny fatty hernias along the tracks of cutaneous nerves through the lumbar fascia give rise to severe low back pain with radiation to the buttocks and thigh. These hernias are palpable and tender. They are similar to the fatty hernias that occur through the linea alba and anterior aponeurosis. Local anesthetic infiltration abolishes the pain and confirms the diagnosis. Local excision and closure of the defect cures the condition. The diagnosis is made/confirmed by CT scan, which will delineate the defect [10, 17].

Fig. 36.2 Preoperative appearance of a "denervation hernia" after a right nephrectomy

The patients that have the "denervation" injury that leads to the protrusion of the flank will frequently complain of back pain that is related to the defect. It is difficult to explain the source of this complaint, as many of these patients will have had a long preexisting complaint of back pain requiring the disk surgery. The most common presentation is the acknowledgment of the significant cosmetic deformity that is caused by the musculature paralysis. This will cause asymmetry to the contour of the abdomen (Fig. 36.2).

The Operation

Operative treatment of lumbar hernia varies in abovementioned different clinical situations. Primary lumbar hernias rarely extend over 7–10 cm, and many alternative operations have been described giving positive results in short- and medium-term follow-up. Different methods and approaches should be used in the “denervation” hernias. Acute traumatic hernias with comorbid injures create many clinical situations, so the time and extension of the procedure should be the point of consideration.

Elective treatment of primary lumbar hernia could be performed via open or laparoscopic approach. Small hernias (diameter less than 5 cm) have been successfully treated without synthetic implant using simple closure of the defect with nonabsorbable sutures. In these cases open access parallel to the 12th rib was performed and the sac identified and reduced. If only the preperitoneal fatty mass was found in the hernia orifice, excision after ligature was performed to reduce the content. No recurrences were found in this series of patients in the mean 8-month follow-up [18]. While this treatment option could be taken into consideration, most of the authors believe that synthetic material implanted in the sublay position will improve the results. Small hernia was cured successfully with open implantation of a plug (Bard Mesh Dart) in one described case [19]. In other series (ten patients), an open approach was used (incision over the hernia typically in the parailiac location) to place the implant in the preperitoneal space. Mesh should extend the defect with an overlap of minimum 5 cm to secure the repair. In the area of iliac crest when the overlap was not sufficient (hernia orifice extended to the bone), fixation to the bone with double suture-arm bone anchor (Mitek GII titanium anchor) was performed [20].

In the recent years, the laparoscopic approach seems to dominate over open techniques due to better visualization of the defect, its simplicity, and proven good results [8, 21, 22]. For incisional lumbar hernias, the transperitoneal approach allows dissection of the omental adhesions from the previous surgery, careful extraction of the hernia content, and exposure of the hernia orifice [8, 23]. Even if the open repair must be performed due to the hernia size, laparoscopic exploration of the abdominal cavity is advised to assess the clinical situation [13]. In this method the approach and technique is similar to that of the incisional hernia repair (described in Chapter on Ventral Hernias). A significant difference is that the patient must be turned in the lateral decubitus position (Fig. 36.3). The use of transfascial sutures and fixation devices is identical to the incisional hernia operation. Mesh could be placed intraperitoneally (composite tissue separating material) or retroperitoneally after hernia sac extraction [24]. In these cases polypropylene or partially absorbable lightweight mesh is used. The peritoneum is closed over the mesh to avoid contact with the viscera [8, 23].

Moreno-Egea has reported on a prospective nonrandomized study of 16 patients, 15 of whom were post nephrectomy and 1 after trauma. Mesh was used in all of the repairs, with seven done by the open method and nine by a laparoscopic approach. They found that the open repair was associated with a longer operative time, a longer length of stay, higher morbidity, and more recurrences. There were no recurrences in the laparoscopic group compared to three in the open group ($p = 0.4$). They concluded that the laparoscopic repair was “more efficient and profitable.” This level 2b evidence supports laparoscopic repair [25]. The International Endohernia Society in 2014 has based its guidelines mainly on this paper with a statement that: “Laparoscopic repair of lumbar hernia (with mesh) is superior to open repair with mesh in terms of morbidity but not recurrence rate” [26].

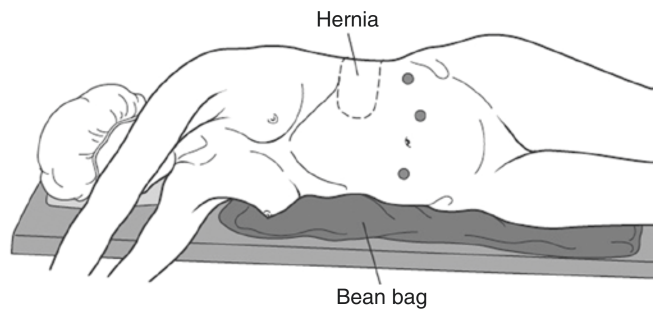

Fig. 36.3 Position of patient to repair a lumbar hernia of the left side. This position is also used for the repair of the “denervation hernia.” The three dark circles connote the approximate location of the trocar sites

An interesting alternative was described in the series of patients operated via laparoscopic approach with combined intra- and extraperitoneal repair [TAPE—transabdominal partially extraperitoneal]. For sufficient overlap in large lateral defects, the retroperitoneal space is dissected laterally (behind the ascending or descending colon) to reach the psoas muscle. A large prosthesis is fixed with tackers to the abdominal wall and with the sutures to psoas muscle. At the end of the procedure, the colon is restored to its natural anatomical position through interrupted sutures to the mesh, making use of the preserved peritoneum above the white line of Toldt [27].

One paper considered the totally extraperitoneal approach and showed the possibility of that repair. The authors believe that retroperitoneoscopy allows safer dissection of the space and tension free placement of the mesh. However, only one case has been described to date, but this method is very similar to the TEP in inguinal hernia repair. While it could be a valuable alternative, it was never followed by other authors [28].

In the acute traumatic situation, where full laparotomy to exclude intraperitoneal bleeding is mandatory, the abdomen should be explored through a midline abdominal incision.

Extensively damaged, ischemic colon in the hernia will need resection with the formation of a stoma if indicated. The defect in the lumbodorsal fascia should be sutured with nonabsorbable sutures. The defect in the fascia is best reinforced with a prosthetic biomaterial in addition to primary closure. However, the acute repair of the traumatic lumbar hernia is associated with a high recurrence rate. In recently described series, 50% of patients developed a recurrence. Due to this data delayed repair was proposed. The authors believe that even if the patient requires abdominal exploration for other injuries, the repair of traumatic lumbar hernia is not mandatory at that time and should be individualized. At that time, it may be best to defer to an expeditious, elective repair once the other acute issues have resolved. Repair in high-risk patients with associated injuries and contaminated wounds may lead to wound infection and, eventually, failure of the repair thereby making any subsequent repair more difficult [13].

In the situation of the denervation injury, the repair is more problematic. Because no fascial defect is present, many surgeons are reluctant to repair what is reasonably believed to be a cosmetic problem [29]. As mentioned, according to the recent follow-up studies, the flank bulge leads very often to persistent pain and limitation of daily activity [14]. Because of this many such patients have a strong desire to undergo a reparative operation. The difficulty lies not only in the decision to operate but also in the type of repair that can be done in these patients. The data on any of these choices is sparse. There are three basic options in which to approach this problem. The first is seemingly a very simple procedure. The involved flank muscles can be exposed and sutured in the form of a plication. Several layers of these sutures can be applied which will result in a very appreciable improvement in the appearance of the contour of the abdomen at the time of surgery and shortly thereafter. Unfortunately, the denervated muscle cannot be cured nor does the plication provide a final solution. The muscle adjacent to the plication is still paralyzed and will bulge as before within several months to a few years. Because of this failure, the use of a prosthetic material is recommended. The surgeon must provide for a very wide overlap of the prosthetic to affect a positive long-term result. The prosthetic can be placed in the extraperitoneal position or over the external oblique muscle. The muscles are divided and the extraperitoneal space is dissected. A large piece of material is placed in that location. It is important to ensure that the mesh extends from above the ribs to the level of the iliac crest. Only in this manner will all of the denervated muscle be covered. The difficulties lie in the dissection of the preperitoneal space, as this area will be densely scarred.

There are two proposed approaches to the preperitoneal space. A lateral approach through the previous incision or a medial approach through an incision of the rectus sheath can be done. Placement of the mesh should extend it onto the unaffected site to overlap the defect. In a small series (7 lateral vs. 8 median), the lateral approach to the denervation area did not provide satisfactory long-term results. Conversely the median approach resulted in the maintenance of the proper shape of the flank in long-term observation [30].

The results achieved can be even more satisfying when plication of the muscles is performed concomitantly. Because the fibers of the abdominal muscles are orientated in opposing directions, the forces that the muscles exert are in opposition. The anatomical repair restores these opposing forces through plication of the lateral muscles transversally. In these cases implanted mesh additionally reinforces the strength of the repair [2].

Another, less favored, method is the prefascial (onlay) method. In this case, the denervated muscles are plicated. A large piece of a prosthetic material is then placed from above the ribs to below the iliac crest. This can be sutured with permanent sutures in an interrupted or continuous fashion. The theoretical disadvantage of this approach is that the denervated muscle is supported from above rather than behind the fascia. Although this repair seems to be easier to perform, it does not increase the possibility of intra-abdominal injury due to the underlying adhesions. Additionally recurrent hernias can occur in the previous scar underneath the mesh [31]. Evidence favoring either the onlay or extraperitoneal approach is still sparse due to the relatively infrequency of these hernias.

Laparoscopic/Robotic Repair

General Technique Comments

A nasogastric tube and urinary bladder catheter is placed after the patient has undergone general anesthesia. The patient will then be placed in a near lateral decubitus position. The use of a "bean-bag" or "jelly rolls" will greatly assist in this task. It is important to maintain exposure from below the midline of the contralateral side of the abdominal wall to the spine. This is necessary to place trocars and transfascial sutures (if used). I sometimes mark the skin to identify the costal margin and the iliac crest. Flexing of the table is avoided. Although this would facilitate placement of trocars, this would separate the fascial edges, making the hernia larger and the repair more difficult.

The laparoscopic and robotic approaches do have different considerations that should be mentioned. The usual locations of the trocars when the laparoscopic technique is employed are shown in Fig. 36.3. There is significant latitude in the locations of them with this approach.

The use of the Intuitive Surgical (Sunnyvale, CA, USA) robot influences the location of the trocars used depending on the robot employed. The older Si places the camera trocar slightly behind that of the other two trocars. The Xi version requires that the trocars be aligned in a straight line. These differences and the typical locations are shown in Fig. 36.4.

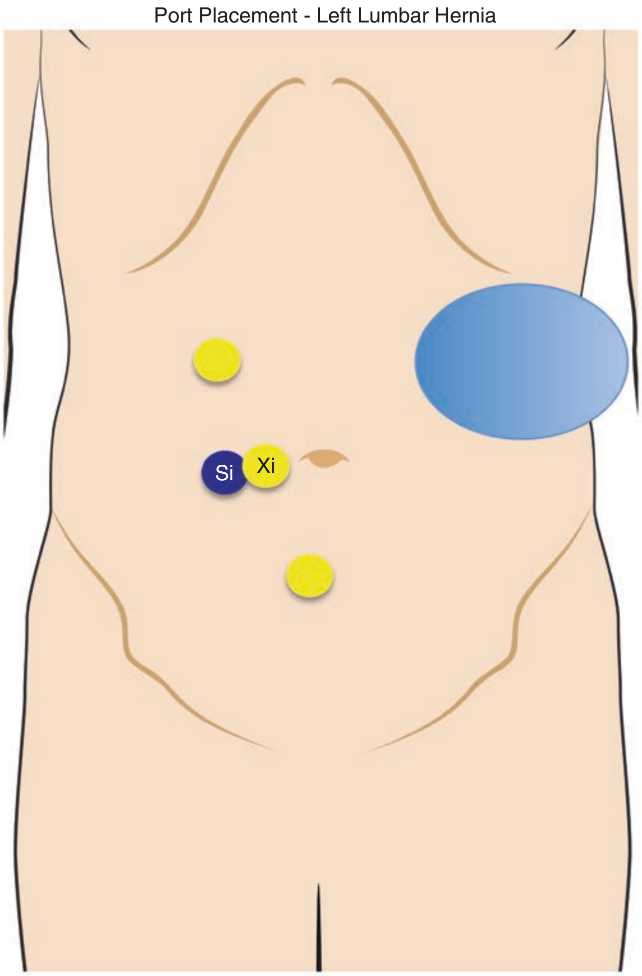

Fig. 36.4 Robotic trocar positions for the left sided lumbar hernia (shown in *blue*)

Undoubtedly there will be other surgical robots in the future, but at the time of this writing, these are the only ones available.

Repair of True Fascial Defects

These hernias can be repaired with either the preperitoneal placement or intraperitoneal placement of mesh (IPOM). It has been shown that the main consideration in the repair of lumbar hernias is the placement of a prosthetic material [26]. The choice of mesh will be influenced by the location of its final placement (see Chap. 7 on Prosthetics). The preperitoneal dissection will expose the fascia as part of the procedure and covers it once the repair is complete. In that method, a "non-coated" product may be used. A "coated" product is required if the IPOM is performed. If the latter technique is utilized, it is important to dissect the preperitoneal fat away from the fascia so that the uncoated surface of the mesh contacts as little of the adipose tissue as possible to ensure an effective repair. This is the fundamental difference between these methods. The following procedure description will apply to both.

This repair will be similar to the traditional incisional hernia repair. If possible, the fascial defect can be closed with either transfascial sutures or intracorporeal sutures. The latter option seems easiest if barbed sutures are utilized in the closure (Fig. 36.5). If transfascial sutures are to be placed, one must be careful not to inadvertently place them through the chest if the hernia is adjacent to the thoracic cavity. Closure of the defect becomes more difficult with larger defects.

The mesh will be placed to cover the defect with at least a 5-cm overlap of the fascial defect. It is preferred that the size be selected on the measurement of the unclosed defect as one cannot be assured that the closed defect will remain permanently closed [5]. If fixation to the diaphragm is necessary, this should be sutured with either interrupted or running permanent sutures. If additional fixation with a device is needed, one should only place them below the diaphragm (see Chapter on Prosthetics).

Repair of "Denervation Hernias"

These are challenging hernias because there is no fascial defect but paralyzed musculature. This represents a large surface to be repaired. The repair is entirely dependent on the placement of mesh. For these types of hernias, a hybrid approach is recommended. Generally, the procedure is started open, converted to either laparoscopic or robotic and then returning back to open if not competed prior to that. In most cases, I complete the open portion prior to beginning the laparoscopic/robotic portion.

The skin incision of the prior procedure is utilized, and in most cases, this must be extended. The initial dissection will require the development of significant skin flaps in all directions. An onlay mesh will ultimately be placed, which requires the overlap to extend above the ribs superiorly,

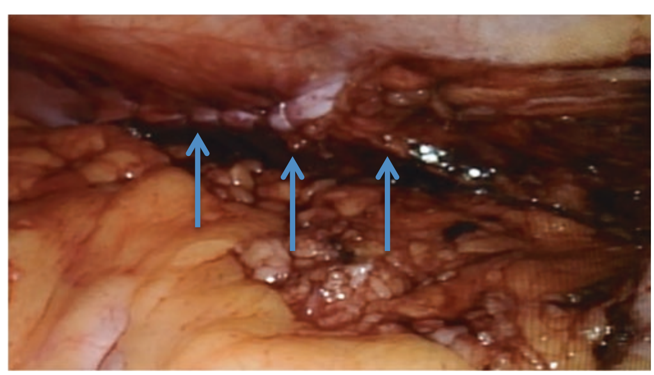

Fig. 36.5 The *blue arrows* indicate the closed fascial defect

below the iliac crest inferiorly, onto the rectus sheath medially, and near the spine posteriorly. This will provide coverage of the entire area of denervation.

At that point, the muscles are incised to enter the abdominal cavity. Adhesiolysis is performed as necessary. Again, this dissection must extend above the diaphragm superiorly, into the pelvis inferiorly, to the midline medially, and to the paraspinus muscles posteriorly (Fig. 36.6). The mesh should be large enough to cover all of these areas. It will be inserted and sutured to the paraspinus and/or psoas muscles initially. Transfascial sutures are also utilized. The superior portion of the mesh will then be sutured to the diaphragm with interrupted sutures. Additionally, transfascial sutures are added below the costal margin and medially.

After this has been performed, three trocars are placed where best located. This will vary slightly if the procedure will be laparoscopic or robotic (see above). At this point the divided muscles will be plicated in a "vest over pants" configuration (Fig. 36.7). These should be pulled a tight as feasible. One must account for this portion of the procedure during placement of the subcostal transfascial sutures. One may elect to place the onlay mesh at this time (Fig. 36.8). A single closed suction drain is used. If one elects to not close the subcutaneous tissue and skin after this, these muscles

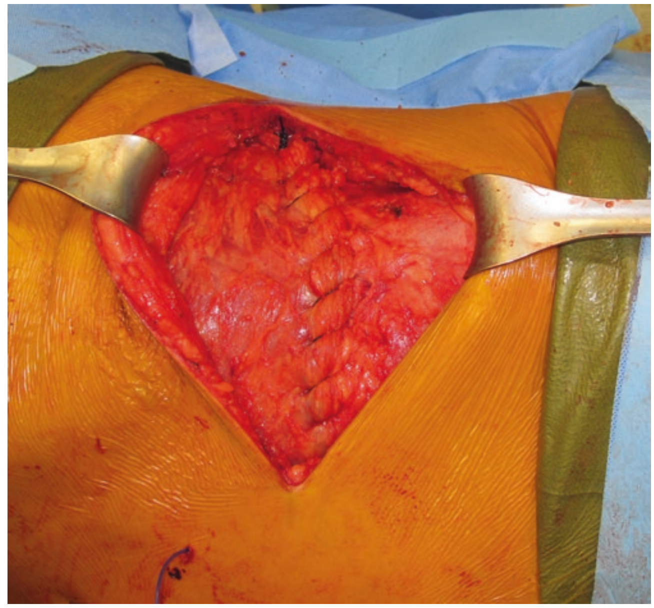

Fig. 36.7 "Vest over pants" plication of the flat muscles

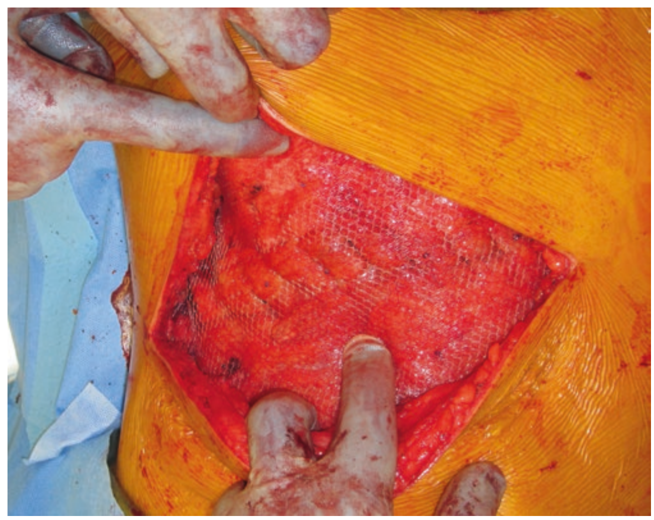

Fig. 36.8 Onlay of polypropylene mesh

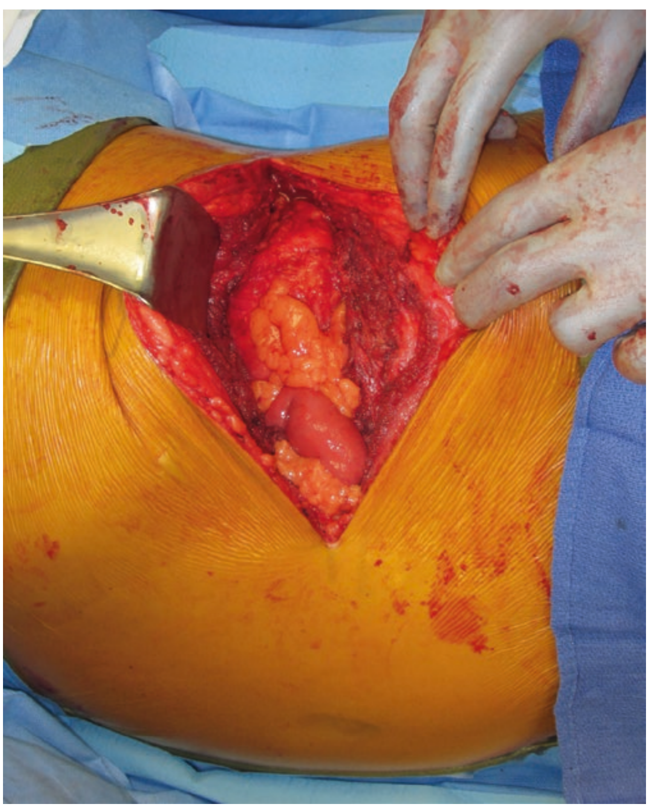

Fig. 36.6 Completed intra-abdominal dissection

will be then covered with either lap sponges or a towel. Occasionally, it will be necessary to close the skin with towel clips to maintain pneumoperitoneum but this is seldom required.

If used, the robot will be docked and the laparoscopic portion will commence. The goal of this portion of the procedure is to pull the inferior portion of the mesh taut and fixate it firmly. This will be done with transfascial sutures laparoscopically or running barbed sutures robotically. The robotically placed sutures will also be run over the interior of the mesh to firmly fixate all of it to the abdominal wall (Fig. 36.9). This will be accomplished laparoscopically

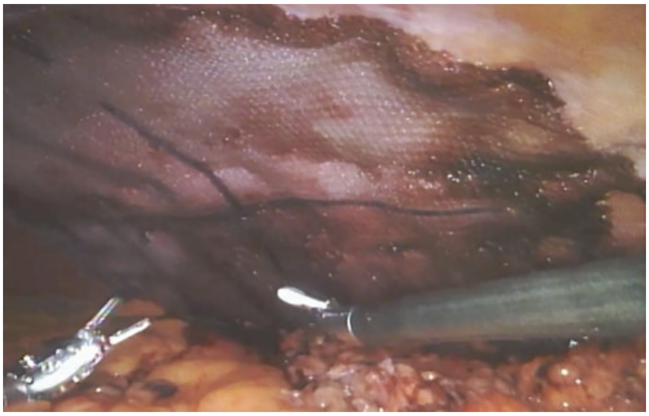

Fig. 36.9 Completed robotic fixation of the intraperitoneal mesh

with a fixation device of either permanent or absorbable tacks. Both options will aid in the prevention of a seroma, while assuring firm attachment of the prosthesis. At this point, the procedure returns to the open portion (if not competed). The subcutaneous tissue is closed in layers and the skin closed.

Although not mentioned above, it is extremely beneficial to inject a long-acting local anesthetic into the tissues during the first open portion of the operation. Liposomal bupivacaine is preferred. This is a painful operation and the addition of this drug aids in pain control posto peratively.

Postoperative Management

The use of a patient-controlled analgesia pump is preferred. Additional medications such as intravenous acetaminophen or ketorolac are also helpful. The NGT and urinary catheter are typically removed on postoperative day 1. The timing of discharge will be usually determined by the ability to control the pain. Most patients will remain hospitalized for 2–4 days. The drain should be left in until the output is less than 25cc per day.

There will be a prolonged asymmetry to the repaired side in the hybrid cases that should be discussed with the patients preoperatively. Although in many cases this will resolve within a year, the majority will never be perfectly symmetric due to the paralysis of the musculature and the sole reliance on the mesh product. However, there is never a complaint by the patient, as this will be vastly improved than their appearance preoperatively (Fig. 36.10a, b).

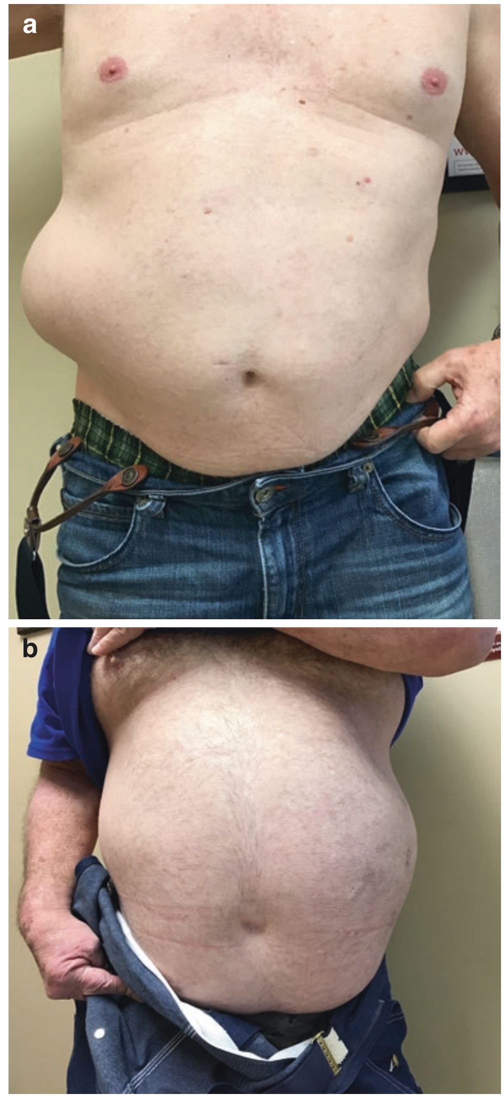

Fig. 36.10 Preoperative (**a**) and postoperative (**b**) appearance of a right sided "denervation hernia"

Conclusions

- The incidence of lumbar hernias is low.
- The use of prosthetic reinforcement is recommended in the light of evidence.
- Laparoscopic approach is beneficial for small- and middle-sized hernias, feasible in large defects, and even in the cases of open repair of the large hernias allows better assessment of the clinical intra-abdominal situation.
- The problem of the denervation flank bulge needs an extended approach and complex repair. A large prosthesis should be used in these cases.

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Hernias of the Pelvic Wall

37

Michael S. Kavic, Suzanne M. Kavic, Mary K. Hanissee, and Stephen M. Kavic

There are several large openings in the bony pelvic girdle, including its floor that can allow for intestine or viscera to pass through and develop a hernia. However, the near vertical walls of the pelvis mitigate against the development of hernia—mitigate—but not completely deny hernia formation. Although rare, hernias of the deep pelvic structures can occur and cause debilitating symptoms.

Unfortunately, physicians often ignore these symptoms because hernias in the pelvic areas are difficult to see and to palpate. For the most part, pelvic wall hernia is not even considered in females with vague abdominal or pelvic symptoms. Nonetheless, general surgeons need a thorough knowledge of pelvic anatomy, particularly, potential hernia sites in women, to avoid inadequate diagnostic workup and examination. Patients, usually older female patients, suffer the consequences of our inattention.

A good example of disease neglected by the general surgeons is chronic pelvic pain in females. Chronic pelvic pain is a common problem in women accounting for 10–30% of all gynecological visits. It is considered the principle indication for 20% of hysterectomies performed for benign disease and approximately 40% of gynecological laparoscopies [1]. About 78,000 hysterectomies are performed each year in the United States for chronic pelvic pain [2]. It has been estimated that 70% of female patients who have chronic pelvic pain have disease in the reproductive genital tract; however, 10% of patients with chronic pelvic pain had gastrointestinal tract disorders, 8% had musculoskeletal neurologic disease, 7% had myofascial abnormalities, and 5% had urologic causes of chronic pelvic pain [3]. Chronic pelvic pain can have many etiologies, and the general surgeon must not shirk from actively participating in the evaluation of these patients.

Chronic pelvic pain has three main dimensions: (1) duration, pelvic pain lasting 6 months or more; (2) anatomic, pain in the pelvis defined by physical findings at laparoscopy; and (3) affective/behavioral, pelvic pain accompanied by significant alterations in physical activity such as work, recreation, and sex, as well as changes in mood related to the chronic pain [3]. Most standard laboratory and imaging studies such as complete blood count, abdominal and pelvic ultrasound, and computed tomographic studies are often within normal limits.

Frequently dismissed as "female trouble," chronic pelvic pain has resisted intensive efforts to determine its cause. Chronic pelvic pain can have many etiologies, and a multidisciplinary approach is frequently necessary for proper patient evaluation [4]. Nevertheless, chronic pelvic pain is a real entity, and it is now appreciated that obscure, rare conditions such as sciatic, obturator, supravesical, and perineal hernia may cause chronic pain in women. A case in point is the seldom diagnosed sciatic hernia.

Sciatic Hernia

Sciatic hernia, one of the rarest of abdominal and pelvic wall hernias, was first described by Verdier in 1753 [5, 6]. It is the protrusion of peritoneal sac and content through the greater or lesser sciatic foramen. The hernia may occur superior to the piriformis muscle (suprapiriformis), inferior to the piriformis (infrapiriformis), or through the lesser sciatic notch (subspinous) (Fig. 37.1). Known variously as sacrosciatic hernia, ischiatic hernia, ischiocele, hernia incisurae ischiadicae, or gluteal hernia, the hernia sac may contain the ovary,

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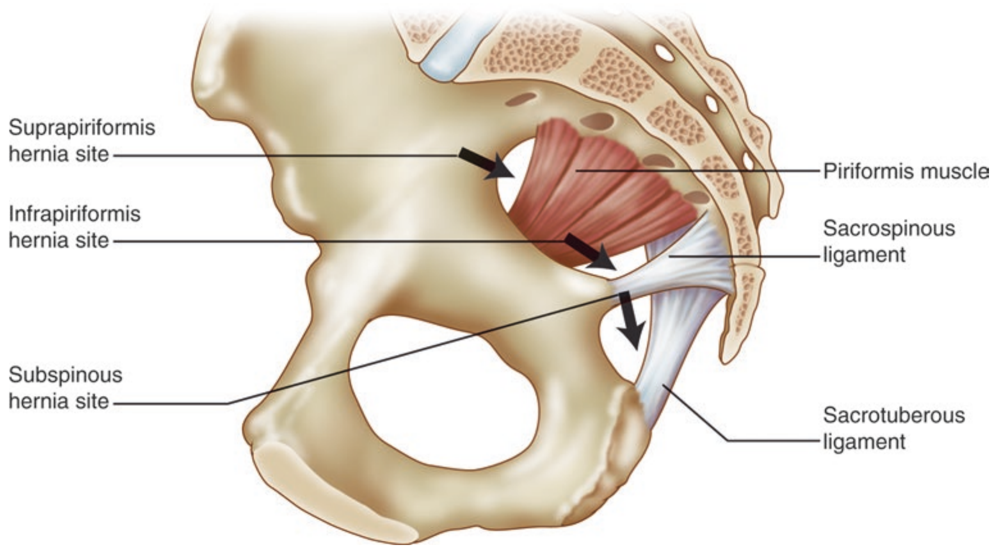

Fig. 37.1 Sciatic hernia. The hernia may occur superior to the piriformis muscle (suprapiriformis), inferior to the piriformis (infrapiriformis), or through the lesser sciatic notch (subspinous)

tube, or intestine. Entrapment of these organs may cause chronic pelvic pain or bowel obstruction.

There were only 39 cases of sciatic hernia reported in the world literature up to 1958 [5, 6]. However, in 1998, Miklos and colleagues reported 20 cases of sciatic hernia diagnosed in a series of 1100 female patients who had diagnostic laparoscopy for chronic pelvic pain. All of these cases had the ipsilateral ovary alone or fallopian tube contained within the hernia sac. If this incidence of sciatic hernia in patients who required diagnostic laparoscopy for chronic pelvic pain (1.8%) is carried over into the general population, sciatic hernia cannot be as rare as previously thought [7].

Anatomy

The sacrospinous ligament converts the greater sciatic notch into the greater sciatic foramen which is filled with the piriformis muscle. In addition to the piriformis muscle, the greater sciatic foramen transmits the gluteal vessels and nerves, internal pudendal vessels and nerve, and nerves to the obturator internus and quadratus femoris muscles. Above the piriformis muscle, the suprapiriformis area allows for passage of the superior gluteal artery, vein, and nerve. Below the piriformis muscle lies the infrapiriformis space which transmits the inferior gluteal vessels, posterior femoral cutaneous nerve, nerve to the obturator internus, internal pudendal vessels and nerves, and sciatic nerve.

The lesser sciatic notch is transformed into a foramen by the sacrospinous ligament superiorly and the sacrotuberous ligament inferiorly. The lesser sciatic foramen transmits the tendon of the obturator internus, its nerve, and the internal pudendal vessels [5]. In females, the abdominal opening of a sciatic hernia is posterior to the broad ligament. In males, the opening lies in the lateral pelvis between the urinary bladder and rectum. Hernias below the sacrotuberous ligament are considered to be perineal hernias [8].

Clinical Presentation

Sciatic hernias are rarely noted on physical examination as the large gluteal muscles cover and overlap the sciatic foramen. To further complicate matters, openings in the sciatic foramen are small, and many of these cases present with incarceration and obstruction. Frequently, the diagnosis is only revealed at laparotomy. Even so, the pain of chronic sciatica may call attention to the gluteal area where physical examination may suggest a gradually increasing infragluteal bulge or a bulge that is more pronounced on standing and can cause pain with sitting [9]. Compression of the sciatic nerve can cause muscle weakness of the lower leg with pain radiating down the posterior thigh made worse with dorsiflexion. Herniography can be helpful in delineating a sciatic hernia; however, a computerized tomography (CT) scan is the initial diagnostic imaging of choice.

Treatment

Sciatic hernias have been repaired by a transabdominal or transgluteal approach [10, 11]. A transabdominal approach is usually recommended as these hernias are difficult to diagnose, and most surgeons are more comfortable performing an exploration for possible bowel obstruction in an open manner. Laparoscopic access, however, can offer satisfactory visualization of a sciatic hernia [7] (Fig. 37.2).

After the abdomen has been opened or pneumoperitoneum established for laparoscopic access, a thorough intra-abdominal examination is performed. The liver, gallbladder, stomach, intestine, appendix, uterus, tubes, ovaries, and peri-

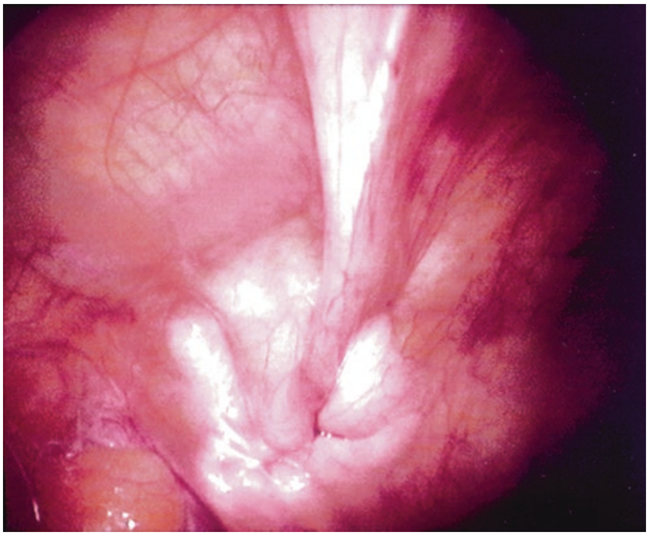

Fig. 37.2 Laparoscopic view of a sciatic hernia

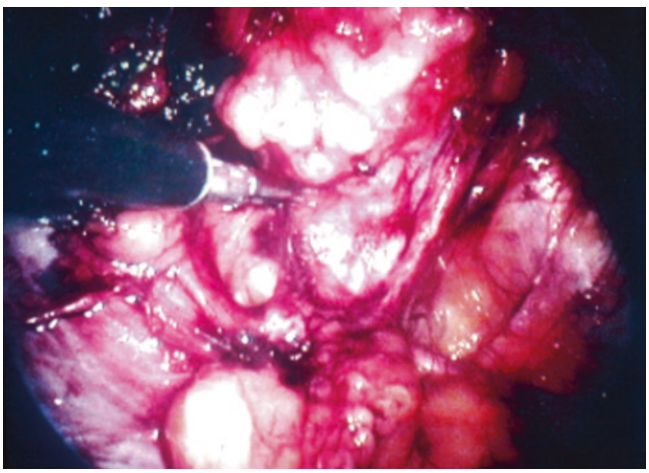

Fig. 37.3 Sciatic hernia sac reduction

toneal surfaces are examined [12]. The entire pelvis is inspected for hernias, adhesions, and endometriosis.

If a sciatic hernia is found, its content is reduced. Dusky bowel should be observed for 5–10 min to see that adequate circulation is reestablished. Nonviable bowel should be resected with primary anastomosis. If the bowel is viable, a preperitoneal incision is made superior to the hernia defect and the hernia sac reduced (Fig. 37.3). The sciatic foramen is visualized and completely covered with nonabsorbable synthetic mesh. There should be a 2.5–3.0 cm overlap of the hernia defect with mesh circumferentially. The mesh is secured with endohernia tacks or fasteners to the obturator internus fascia laterally and coccygeus medially (Fig. 37.4). The area is reperitonealized by closing the peritoneal incision with intracorporeal suture, tacks, or fasteners. The laparoscopic trocar sites or abdominal incision is then closed in the standard manner.

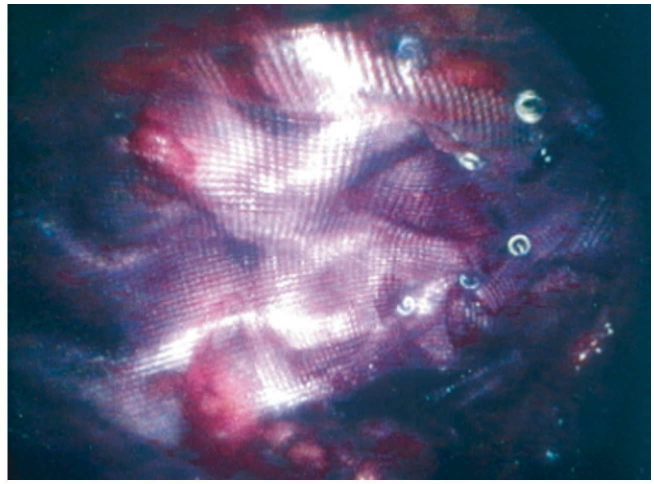

Fig. 37.4 Mesh repair of a sciatic hernia

Obturator Hernia

An obturator hernia is an abnormal protrusion of preperitoneal fat or intestine through the obturator canal. These hernias are rarely visualized and are usually not found preoperatively unless a palpable bulge is noted on rectal or bimanual pelvic examination [13, 14]. An obturator hernia may contain a “pilot tag” of preperitoneal tissue, large or small bowel, appendix, uterus, tube, or ovary [15]. Herniation through the obturator canal is rare, occurring in 0.073% of all hernias in one series [16]. Two broad groups of patients have been described who most frequently suffer obturator hernia [15–17]:

1. Elderly patients, usually women, with a history of chronic disease, weight loss, increased intra-abdominal pressure, and attenuation of the obturator membrane
2. Women of childbearing age

Anatomy

The obturator foramen is the largest bony foramen in the human body (Fig. 37.5). It is roughly circular in shape and shielded by the obturator membrane. The internal opening of the obturator canal is about 1 cm diameter and sited in the superior midsection of the obturator membrane. The obturator canal itself is a fibro-osseous tunnel about 2–3 cm in length whose roof is formed by the obturator sulcus of the pubic bone and its floor by the internal and external obturator muscles and their fascia. The obturator nerve, artery, and vein pass through the obturator canal with the nerve typically superior to the artery and vein (Fig. 37.6). After passing through the obturator canal, the obturator nerve divides into an anterior and posterior branch. The

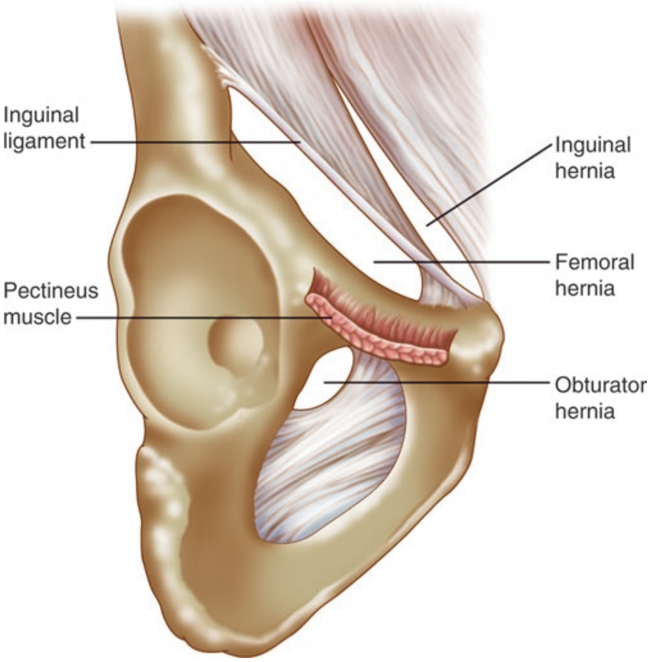

Fig. 37.5 Obturator anatomy

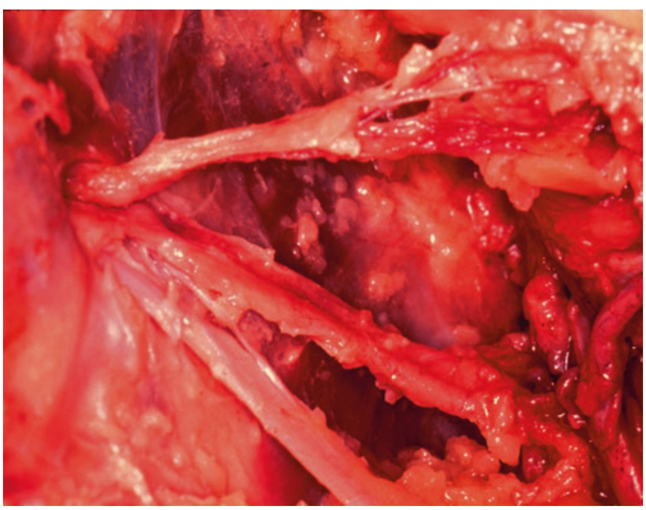

Fig. 37.6 Obturator nerve, artery, and vein

anterior branch courses over the superior border of the obturator externus muscle to supply the adductor longus, gracilis, and adductor brevis muscles. The posterior branch pierces the obturator externus muscle to supply the adductor magnus and adductor brevis. Obturator hernia sacs that follow the anterior division of the obturator nerve pass between the pectineus and above the obturator externus muscle. Hernia sacs that follow the posterior division of the obturator nerve pass through the obturator externus muscle.

Clinical Presentation

Historically, obturator hernia has been associated with four signs or symptoms [15]:

1. Intestinal obstruction (elderly females, frequently intermittent)
2. Howship-Romberg sign
3. History of previous attacks
4. Palpable mass (rare)

Although the first two are the most common signs, the nature of intestinal obstruction is usually unclear and the Howship-Romberg sign only recalled after exploration has revealed the presence of obturator hernia. Upon exploration, up to 50% can be associated with gangrenous bowel, resulting in high perioperative morbidity and mortality. The hernia can also present with a medial thigh mass [18], but the most common symptoms are crampy abdominal pain and obstructive symptoms [9]. The absence of bowel motion and a high serum urea level at the time of operation have been shown to be independent factors for mortality [19].

A palpable mass is occasionally noted on rectal or pelvic examination. However, since obturator hernia is rarely considered in a differential diagnosis of vague abdominal pain, the presence of a mass in the obturator region is rarely sought.

John Howship first noted the pain characteristic of obturator hernia in 1840. He described this pain as extending down the inner surface of the involved thigh, exacerbated by thigh extension, adduction or medial rotation [20] (Fig. 37.7). Howship's sign was independently described by Moritz Romberg in 1848 [21]. Although the Howship-Romberg sign is pathognomonic of obturator hernia, by no means is it invariably present. About 50% of patients will complain of this radicular pain or paresthesia down the inner aspect of their thigh caused by compression of the cutaneous branch of the obturator nerve in the narrow confines of the obturator canal [15, 22]. Karasaki described that the Howship-Romberg sign is present in 67% of anterior obturator hernias and only 30% of posterior [23].

Some have suggested that an obturator hernia develops over several stages. It first begins as a prehernia with a plug of preperitoneal connective tissue or "pilot tag" entering the obturator canal [15] (Fig. 37.8). This concept was supported by a post mortem study of female cadavers. In this report, a "pilot tag" was found in 64% of female cadavers that were examined [24]. The second stage of obturator hernia formation continues with dimpling of the peritoneum over the obturator canal and progresses to invagination of a peritoneal sac (Fig. 37.9). Finally in the evolution of an obturator her-

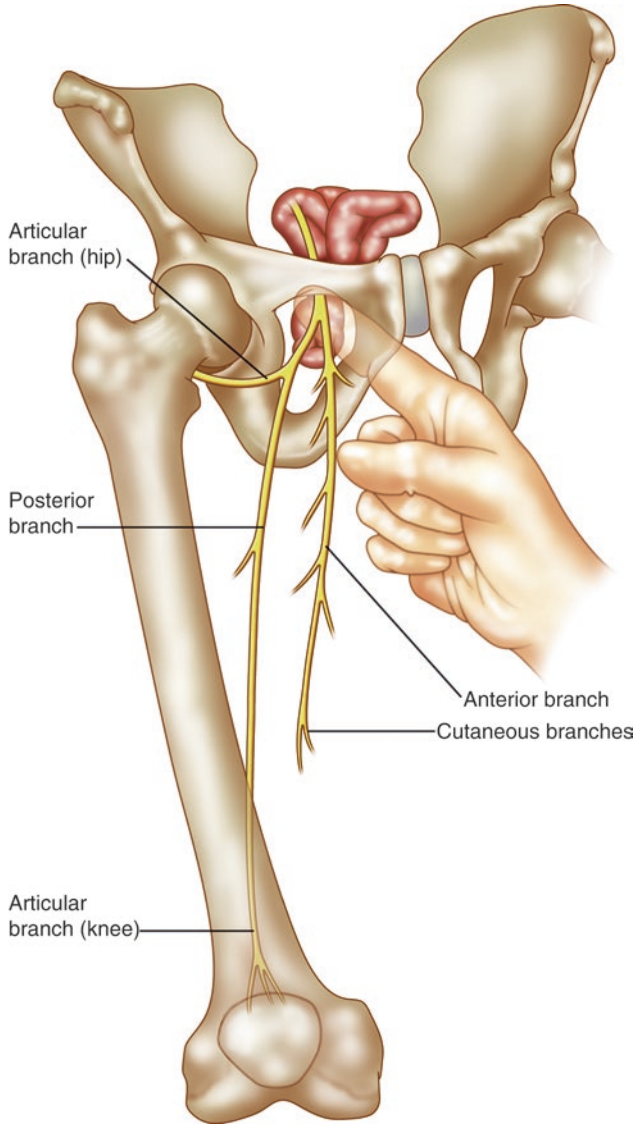

Fig. 37.7 Palpation of the obturator hernia

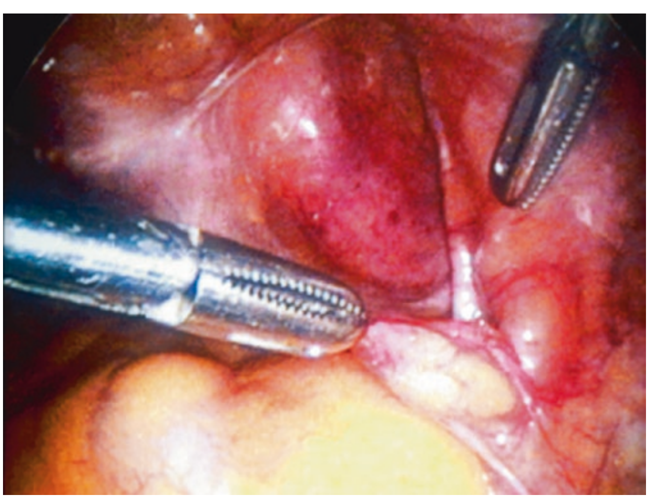

Fig. 37.8 Obturator canal pilot tag

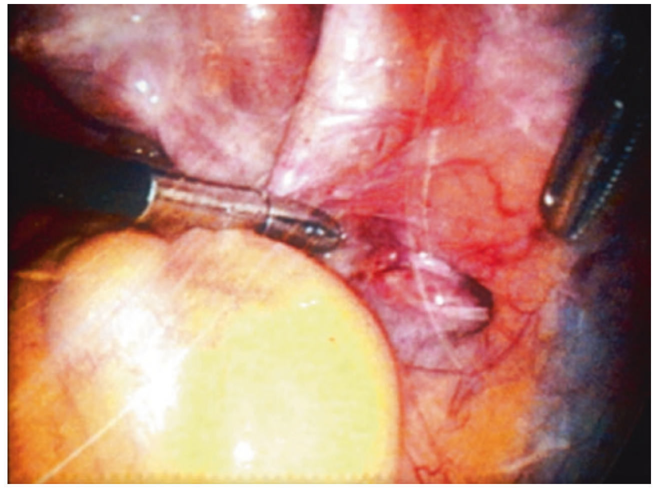

Fig. 37.9 Reduction of an obturator canal hernia

nia, bowel, uterus, tube, or ovary may enter the peritoneal sac and pass along the obturator canal.

Chronic pelvic pain can result from incarceration of tube or ovary in the obturator hernia. Symptomatic intestinal obstruction can result from incarceration of small or large bowel in the obturator canal [25]. Delay of diagnosis, however, is common as an obturator hernia is usually not visible or even palpable because of its deep location between the pectineus and adductor longus muscles.

More recently, computerized tomography has developed into a reliable diagnostic tool for evaluation of patients with possible obturator hernia. In two small series, CT scans detected the presence of an obturator hernia in 87 and 100% of the cases studied [13, 14]. Gas below the superior pubic ramus on plain film is diagnostic [18].

Treatment

Despite advances in imaging technology, the mainstay of diagnoses and treatment remains abdominal exploration. Exploration may be via open laparotomy or with laparoscopic visualization. Literature supports that laparoscopy is a safe and effective surgical option and has even been associated with decreased complications and hospital days [26–28].

Regardless of the method used to obtain access, the entire pelvis must be examined and evaluated. If bilateral obturator defects are found, both hernias should be repaired.

After an obturator hernia has been identified, contents of the sac are reduced and a preperitoneal dissection is done to expose the internal obturator opening and obturator canal. At this point, the internal opening of the obturator canal can be closed with permanent monofilament suture securing periosteum of the symphysis pubis to fascia of the internal obturator muscle. It is necessary to take care not to injure the obturator nerve or obturator vessels. An alternative method to repair obturator hernia is to use permanent synthetic mesh to secure the breach in the obturator membrane. Polypropylene, polyester, or expanded polytetrafluoroethylene mesh can be used. Mesh must cover the entire defect with a 2.5–3.0 cm overlap circumferentially and secured with adequate fixation. In addition to the obturator opening, it is usual to cover the entire myopectineal orifice—femoral and inguinal orifices—with mesh (Fig. 37.10).

After the mesh has been secured, the operative area is reperitonealized. Typically, the peritoneal incision is closed with an intracorporeal running suture of 2-0 absorbable suture; polydioxanone or polyglactin 910 are suitable choices (Fig. 37.11).

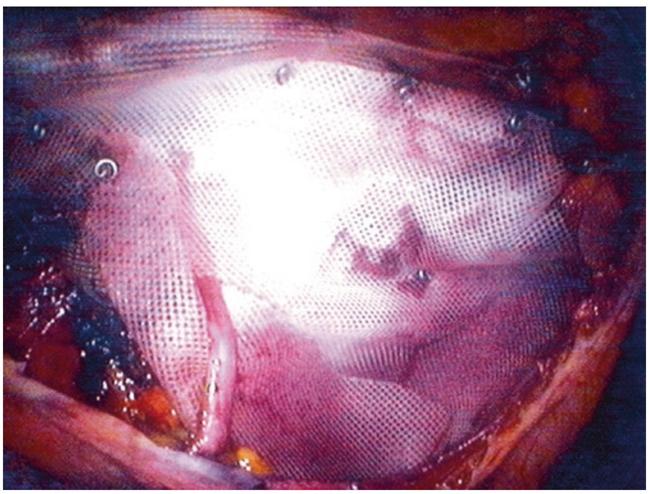

Fig. 37.10 Obturator hernia mesh repair with tacks

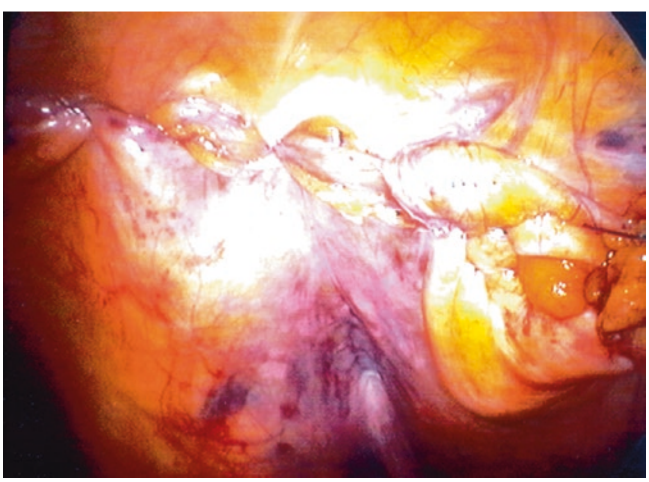

Fig. 37.11 Closure of the peritoneum in obturator hernia repair

Perineal Hernia

Perineal hernias are very rare hernias that insinuate themselves through muscle and fascia of the pelvic floor (pelvic diaphragm) into the perineum (Fig. 37.12). The first report of a perineal hernia was documented in 1743 by de Garangeot. Moscowitz was the first to treat a perineal hernia surgically in 1916. Perineal hernias have also been called ischiorectal hernias, subpubic hernias, pudendal hernias, posterior labial hernias, hernias of the pouch of Douglas, and vaginal hernias. Perineal hernias are commonly found in women and are true hernias with a distinct peritoneal sac.

Congenital perineal hernias are very rare, with only nine cases being reported in the literature [29]. Acquired (incisional) perineal hernias occur in both males and females after abdominoperineal resection of the rectum and after pelvic operations for genital malignancy (radical prostatectomy and gynecological exenteration), though still being very rare with rates of less than 1% and 3–7%, respectively [30].

Factors thought to contribute to perineal hernia include the broad female pelvis, childbirth, injuries incident to childbirth, obesity, exenteration procedures for pelvic cancer, abdominal perineal resection, and, in men, perineal prostatectomy. Perineal hernias may present anterior or posterior to the superficial perineal muscle, through the levator ani, or between the levator ani and coccygeus muscle.

Anatomy

A pudendal hernia is an anterior perineal hernia that occurs only in females. This hernia is also known as a labial hernia and may protrude into the labium majus as an overt mass. A pudendal hernia exits the pelvis through a triangle bounded by the bulbocavernosus, ischiocavernosus, and transversus perineal muscles [24]. A posterior perineal hernia may emerge between fibers of the levator ani or between the levator ani and coccygeus muscles [31, 32]. Hernia contents can be intraperitoneal or extraperitoneal, and contents usually include the bowel and omentum, though unusual contents such as bladder diverticulum and leiomyoma have been reported [29].

Presentation

Perineal hernias are bounded by compliant muscle and soft tissue and, as such, rarely cause intestinal obstruction. They can, however, cause chronic pelvic pain. Typically, perineal hernias present as a palpable, soft bulge in the perineum that

Fig. 37.12 Location of perineal hernias

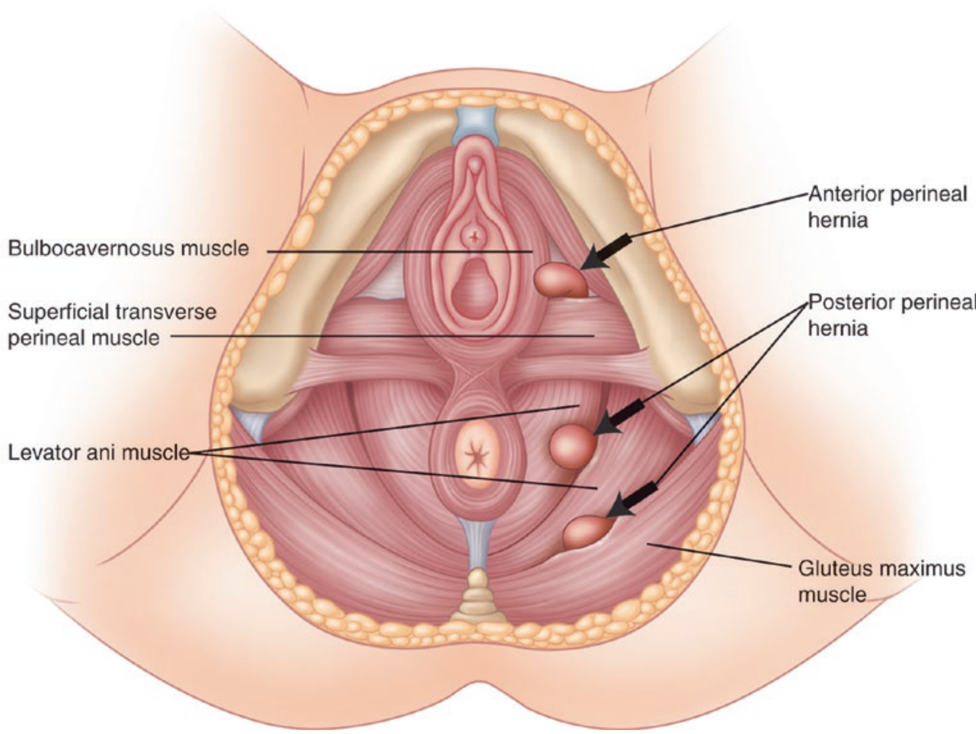

Fig. 37.13 Perineal herniography (Note: the *arrow* is an X-ray mark and is irrelevant to the present discussion)

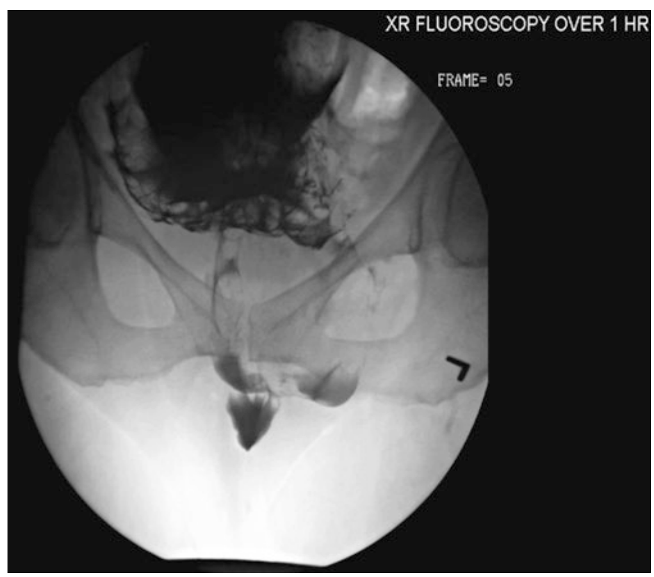

Fig. 37.14 Perineal herniography

is easily reducible or reduces itself when the patient is recumbent. If an overt perineal bulge is not evident, herniography with intra-abdominal instillation of radiopaque dye may be used to further refine a diagnosis of perineal hernia (Figs. 37.13, 37.14, 37.15, and 37.16). A contrasted CT scan is also helpful in identifying these hernias.

Treatment

The only definitive treatment for perineal hernia is surgical repair. Access to a perineal hernia can be obtained via a perineal incision, or transabdominally using open laparotomy or laparoscopic techniques. Traditionally, these hernias have

Fig. 37.15 Perineal herniography. If an overt perineal bulge is not evident, herniography with intraabdominal instillation of radiopaque dye may be used to further refine a diagnosis of perineal hernia

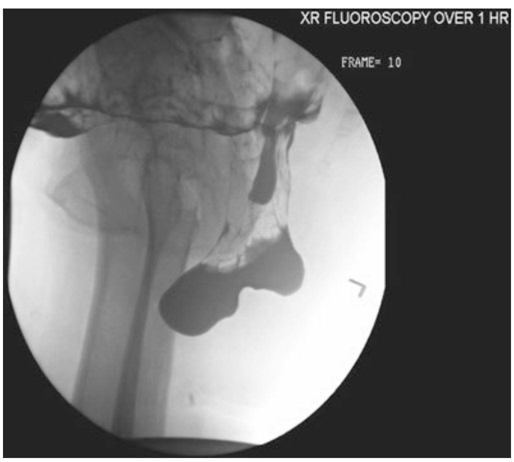

Fig. 37.16 Perineal herniography: X-ray fluoroscopy over 1 h

been repaired by closure of the perineal defect with nonabsorbable suture and the patient's own tissues. This procedure, while grounded in the principles of classic open surgery, has the disadvantage of using attenuated muscle and fascia to secure the repair.

Another approach that is gaining favor for the evaluation of abdominal and pelvic wall hernias has been that of laparoscopy [12]. A transabdominal laparoscopic examination offers the benefit of minimal access with maximum visualization of potential hernia sites in the abdominal and pelvic cavities. Once a perineal hernia has been visualized, its contents are reduced and a preperitoneal dissection carried out to define the borders of the hernia defect. Permanent synthetic mesh is used to cover and overlap the hernia defect with a 3 cm margin. Laparoscopic suture, staples, or tacks are used to fix the mesh, and the operative area is reperitonealized closing the peritoneal incision with intracorporeal absorbable suture.

Supravesical Hernia

Supravesical hernias are herniation of abdominal content through a supravesical fossa of the anterior abdominal wall. They are classified as either external or internal supravesical hernias [32]. External supravesical hernias pass inferiorly through the supravesical fossa to present medially as direct inguinal hernias or intraparietal hernias of the anterior inferior abdominal wall. Internal supravesical hernias pass downward to enter the retropubic space of Retzius (Fig. 37.17).

The diagnosis of supravesical hernias that exit through the posterior inguinal wall or femoral canal may be obvious. However, an internal supravesical hernia that passes into the retropubic space of Retzius is usually more difficult to diagnose. Although a small bowel series, ultrasound, or computed tomography may aid in the workup, diagnosis is usually made at abdominal exploration.

Management of supravesical hernia is that of operative repair. Hernias that present as external supravesical hernias (i.e., as direct hernias) may be managed with traditional Bassini or Shouldice herniorrhaphy techniques or Lichtenstein anterior hernioplasty with mesh. A laparoscopic repair is also feasible. Hernia in the retropubic space of Retzius—internal supravesical hernia—may be better served with a transabdominal laparoscopic approach that permits a complete visualization of abdomen and pelvis. As with other hernias of the abdomen and pelvic wall, a preperitoneal dissection is performed after reduction of hernia content. Hernioplasty with appropriate synthetic mesh and adequate overlap of hernia margins is followed by reperitonealization of the operative site.

Conclusion

In years past, diagnosis of hernia was only seriously entertained when a mass was seen or a bulge was palpable at a hernia's point of presentation. This mindset did not include the possibility of non-visualized, non-palpable symptomatic hernias that were evident only at their site of origin [33–36]. All the same, nonpalpable, clinically significant occult hernias do exist and in one series constituted 8% of those hernia cases repaired [33].

Occult symptomatic abdominal and pelvic wall hernias can be visualized at their site of origin with advanced imaging and during laparoscopic exploration. The use of laparoscopic visualization allows for the diagnosis and repair of common and rare abdominal and pelvic wall hernias at their site of origin rather that at their point of presentation. A principle of hernia repair that was first

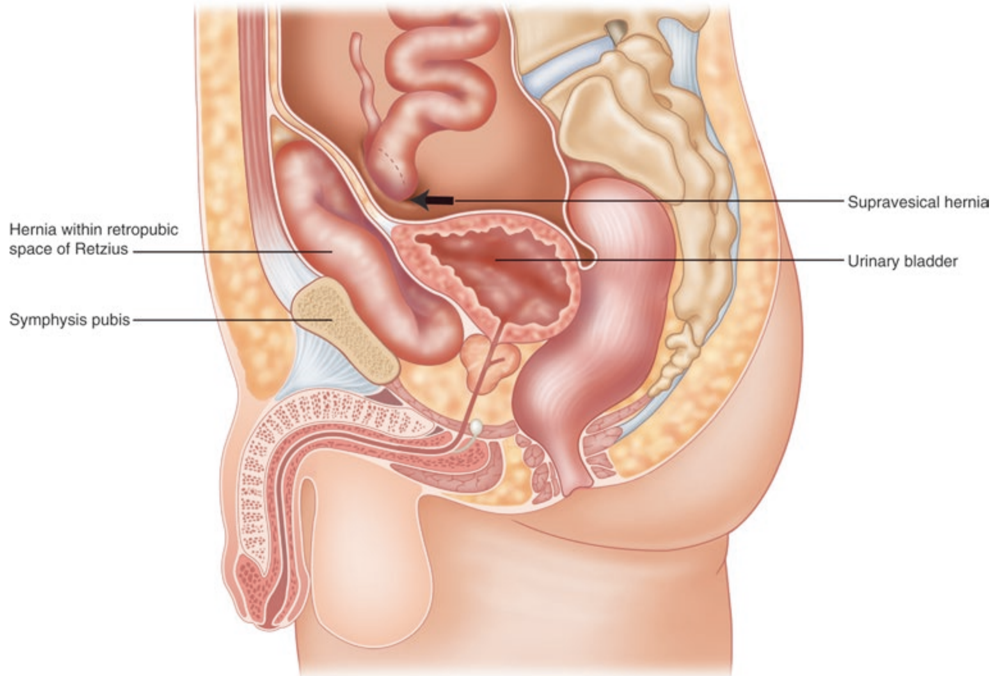

Fig. 37.17 Supravesical retropubic hernia

clearly articulated by Henri Fruchaud in his 1956 insightful discussion of groin anatomy and description of an abdominal myopectineal orifice [36].

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Umbilical Hernia in Babies and Children

38

R. Miller, A. Khakar, and S. Clarke

Introduction

A congenital umbilical hernia can be defined clinically as a protrusion of intra-abdominal contents through the umbilical ring. It is covered by the skin and is present from birth. Usually, the abdominal content is intestine within a peritoneal sac.

Some author's specify that a true umbilical hernia is a saccular swelling, present and protruding on straining [1–3]; however, others use less strict criteria, with a palpable gap at the umbilical orifice alone being sufficient [4]. Congenital umbilical hernias are one of the commonest conditions managed by paediatric surgeons.

The History of Umbilical Hernia Management

Observations regarding the management of paediatric umbilical hernias date back to the first century. Celsus described an operation by 'ligature', whereas Soranus (AD 98–117) suggested 'doubling the cord over, rolling it in wool and laying it gently against the middle of the navel' [1].

In 1884 Erichsen declared that 'these small umbilical hernias never strangulated, never caused death, and were rarely seen over the age of ten' [5]. Woods observed that no case of strangulation of an infantile umbilical hernia had ever been recorded and treatment by strapping may actually delay the disappearance of the hernia or even increase its severity [1].

Surgical closure is now the accepted treatment if spontaneous resolution has not occurred or if complications arise. More recent reports suggest that incarceration, with or without strangulation, occurs more commonly than was previously thought [6–12].

Epidemiology

Establishing the true incidence of umbilical hernias is difficult for a number of reasons, and is reflected by the wide range documented within the literature. The incidence is dependent on factors such as the age and ethnicity of the patient group studied, the definition used and the method of patient selection. Small hernias may not be identified without specific clinical assessment of the area, and the majority resolve spontaneously. These will therefore go unreported unless the patient group is specifically examined. A true figure could only be obtained from a large population-based study of all births with specific clinical assessment at set ages.

Taking this into consideration, umbilical hernias reportedly occur in 4–30% of Caucasian infants [1, 2, 4, 13]. Of 583 healthy infants below the age of 6 months attending a welfare clinic, 106 (19%) had an umbilical hernia, and in another study of 105 children at nursery school, 10 children (9.5%), all age 2 years, had umbilical hernias, which all resolved by 5 years of age [1]. However, they may be seen in up to 62% of children of African origin. In the West Indies, 58.5% of children of African origin have umbilical hernias compared with 1–8% of white, Indian and Chinese children [14]. Similarly in East Africa, 60% of children with African origin have umbilical hernias, compared with 4% of Indian origin [15], and in South Africa 61.8% of children among the Xhosa tribe have umbilical hernias [16]. In contrast, one study from South Africa showed no significant racial disparity in incidence, with umbilical hernias present in 23% of black and 19% of white South Africans [2]. Leading on from this, Meier and colleagues prospectively evaluated the umbilical area of 4052 Nigerians. 'Outies' (umbilical protrusion past the periumbilical skin in an erect subject) were

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identified in 92% of subjects below the age of 18 years; however, there was no fascial opening felt in 39%. Umbilical hernias, defined as protrusion of at least 5 millimetres and a diameter of at least 10 millimetres, were present in 23% of patients under the age of 18 years [17]. In contrast in older children, examination of 19,750 Turkish school children, over the age of 6, gave a low incidence of 15.85/1000 [18].

Clearly, umbilical hernias are not uncommon, there is geographical and racial variation in the incidence, and the incidence reduces with age.

Embryology and Development

Umbilical hernias fall into the spectrum of congenital abdominal wall defects. They may be due to an abnormal embryologic process, a physiological process or secondary to iatrogenic injury (Table 38.1).

The embryonic development of the umbilical area is complex, but after birth the normal umbilicus is a relatively simple structure. During foetal life, the anterior abdominal wall development depends on differential growth of embryonic tissues. This occurs by a combination of cranial, caudal and lateral infolding of the head and tail folds as well as acute ventral flexion, beginning in the fourth foetal week. Return of the midgut and a reduction in the relative size of the body stalk also play an important part [19]. Apart from the umbilical ring, the rectus muscles are approximated and closed by the 12th gestational week. The connective tissue of the umbilical cord originates from the primitive mesoderm, whereas the rectus sheath, the linea alba and the fascia of the anterior abdominal wall are formed from intra-embryonic mesoderm. Fusion of these two types of mesoderm occurs at the embryonic rim, which then becomes the umbilical orifice. Proliferation of lateral connective tissue plates is then responsible for closure of the umbilical ring. If this process is incomplete, a patent umbilical ring forms [1].

In addition to the embryological explanation of umbilical hernias, there are also anatomical theories. Shortly after birth, a fall in temperature reduces the blood flow through the umbilical cord. Wharton's jelly swells and blood vessels within the cord collapse. After cord ligation, the vessels thrombose and the cord dries and sloughs. This leaves a granulating surface that heals by cicatrisation and epithelisation.

Elastic fibres that reinforce the umbilical ring, together with proliferation of the lateral connective tissue plates, are responsible for closure of the umbilical ring. Atrophy and obliteration of the umbilical vessels continue the process with the scar contraction resulting in a retracted umbilicus. Delay in development can result in umbilical defects, with minor degrees of herniation of the umbilicus observed in many neonates (Table 38.2) [13].

It is important to remember the distinction between an umbilical and supraumbilical hernia when considering the anatomy. To distinguish them, a supraumbilical hernia is a defect in the linea alba, from the umbilicus to the xiphisternum.

Table 38.1 Summary table of abdominal wall defects

Pathology	Examples
Failure of normal physiology	• Delayed cord separation
	• Umbilical granuloma
Abnormal embryological process	Abdominal wall defects: • Hernia of umbilical cord • Exomphalos/omphalocele • (Gastroschisis) • Umbilical hernia
	Others: • Dermoid cyst • Vascular malformation
	Embryological remnants: • Vitelline duct remnants: – Umbilical polyp – Patent vitello-intestinal duct – Meckel's diverticulum/band/cyst • Urachal remnants: – Umbilical polyp – Patent urachus – Urachal sinus/cyst
Iatrogenic injury	Port site insertion for laparoscopic surgery

Predisposing Factors

Predisposing factors include prematurity, low birth weight [1, 20, 21], respiratory distress syndrome and malnutrition [1]. Conditions such as trisomy 21 [13], 13 and 18, Beckwith-Wiedemann syndrome, congenital hypothyroidism and mucopolysaccharidosis [22, 23] are also reported associations. Umbilical hernias occur in 75–84% of premature (<1500 g) neonates at birth but only 20% of larger neonates (2000–2500 g) [20, 21].

However, the majority of umbilical hernias in children occur with no other associated anomaly, and there does not appear to be a gender difference.

Table 38.2 Summary of the embryologic and anatomical theories predisposing to development of umbilical hernia

Failure of the recti to approximate in the midline after return of the midgut
Variability in the attachment of the ligamentum teres and median umbilical ligament
Variability in coverage of the umbilical ring by umbilical (Richet's) fascia
Anatomical maturity of the umbilical fascia

An interesting suggestion is the association between umbilical hernia and socio-economic class. A prospective study of 7968 Nigerian children seeking admission for private school found only 1.3% had umbilical hernias, a prevalence of 1.8 per 1000 [24]. This is a much lower frequency than that usually observed in Nigeria [17]; however, this provides little evidence of causation, and there is no further evidence to support it.

Natural Progression

Umbilical hernias regress spontaneously in the majority of children. Early reports demonstrated that up to 93% resolve automatically in the first year of life [1] which is echoed by more recent reports from Japanese cohorts with closure in 80% of those <1 and 90% for those less than 2 [25]. Spontaneous closure occurs in most children by the age of 4 years [3, 4, 12, 26, 27]. In Africa however some demonstrate resolution continuing up to 14 years of age [17].

If not repaired in childhood, 10% of umbilical hernias will persist to adulthood [14] and have an increased risk of incarceration compared to childhood hernias [22]. Emergency surgery for incarcerated umbilical hernias in adults has significant morbidity and carries a mortality rate of up to 6% [28], and in a series of 385 incarcerated hernias in adults, umbilical hernia incidence was 12.5%, representing a significant burden in the adult population if not fixed [29].

Some authors have observed the size of the fascial defect, and even its 'sharpness', as indicative of its ability to close naturally [2, 30, 31]. Walker demonstrated in a series of 314 children that fascial rings measuring less than 1 cm in diameter tend to close spontaneously, whilst those larger than 1.5 cm rarely do and, in general terms, the larger the defect, the older the child at closure [31]. A hernia with a thicker, rounded fascial edge is suggested by some as more likely to close than one with a thin, sharper edge [30].

Presentation and Diagnosis

Umbilical disorders are common in paediatric surgical practice and usually present with an umbilical mass with or without pain.

The diagnosis of an umbilical hernia is made clinically. The usual history is of an umbilical protrusion since birth. It will often protrude during crying and may cause intermittent abdominal pain. Whether the enlarged hernia is causing distress, and therefore crying, or the crying and subsequent raised intra-abdominal pressure is causing the hernia to protrude is difficult to determine.

Clinical examination should focus on the position of the hernia and its differentiation from other causes such an epigastric or supraumbilical hernia and embryological remnants such as a residual urachal cyst [32]. An umbilical hernia has a circumscribed central defect at its base, whereas the defect in a supraumbilical hernia is often transverse or irregular with the defect outside the central umbilical area, in the linea alba. The contents of the hernia are often disproportionally large relative to the defect. In a 53-year review of umbilical surgery, the size of fascial defects was seen to vary widely from 0.2 to 7 cm (mean = 1.3 cm) [33]. The diameter and sharpness of the fascial edge of the hernia orifice can be recorded during the examination. A smooth edge and a diameter of less than 1.5 cm are seen by some as predictors of spontaneous closure [2, 30, 31].

Prenatal diagnosis of congenital umbilical hernia is possible using ultrasound and must be differentiated from persistent omphalomesenteric duct or omphalocele [34]. Postnatally, imaging studies are not usually required for the hernia to be confirmed. An ultrasound may help if there is doubt as to the site of the defect, i.e. paraumbilical or umbilical or the contents. However, clinical confusion in children is rare.

Rarely, other conditions can mimic an incarcerated umbilical hernia in the acute setting. Tender distended umbilical hernias may occur in intraperitoneal disease, peritonitis, intestinal obstruction and in liver cirrhosis patients, due to ascites [35]. There are several reports of an incarcerated Meckel's diverticulum being found in umbilical hernias, the oldest being 22 years [36–39]. Appendicitis has also been reported to present as an incarcerated umbilical hernia, both in children and adults in paraumbilical hernias [40, 41]. Although these are rare, it is worth considering and making a full clinical assessment of the patient.

Complications

Incarceration is the most common complication, followed by strangulation of bowel or omentum. Rupture and evisceration of contents is rare.

Incarceration should be considered on clinical assessment or in the acute presentation of an umbilical mass with pain. It usually presents with progressive tenderness in the umbilical region with a history of a hernia. Historically, it was considered 'rare', occurring in approximately 1:1500 (0.06%) umbilical hernias [2]. In 1975 a large European study of 590 children found 5% of umbilical hernias incarcerated [4]. More recently, several case series and retrospective studies of incarcerated umbilical hernias [4, 6, 8–12, 33, 42–44] have highlighted that this complication is more common than previously thought (Table 38.3). However, there does not appear to be a trend in the incarceration rate of these hernias. As mentioned previously, the contents of incarcerated hernias may be large or small bowel, omentum, the appendix or a Meckel's diverticulum [27].

Table 38.3 Summary of incarceration rates for paediatric umbilical hernias

Location	Time period (years)	Total number of hernias	Age	Incarceration	Comments	Year	Reference
UK	Unclear	283	Infants only	0	Nil	1953	[1]
USA	10	590	<12 years	5.1%	• 377 children were operated on • 5.1% included incarceration, strangulation and evisceration • 2/3 children of Afro-Caribbean origin • Incarceration most frequent in defects 0.5–1.5 cm	1975	[4]
Zimbabwe	4	38	1 month–13 years	37.5%	• 86% of obstructed group reduced spontaneously • Only 2 needed operative reduction	1994	[11]
France	5	Not stated	25 months (mean)	$n = 4$	• 1 strangulated requiring emergency surgery • 3 were reducible preoperatively • All African descent	1997	[12]
UK	20	Not stated	36.7 months (mean)	$n = 3$	• Caribbean descent • 2 had mass of undigested material in the incarcerated bowel	1998	[30]
Nigeria	15	Unknown	0–18 years	$n = 2$	Nil	2001	[17]
UK	3	7 (case series of incarcerations over 3 years)	3 years. (median)	$n = 7$	• 5 acute, 2 recurrent. • 4/5 reduced under G/A or at surgery. 1 with taxis • 1 necrotic omentum • Incarceration most frequent in defects <1.5 cm	2003	[6]
Nigeria	14	47	≤12 years Acute: 5 years (median) Recurrent: 3 years (median)	53% ($n = 25$)	• 15 acute (32%) • 10 recurrent incarceration (21%) • 5 (11%) had spontaneous evisceration • Defect diameter >1.5 cm associated with complication	2003	[8]
South Africa	15	389	6 years (mean)	7% ($n = 28$)	• 2 had resection of ischaemic omentum • 22 African origin • 5 spontaneously reduced • 14 reduced by taxis, 9 reduced at surgery • Mean defect size 2.24 cm	2006	[7]
Nigeria	8	52	4 years (median) Acute: 4 years (median) Recurrent: 8.5 years (median)	44% ($n = 23$)	• Acute = 33% • Recurrent incarcerations = 11% • 1 resection for gangrenous bowel and Meckel's	2006	[9]
Senegal	5	Unknown	14 months (average)	15% ($n = 41$)	• 5 necrotic bowel (1 had perforated Meckel's diverticulum) • 5 reduced at anaesthetic induction • All operated as emergency	2006	[10]
USA	15	Not stated	Not stated	0	• Statement in review article • Presumed retrospective	2007	[45]

Table 38.3 (continued)

Location	Time period (years)	Total number of hernias	Age	Incarceration	Comments	Year	Reference
France	3	162	3.5 years (complicated hernias only)	19.2% ($n = 30$)	• 19.1% = complicated hernias • 17.9% = incarcerated • 1 patient death • (Full text in French)	2010	[44]
USA	53	489	3.9 years (mean)	5.5% ($n = 27$)	• 53-year experience at a single clinic • Complications: – 22 recurrent incarceration – 4 strangulations – 1 evisceration – +7 enteric fistulas	2011	[33]
Nigeria	10	22	6.2 years (mean)	41% ($n = 9$)	• 9 acute incarcerations (1 had strangulated) • 2 recurrent incarcerations	2012	[42]
Australia	12	433	5 years (mean)	1.2% ($n = 5$)	• Of these 3/5 had had previous episodes	2014	[43]
UK	12	323	54 months (median)	4% ($n = 13$)	• 13 required emergency surgery • 7 cases of recurrent/ symptomatic hernias	2016	Our series (unpublished)

Interestingly, there is a stark geographical variation in incarceration rates. Of the four studies from Nigerian cohorts from between 2001 and 2012, incarceration rates are dramatically higher than other studies at 42–53%. However, they also seem to report few cases per year than other studies. These patients may represent a self-selected group with patients only presenting when hernias become symptomatic, as umbilical hernias are considered normal in their society and presentation for cosmesis is rare [17].

In the same continent, a South African study of mainly Caucasian (93%) children observed an incarceration rate of 7% [7], a figure more in line with the 5% from the only comparable other series from Europe, Australia and the USA. Indeed in our own, unpublished, series of 323 patients undergoing umbilical hernia surgery over a 12-year period, 13 patients (4%) presented with incarceration, and 7 patients (2.2%) reported intermittent abdominal pain associated with a temporary irreducible hernia. Clearly, although relatively rare, incarceration does occur at different rates across different geographical locations.

Conflicting evidence suggests defect size has a role in predicting complications. Lassaletta observed that small defects (<1.5 cm) are at higher risk [4], a finding supported by others [6, 33, 44]. Several case series however found the opposite, with their complications arising in defects 1.5 cm or larger [8, 9]. Brown et al. suggest that size has no impact on whether the hernia incarcerates [7]. Age at presentation of patients with acute incarceration ranged widely from 14 months to 10 years.

Precipitating factors for incarceration are unclear. Severe abdominal wall spasm associated with an umbilical hernia incarceration during vigorous swimming has been described in two children. High intra-abdominal pressures from breathing using the abdominal muscles are suggested as causing umbilical herniation and incarceration under such circumstances [46]. Accumulation of undigested foreign material in bowel, such as chewing gum, sand or even the presence of ascarids, may predispose to irreducibility of a hernia. They have been observed in incarcerated hernias, and it is presumed that the size of the mass prevents reduction through a narrow neck [7, 30].

Recurrent incarceration may be due to intermittent trapping of omentum within a closing hernia and presents as episodes of vomiting with umbilical pain [27, 47]. Studies show this is not uncommon and is reported in many of the studies referenced in Table 38.3. Recurrent incarceration may be significantly underreported, as some studies may not have reported this specifically [3, 4, 7]. In addition, patients may not present in the acute setting if the incarceration self-resolves. Clearly, recurrent incarceration can occur, but the significance and relevance is unknown.

Two studies found that 86% of incarcerated umbilical hernias spontaneously reduce, in or just prior to arriving at the hospital, and, in a recent study from Australia, 4 of five hernias requiring emergency surgery reduced within hospital prior to operative intervention [11, 43, 48]. In contrast to these results, one study from Senegal found that of the 41 patients operated on as an emergency, only 5 hernias (12.2%)

reduced at anaesthetic [10]. Others showed that 6–18% of irreducible hernias resolved without intervention, 50–80% being reduced by taxis with sedation or analgesia [7, 9].

Strangulation of hernia contents is reported in up to 13% of incarcerated hernias undergoing bowel resection [7–10, 17] and 14% undergoing omentum excision [6, 7]. Postoperative infection is reported to occur in 4–7% of those that had been previously been incarcerated or strangulated [7–10].

Spontaneous rupture is a rare complication of umbilical hernias in children, with only 19 cases in the literature [49]. It is usually bowel that eviscerates [47, 48, 50–52] but can be omentum alone [23] or more rarely the urinary bladder dome [53]. Factors implicated in spontaneous rupture include local skin ulceration [8, 47, 48, 51, 54], umbilical sepsis [52, 55], and prematurity with prolonged positive pressure ventilation [51]. Severe coughing and crying coughing may also contribute and are recorded in several cases [8, 47–50]. Fascial defect size >1.5 cm is associated with an increased risk of this rare complication. Thirteen out of the nineteen cases had a defect greater than 1.5 cm. In the remaining five, the defect size is not known [49]. There is one case report of rupture of an umbilical hernia in an infant with Hurler's syndrome, (mucopolysaccharidosis type 1), a condition in which umbilical hernias are commonly seen though rarely repaired due to high anaesthetic risk and short life expectancy [23]. There has been only one reported case of patient death in the umbilical hernia literature [44].

Management Options

The expectant approach to management of paediatric umbilical hernias relates to their natural history and asymptomatic nature.

An initial conservative approach is the suggested management for most children presenting at pre-school age. This is supported extensively by the literature referenced above. Parental reassurance is important, as the size of the herniation can be of considerable concern. Follow-up is not indicated in the majority unless reassurance is difficult to convey. A referral back to a surgeon once the child is of schooling age is typical.

Conservative management with the use of adhesive strapping as a treatment for infantile umbilical hernias is not commonplace in the twenty-first century. Yanagisawa et al. recently revisited this treatment approach. They examined 89 infants with an umbilical hernia over a 23-month period and assessed fascial defect closure time compared to an observation alone group. They found that strapping significantly reduced the closure time. However, 26% of the strapping group experienced complications [25].

The precise age at which surgery should be carried out in an asymptomatic umbilical hernia is debated. Most paediatric surgeons have a tendency to offer repair for an asymptomatic hernia prior to regular schooling, around the age of 4. In our own series, the median age for elective repair was 55.5 months (approximately 4.5 years). However, expedited or emergency surgery may be required for hernia incarceration, recurrent abdominal discomfort associated with herniation or evisceration. In our series, 4% required expedited/emergency intervention with a mean age of 23 months (approximately 2 years) (Table 38.4).

For most surgeons, cosmetic appearance is not an indication to operate until the natural regression of the defect has occurred. There is often a parental desire for surgical intervention due to the difference in appearance from their contemporaries, and teasing from an umbilical bulge is not an infrequent complaint from school-aged children. Indeed, Zendejas et al. found that parental concern accounted for 10% of operations in their cohort [33].

If opting for expectant management, although incarceration and complication risk is low, parents should be made aware of the signs and symptoms of incarceration and when to seek medical assessment (Table 38.5).

Incidental Finding of Umbilical Hernia

It is important to mention that umbilical hernias may be diagnosed incidentally during any laparoscopic procedures. This results in the conversion of a natural orifice into an unnatural one, making it unlikely to be subject to the normal forces of closure. Most paediatric surgeons would close this at that time of detection, whilst the child is already anaesthe-

Table 38.4 Chelsea and Westminster Hospital series 2004–2016

Total number of patients: 323 patients Median age at surgery: 54 months
Elective: 293 (91%) Median age = 55.5 months
Emergency surgery for incarceration: 13 (4%) Median age 23 months
Symptomatic hernias/recurrent incarceration: 8 (2.5%)
Repaired incidentally when other surgery being performed: 12 (3.7%)

Table 38.5 Indications for surgery in umbilical hernia

Absolute	Incarceration and/or strangulation Spontaneous rupture and evisceration
Relative indications	Hernia causing pain Cosmesis Large rings, unlikely to close >1.5 cm Asymptomatic age 3 years +
Incidental	At time of other surgery if appropriate

tised. The senior author supports this approach, regardless of age, based on discussion with surgeons in a multicentre international randomised controlled trial into paediatric laparoscopic inguinal hernia repair.

In our own series of laparoscopic inguinal hernia repair associated with an umbilical hernia, one umbilical hernia did reoccur [56]. This was presumed to be due to an inadequate umbilical herniotomy at time of umbilical port closure.

Preoperative Considerations

Preoperative Reduction

Any umbilical hernia incarceration should be considered for reduction following resuscitation. Reduction after administration of simple analgesia should be attempted first. If sedation is required, this should always be carried out in a suitable environment with anaesthetic discussion and support. Any doubt as to the viability of the herniated contents or failed reduction necessitates emergency examination of the contents and open reduction with repair under general anaesthesia.

In the unlikely event of spontaneous rupture with evisceration, the child should be resuscitated, the eviscerated bowel should be covered to protect and prevent heat loss, and the hernia should be repaired urgently.

Surgical Options for Umbilical Hernia

Operative technique for umbilical hernia repair was highlighted by Mayo more than a century ago [57]. Over the past few decades, observational studies have continued to describe alterations in technique as well as outcome [2, 3, 26, 58, 59].

The most established accepted technique for strength and closure in an adult is similar to that originally described by Mayo and involves closing of the defect using an overlapping fascial technique. In children, where the defect is usually not as large as in adults, the most commonly performed method involves a primary interrupted repair of the defect following control and excision of the sac [3]. Repair can be performed via an open approach or with minimally invasive techniques.

Consent

Consent will require the use of a parental consent form but involvement of the child if they are of a suitable age. The parents should be fully informed regarding the procedure including the incision (e.g. supra- or infraumbilical), the nature of the repair (open vs minimally invasive), potential complications (outlined below) and post-operative management.

Complications occur in 0.5–1% of patients undergoing umbilical hernia repair and include wound infection, haematoma, pain, damage to surrounding structures including bowel and recurrence. Scarring and the cosmesis of the surgery should also be discussed as the appearance of the umbilicus may be altered secondary to the surgery with either excess skin or puckering. Excess skin may be excised or allowed to settle on its own. Given the likely higher incidence of hernia in those of African-Caribbean descent, hypertrophic and keloid scarring should also be mentioned.

Anaesthesia for Umbilical Hernia

General anaesthesia is preferred in children. For improved analgesia this should be combined with local anaesthesia injection of 0.25% bupivacaine (0.8 ml/kg) within the fascia or as a pararectal block. Some evidence also exists for reduced post-operative pain requirement with a preoperative caudal anaesthetic [60].

The World Health Organisation (WHO) Checklist

The WHO checklist should be completed with a sign in, time-out and sign out.

Regarding the time-out, in a straightforward umbilical hernia repair, there are no critical steps, minimal anticipated blood loss and an estimated duration of 45 min. There is no essential imaging and weak evidence for the use of antibiotic prophylaxis, although one study did find a beneficial effect on wound infection rate [61].

Patient Positioning and Theatre Setup

The child is placed supine on the operating table (Fig. 38.1). Careful aseptic technique combined with a Betadine or chlorhexidine prep will suffice. Drapes are applied so that the umbilical area is exposed throughout the operation.

Incision and Access

Most paediatric surgeons carry out a simple curved sub- or supraumbilical incision, with circumferential dissection of the sac around its base to achieve control (Fig. 38.2). The supraumbilical incision is seen by many as preferable; as with growth this is hidden within the superior umbilical fold

Fig. 38.1 Pre-operative paediatric umbilical hernia

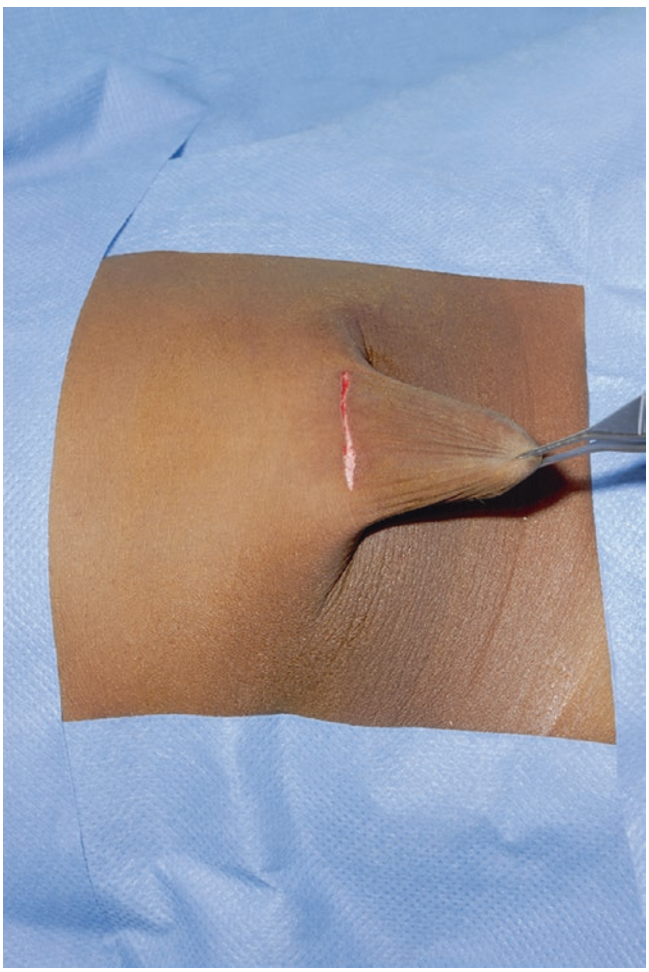

Fig. 38.2 Incision

itself and is not visible to the patient. Hernia reduction has usually occurred following anaesthesia, though it is important the operator should confirm reduction of contents before opening the sac. In addition, it is important to examine for the possibility of multiple hernia orifices being present.

Operative Steps

Open

A circumferential dissection begins to isolate the sac (Fig. 38.3). Once controlled, the sac can be incised at its base (Fig. 38.4) and the distal part removed from the overlying skin to avoid a bulky appearance (Fig. 38.5). An alternative method, or if the sac is particularly large, involves opening the sac immediately following the skin incision. The umbilical ring can be seen from inside the sac. The sac can then be stripped from the umbilical fascia and overlying skin [58, 62, 63].

Regardless of technique, removing some of the sac, especially in the larger hernias, will result in an improved and inverted cosmetic appearance. Care must be taken when stripping the sac off the overlying skin to avoid puncture. It is not customary to excise excess overlying skin in children

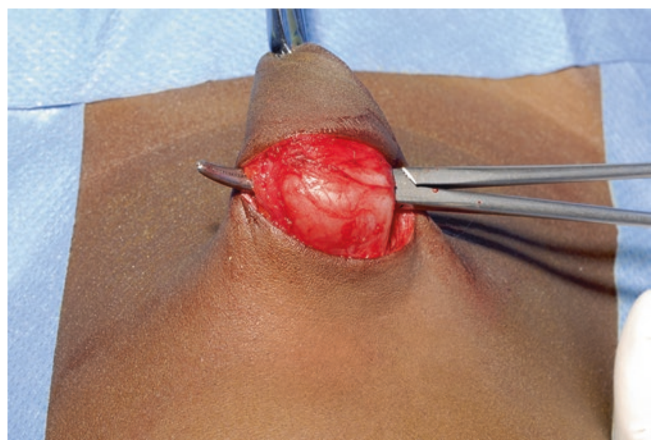

Fig. 38.3 Controlling the sac

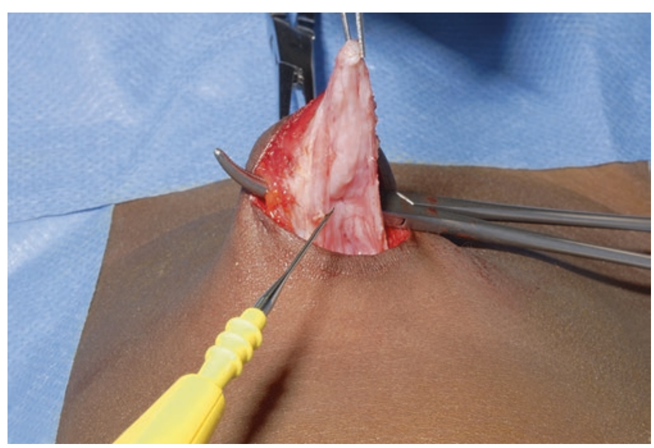

Fig. 38.4 Freeing the sac from the defect

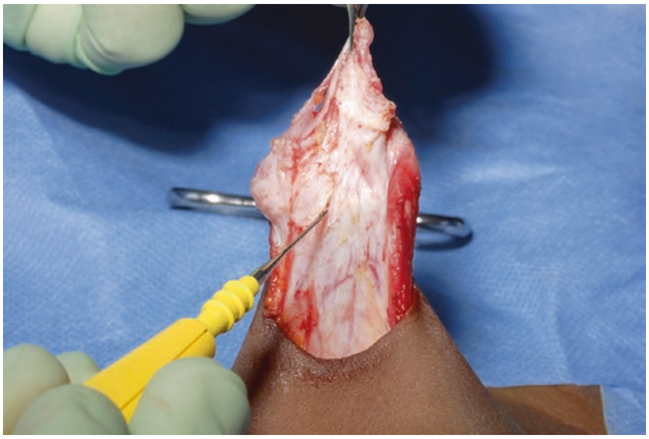

Fig. 38.5 Excising the sac

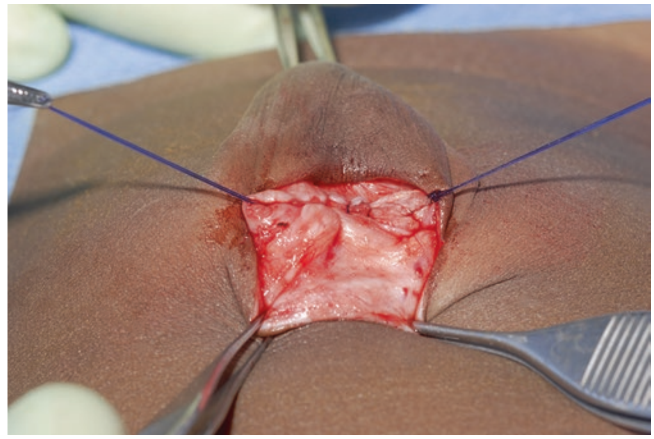

Fig. 38.7 Defects closed with knots buried

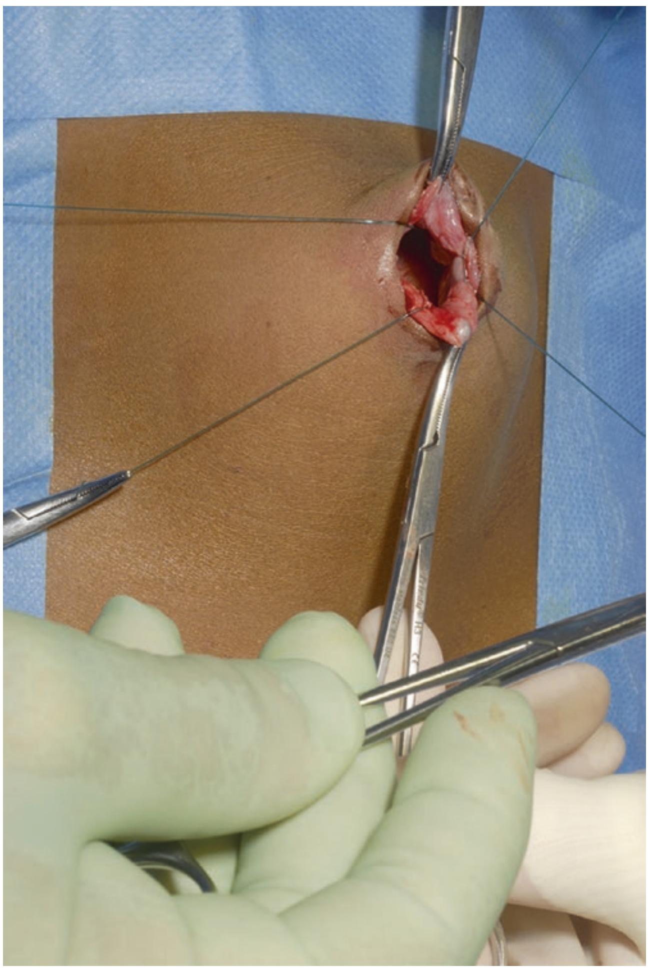

Fig. 38.6 Interrupted sutures to defect

as this usually resolves with time, and excision may result in a distorted or flattened appearance.

An important point to make is that almost all paediatric umbilical hernias are 'true' umbilical hernias. In contrast, the majority of adult umbilical hernias are paraumbilical, occurring adjacent to the umbilical cicatrix. As outlined above, in true umbilical hernia repair, an important step is stripping the hernia sac off the overlying skin and therefore dividing the umbilical cicatrix. This is not necessary in paraumbilical hernia repair as the defect arises adjacent to the cicatrix.

The defect itself, once identified clearly, can be closed with an overlapping fascial technique. A monofilament absorbable suture such as PDS (Ethicon) 2-0 or 3-0 will suffice in most children. A monofilament suture runs easily through the thickened umbilical fascia than a braided suture. Non-absorbable sutures can be used, but Zendejas et al. found that this was associated with a six times higher risk of recurrence [33].

The peritoneum and muscle are closed as one layer, either transversely or in a midline fashion depending on the shape of the umbilical defect. Applying a haemostatic clip to each suture (Fig. 38.6) and tying after all have been placed allows for a controlled repair as well as superior retraction and avoidance of damage to intraperitoneal viscera (Fig. 38.7).

Sometimes multiple defects may be found in the abdominal wall. These can either be closed individually or joined to form one larger defect, which is then closed, in order to avoid several close suture lines.

Minimally Invasive Techniques for Umbilical Hernia Repair

Minimally invasive techniques have been described for treating umbilical hernias in children. These involve the injection of polymers or using laparoscopy. Feins et al. described 25 children with umbilical hernias of 1.5 cm or less, where Deflux, a biodegradable compound of dextranomer microspheres in hyaluronic acid, was injected percutaneously in the border and preperitoneal space in 4 quadrants of the hernia defect occluding the lumen. They report 21 of the 25 (84%) umbilical hernias as being closed between 2 and 24 months postinjection. The average age at the time of the procedure was 6 years and 7 month, and the average defect was more than 6.4 mm [64]. The significant limitations of this study are the small sample size and lack on control group. Albanese et al. describe a novel technique for the repair of umbilical and epigastric hernia using 3 mm laparoscopy back in 2008. They repaired 41 umbilical hernias using two 3 mm lateral ports at a mean age of 4.2 years. They report no operative or post-operative complications and no recurrence at follow-up between 6 and 35 months later [65]. Since 2008 we have found no more up-to-date studies of laparoscopy being used for umbilical hernia repair. There is a single case report of an epigastric hernia being successfully closed laparoscopically using a 5 mm trocar port and an epidural needle in 2013 [66] and a ten patient case series of laparoscopic epigastric hernia closure in 2015 [67] but none discussing umbilical hernias. Both reported no perioperative complications or recurrence.

Closure

One suture is used to anchor the central subdermal area of the umbilicus to fashion an inverted appearance and essentially reform the umbilical cicatrix (Fig. 38.8). The superficial fascia is closed with an interrupted non-absorbable suture, and, finally, the skin can be closed with either a continuous subcuticular absorbable suture or glue (Fig. 38.9).

A dressing can be applied which may or may not have a pressure pad to avoid haematoma/seroma formation. Some authors doubt the necessity of this step based on one randomised controlled trial in children in 2006 [68].

Post-operative Management

Children should expect a full and quick recovery following umbilical hernia surgery, providing no complications occur. A dressing, if used, is usually removed 48–72 h after surgery. Follow-up is not routinely offered in our own unit unless the defect is large or at parent's request.

Operative and Post-operative Complications

Important post-operative complications are outlined below and occur in approximately 2% of umbilical hernia repairs [33].

Fig. 38.8 Inverting the umbilicus

Damage to Surrounding Structures Including Bowel

Care is needed during the circumferential dissection of the sac to avoid damage to the sac and potentially sac contents. This is particularly important if the hernia is incarcerated.

Post-operative Swelling

Post-operative swelling may be secondary to haematoma formation or seroma. Bruising around the umbilicus is a possibility and often results from the pararectal anaesthetic block. Both haematoma and seroma formation are rare (0.6% and 0.2% of cases, respectively [33]), but, if large and painful, may require evacuation.

Post-operative Infection

The incidence of infection is approximately 1% [33] and is not influenced by the use or not of a dressing [68]. Infection should be treated with antibiotics and clinical assessment for abscess formation, which may require drainage. As stated previously, prophylactic antibiotics may help reduce operative site infection, but the evidence is limited.

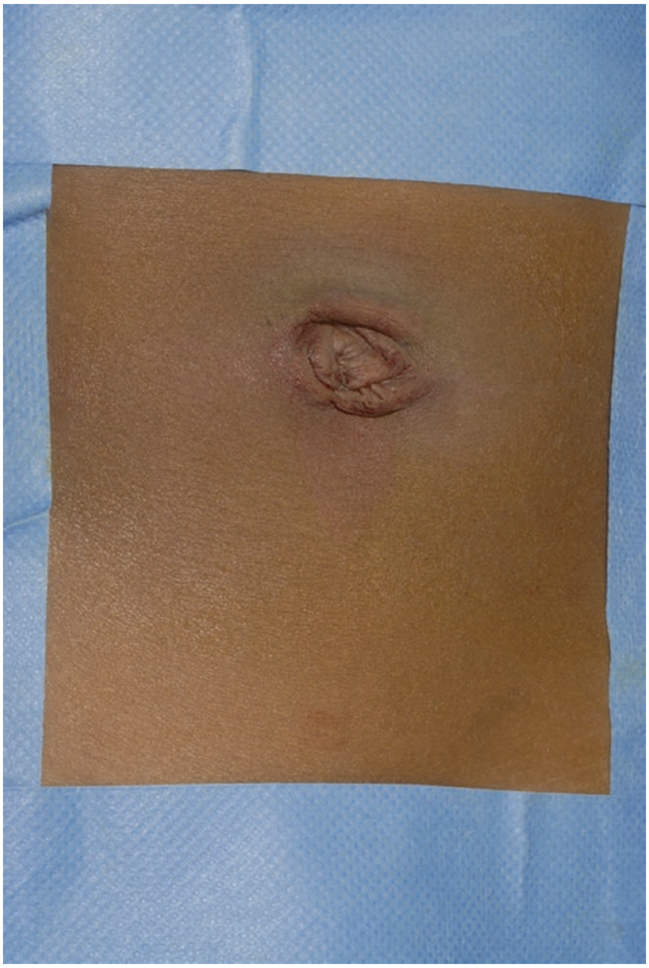

Fig. 38.9 Post-operative umbilical hernia repair

Recurrence

Recurrence is an important complication to consider and consent for. In adults the recurrence rate is reported as being between 8 and 20%. Associated risk factors include high body mass index, cirrhosis with ascites and large defects [69–71]. In children, recurrence is much less common 1–2% [33, 72]. There were no clear indications in either case as both occurred some months after the initial repair, though an incomplete closure at the initial surgery is presumed. Post-operative wound infection, haematoma and obesity are likely risk factors for recurrence in children.

Summary

In summary, paediatric umbilical hernias are common and rarely cause acute complication. It is appropriate to manage asymptomatic patients expectantly until around the age of 4, after which surgery should be offered.

Although complication is rare, it has been reported, and parents should be aware of when to present for emergency assessment. The mainstay surgical management is for open surgery and carries a low complication rate. The surgical method described in this chapter is effective and easily replicated. However, no level 1 evidence exists for this method of congenital umbilical hernia repair.

Tips and Pitfalls

- If there is evidence of the hernia decreasing size, it may still be appropriate to consider delaying a procedure, even if child aged 5. It may close in time.
- If using an umbilical hernia site during a laparoscopic procedure, be sure to always close formally. A simple port site closure is inadequate.
- Clean the umbilical site thoroughly before the procedure as the umbilicus is a dirty site and prone to infection.
- During closure of the umbilical hernia, it is important to meticulously check that no intraperitoneal viscera is caught in the suture repair. The sutures should be tired one at a time and under tension.
- Be wary of excising excess skin at time of initial umbilical hernia repair. Excess skin will usually improve with time, and excess excision can result in a poor cosmetic result.

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39 Adverse Events After Ventral Hernia Repair

S. Ulyett and D.L. Sanders

Introduction

This chapter focuses on the complications of both open and laparoscopic ventral and incisional hernia repairs. As with any major surgery, the range of complications is extensive; they include cardiovascular stressors, anaesthetic side effects, bleeding, deep venous thrombosis, metabolic derangements, postoperative ileus, visceral injury, infection of the superficial or deep tissues, prolonged discomfort or musculoskeletal symptoms, and even death. With the evolution of surgical methodology, material science, and healthcare economics, the primary challenges facing the surgeons have shifted somewhat from preventing hernia recurrences to avoiding infection, maximizing patient satisfaction, and expediting recovery. As the field of ventral and incisional hernia repair continues to move forward, novel solutions are likely to alter the acuity spectrum of the complications.

Early Complications

Mesh Infection

Mesh infection can be devastating for patients and is covered more thoroughly in Chap. 40. Fortunately the overall incidence is low in the range of 0.7–2.1% [1, 2]. A comparison of the techniques used in ventral and incisional hernia repair and the treatment of potential mesh-related infections will be discussed below.

While there is no certainty, laparoscopic repair of ventral and incisional hernias appears to be superior to open repair in terms of infective complications. For example, Forbes et al. in a 2009 meta-analysis found the rate of infections requiring mesh removal was 9 of 257 (3.5%) and 2 of 269 (0.7%) for open and laparoscopic ventral and incisional hernia repairs, respectively. Infective complications are only one outcome measure, and therefore, this should be interpreted with caution and this difference was nonsignificant ($P = 0.09$) [3]. A 2011 Cochrane review using similar data came to similar conclusions [1]. The favourable factors of laparoscopic repair may include lack of extensive tissue trauma and devascularization, avoiding the creation of large subcutaneous spaces (leading to postoperative seroma), and tissue hypothermia. Placing mesh through a trocar may also help as this avoids contact of the mesh with the skin surface. Although, iodine-impregnated adhesive drapes may be useful in this regard [4].

There is no clear association between the type of synthetic mesh used and infection rates, although mesh salvage is improved in large-pore meshes. For example, only two meshes in 291 patients were removed despite an infection rate of 2.7% in one single-centre study [5]. Expanded polytetrafluoroethylene (ePTFE) meshes may have a higher infection rate and are more difficult to salvage, in part, due to the small pore size limiting macrophage infiltration [6]. Conservative management of infected mesh using antibiotics and localised drainage of collections should be considered, although, explantation, particularly in the case of ePTFE mesh, may become necessary [7]. Mesh excision is a morbid operation, which inevitably results in the recurrence of the hernia, requiring a subsequent interval operation to repair the abdominal wall defect. The risk of infection in the subsequent operation increases dramatically due to bacterial colonization of the previous infection site.

The mechanism of prosthetic-associated wound infections is complex. The most common pathogen, *Staphylococcus aureus*, produces a biofilm on the surface of the foreign body to protect itself from the host defences and systemically administered antibiotics. For this reason antibiotic prophylaxis during surgery is less effective than surgeons might hope. The orthopaedic literature, however, strongly supports antimicrobial prophylaxis for implantation of prosthetic devices [8]. Also Wong et al. reviewed the extended use of prophylactic antibiotics in

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the postoperative period following ventral hernia repair. This retrospective study found a significant reduction of infective complications, in patients, given an extended course of antibiotics [9]. Other practices based mainly on surgical opinion that might decrease the risk of infection include the use of antibacterial adhesive drapes to cover the exposed skin and prevent mesh contact with residual skin flora, avoiding mesh insertion directly through the port incision, changing surgical gloves just prior to handling the mesh, and the use of an antibiotic-impregnated mesh. Recent animal data indicate that such strategies dramatically reduce the risk of mesh infection, preserve biological mesh integrity, and may enable successful placement of synthetic mesh in infected wounds.

Biological meshes are also used where there is a high risk of infective complications. While some studies, such as a large multicentre study involving 1500 patients, have found the rate of infection to be high in biological mesh repair, this is likely a result of confounding as high-risk patients will have been selected for [10]. However, a meta-analysis containing over 1000 patients found use of biological mesh significantly reduced the risk of postoperative wound infection as compared to synthetic mesh [11].

Seromas and Pseudocysts of the Abdominal Wall

Seroma formation is common after ventral and incisional hernia repairs. Patients having large dissections are more likely to develop a symptomatic seroma. A Cochrane review comparing open and laparoscopic repair of incisional hernias found evidence of seroma formation in 24 of 423 (5.7%) patients having open repair. Incidence was similar in laparoscopic operations with 30 of 435 (6.9%) patients developing seromas [1]. However, seroma incidence of up to 32% has been reported [20]. The wide incidence range maybe related to the definition as some groups will only define seroma as a complication if it persists after 6 weeks [12]. Abdominal wall pseudocysts are a related but rarer entity and contain cystic fluid surrounded by a fibrous wall. The reported incidence of pseudocysts is in the range of 0.45–0.8% [13, 14].

In laparoscopic surgery, seromas develop above the mesh and within the retained hernial sac with an incidence of 100% when routinely confirmed with ultrasound in clinical studies [15]. While the majority of patients form seromas postoperatively, most resolve spontaneously without intervention within approximately 3 months of the operation. The rate of seroma formation reported in the literature typically falls within 5–25% and represents the fraction of symptomatic patients who obtain further examination or investigation. In the largest reported laparoscopic series, the seroma rate was reported at 31% prior to the use of a postoperative pressure dressing and 20.4% after its routine application. Only 5% of patients had persistent seromas beyond 3 months, and less than 0.5% had excessive symptoms or required multiple aspirations or a reoperation; the mesh was not involved. Seromas rarely result in long-term problems, but the surgeons should inform their patients preoperatively about the likelihood of a seroma and its expectant management in the absence of additional complications. No prophylactic measures work with certainty. However, removal of the hernial sac, elimination of potential space during closure, drains, and compression dressings may be of use. Fibrin sealants and talc have also been used with variable success rates [16–18].

Large, persistent seromas are fortunately uncommon, but they can occur. Large subcutaneous seromas can place tension on the skin leading to skin necrosis and wound breakdown if not appropriately managed and are associated with higher rates of wound infection and other complications.

Once a patient has an established seroma there are two options. The first is to treat conservatively with advice that over time the seroma will gradually resorb. However, if the patient is unwilling to tolerate the symptoms or if the overlying skin is threatened, aspiration should be considered. Aspiration should be performed under sterile conditions using a large gauge needle or cannula connected to a 50 mL syringe via a three-way tap. The three-way tap allows fluid to be evacuated from the cavity to the syringe and then from the syringe to a receptacle without disconnecting. Only one pass of the needle or cannula through the skin minimizes the risk of infection. Pseudocysts generally require the entire fibrous capsule to be excised for definitive treatment [14].

Visceral Injury

Bowel injury is a serious complication of ventral and incisional hernia repair, which may have devastating consequences for the patient if the injury is not recognized and managed appropriately. Laparoscopy carries a similar risk as open surgery of bowel injury [1]. Various strategies have been suggested to minimize the risk of such complications. Sharma reported a 2.2% enterotomy rate and attributed this low rate to utilizing sharp adhesiolysis [19] while using cautery sparingly [2].

An intraoperatively recognized enterotomy should be repaired by open or laparoscopic approach depending on the surgeon’s confidence level [20]. Fluency in laparoscopic intracorporeal suturing is a requirement for a laparoscopic repair of an enterotomy. A limited laparotomy has been described where a small incision is made to control the injury, while the rest of the procedure is performed laparoscopically. When in doubt, the surgeon can convert to laparotomy, because a missed injury may lead to peritonitis and sepsis [21] or a chronic mesh infection with or without an enterocutaneous fistula.

Mesh may still be used in the absence of gross contamination if an enterotomy is promptly recognized and repaired, but this situation warrants a careful risk-benefit assessment. One of the factors to consider in such cases is the mesh prosthetic material. While ePTFE may be somewhat more susceptible to infection, polypropylene-based meshes have been placed in clean-contaminated cases with a very low rate of subsequent infections [22, 23]. The development of large-pore polypropylene and polyester materials has promoted this trend with evidence suggesting that such meshes may withstand measurable amounts of bacterial contamination [24]. In the face of significant contamination, however, the surgeon is wise to postpone elective hernia repair. Biologic or synthetic absorbable prostheses could be used, although their long-term mechanical integrity, particularly in the face of infection, is not fully established. An enterotomy increases the overall rate of postoperative complications significantly as demonstrated in a large retrospective review of the Veterans Affairs Surgical Quality Improvement Program (VASQIP) data [25].

Loss of Domain

Loss of domain occurs where 15–20% of the abdominal contents permanently reside outside the abdomen in the hernial sac [26]. When the hernia is reduced at the time of surgery, intra-abdominal pressure can increase which may put the patient at risk of abdominal compartment syndrome (ACS). ACS is usually defined as intra-abdominal hypertension (>12 mmHg) with evidence of organ dysfunction [27].

Patients with loss of domain may develop a distended abdomen with associated increase in ventilatory pressure and ultimately may develop organ failure (usually renal failure). CT is not diagnostic but may show evidence of venous distension.

Measurement of abdominal pressure, which is usually measured using a urethral catheter, will show raised intra-abdominal pressures, usually beyond 20 mmHg in patients who are developing signs of end-organ failure.

Adequate preoperative planning can reduce the risks of postoperative complications associated with ACS. If clinical assessment suggests loss of domain, a planning CT should be arranged to assess the volume of the hernial sac relative to the abdominal cavity. Postoperative care on a critical care unit will allow for muscle relaxation and ventilation if this is required.

Patients who start to develop signs of ACS are initially treated supportively, including increased ventilatory support, muscle relaxation, nasogastric and rectal decompression, and blood pressure support. Ultimately decompression may need to be considered.

Laparoscopic Considerations

Creation of a Pneumoperitoneum

Since incisional hernias most commonly result from a previous laparotomy, the surgeon is often faced with the task of opening a re-operative abdomen. The primary objective of this step is to establish pneumoperitoneum and obtain visualization without damaging the viscera. We prefer the conservative approach of an open cutdown. The abdominal layers are incised sequentially with careful identification of the abdominal wall structures. It is prudent to enter the abdomen away from the site of the previous incision. Even when exercising proper caution, bowel injury may be unavoidable.

Another approach to a re-operative abdomen is the Veress needle approach. The Veress needle is a small, spring-loaded needle, which is inserted away from the site of the prior operation, usually in Palmer's point in the left upper quadrant two finger breadths under the costal margin in the midclavicular line. Optical trocars offer an opportunity for entry under laparoscopic visualization and have become quite popular in these operations.

Conversion to Open

Conversion of a laparoscopic procedure to open should not be considered a complication but may be a safety measure to obtain better exposure when laparoscopy is deemed inadequate or unsafe by the surgeon. It has been said that conversion is dependent largely on the skill and comfort level of the surgeon to proceed with laparoscopic lysis of adhesions, control of haemorrhage, organ repair, or definitive exposure. As such, conversion rates vary greatly in the literature depending on the study setting, patient selection, and procedure choice. Conversion rate data is important for research purposes and patient counselling in terms of postoperative expectations of laparoscopic versus open procedures and the relative odds of each. In their review of literature, Carlson et al. identified 180 (3.3%) conversions in 5411 operations. The reason for conversion to an open repair was reported in 157 cases, extensive adhesions (48%) and intraoperative complications (29%) being the most common. Whether conversion to an open procedure impacts hernia repair outcomes is impossible to estimate because the predominant factor is likely to be the reason for conversion itself; cases converted from laparoscopic to open, perhaps, should be analysed separately and not included in the open or laparoscopic category in the surgical outcome research.

Late Complications

Chronic Pain

Pain and Quality of Life

With the advancements in hernia repair techniques and materials, attention is increasingly directed to functional outcomes, quality-of-life measures, chronic pain, and aesthetics. Chronic pain is defined as pain persisting more than 3 months after surgery [28]. In open surgery the reported incidence is variable. McLanahan et al. in a single-centre study reported 45% of patients had discomfort at 12 months following mesh repair; however, only 11% of patients described their pain as moderate or severe [29]. Deep pain may be more common following suture repair, which was postulated by Burger et al. to be a consequence of the tension of the repair [30].

In patients having laparoscopic repair, persistent pain has been reported in up to 3% of cases and may be due to the transabdominal fixation sutures. However, a large series not using transfascial fixation reported persistent pain in 7.4% of cases [31]. The mechanism of transfascial suture pain is poorly understood; possible explanations include intercostal nerve entrapment, local muscle ischemia, and possible mesh contraction. On the other hand, pain may also be due to microabrasion of the highly sensitive parietal peritoneum by a mesh that is loosely fixed. Mesh choice in open surgery may affect postoperative chronic pain. Welty et al. examined the used of different types of polypropylene mesh in 235 patients undergoing incisional hernia repair. Patients having repair with a large-pore mesh had fewer complications in terms of pain, paraesthesia, and abdominal wall mobility [32].

Postoperative discomfort at the transabdominal fixation suture sites typically resolves within 6–8 weeks [33]. The first line of treatment for persistent pain is a course of nonsteroidal anti-inflammatory medications. In refractory cases, injecting local anaesthetic at the sites of pain carries at least a 90% success rate [34]. The needle may be blunted to provide the surgeon tactile feedback as it passes through the fascial layers. Typically reported in the literature are clinically unapparent but statistically higher pain scores with suture fixation during the first month postoperatively with no differences at 6 months and thereafter [35–39]. A randomized trial showed no difference in postoperative pain and quality-of-life scores following laparoscopic surgery with fixation using either absorbable transfascial sutures, double crown of tacks, or nonabsorbable sutures [35].

Various measures have been used to assess satisfaction, pain, and activity after hernia repair. The most widely used assessment both for surgical and nonsurgical pain is a visual analog scale. However, a more sensitive and specific for hernia repair outcomes is the Carolinas Comfort Scale (CCS) popularized over the last decade [40, 41]. On a 1–5 scale, patients rate their symptoms of pain, mesh sensation, and motion limitation for common activities such as laying down, sitting, and walking (a total of eight categories). Analysis of our experience showed parallel trends in all categories, with overwhelming resolution of symptoms by the 6-month follow-up.

Recurrence

Hernia recurrence is unfortunately still a common complication following ventral and incisional hernia repair and is more common after repairing recurrences. The clinical presentation of recurrence is variable and is somewhat dependent on the size and location of the recurrence. Some patients may be asymptomatic, especially if the defect is small. If there is diagnostic uncertainty, focused ultrasound imaging can be considered to look for a fascial defect and cough impulse. However, computed tomography (CT) may be more useful, particularly in the obese patient, and CT also has the advantage of excluding other pathologies in patients with undifferentiated abdominal pain. Other causes of postoperative swelling include seroma formation and haematomas in the early postoperative period. Rarely desmoid tumours can form over a longer time frame.

The ultimate success of a hernia repair is the low rate of recurrence. As stated by Sir Cecil Wakely in 1948, "A surgeon can do more for the community by operating on hernia cases and seeing that his recurrence rate is low than he can by operating on cases of malignant disease". The use of prosthetics for defects larger than 4 cm in diameter has reduced the rate of recurrence as demonstrated in multiple studies [42, 43]. In a prospective study evaluating primary tissue repair, Luijendijk and colleagues showed unacceptably high 5-year recurrence rates of 44% for defects 3–6 cm and 73% for defects 6–12 cm in diameter [43]. Hesselink and colleagues reported a 41% recurrence rate for defects greater than 4 cm and 25% recurrence with less than 4-cm-sized defects repaired primarily [44]. The use of mesh has dramatically reduced recurrence. As early as the 1980s, Stoppa noted a much higher failure rate when mesh was not applied [45]. In 2000, Luijendijk et al. reported in a sentinel paper a randomized prospective multicentre trial demonstrating 3-year cumulative recurrence rates of 46% with suture repair and 23% with mesh repair (6% recurrence for defects less than 10 cm^2). A 2008 Cochrane review also confirmed the recurrence benefit of using mesh in open repair of incisional hernias with a relative risk of 1.85 in favour of mesh [46]. Further refinements in technique, prosthetic reinforcement materials, fixation devices, and importantly patient selection and prehabilitation (weight management, diabetic control, and smoking cessation) continued to drive down the recurrence rates. A recent report of 505 laparoscopic hernia repairs showed a 1.8% recurrence rate [44]. The rate of recurrence is broadly equivalent when using open techniques, although variation exists in the reported figures. One randomized, prospective study looking at primary repair of umbilical hernia found a recurrence rate of only 1% in the mesh group at 64 months, although recurrence was significantly higher in the suture repair group (11%) [42].

There may be a benefit of laparoscopic repair in the repair of ventral hernias in the obese population [47]. However, there is inevitable bias in the laparoscopic hernia repair literature as surgical specialists who are involved in large laparoscopic series are not necessarily representative of the typical general surgeon. Another source of bias is that open operations often serve as a fallback strategy for laparoscopic surgeons in complicated or multiple recurrent cases, as well as being the standard of care for emergent cases. In an attempt to eliminate this bias when comparing open and laparoscopic repairs, some authors stratify their patients into open and laparoscopic arms and report a certain conversion rate for the latter while counting the complications and recurrences within each arm. However, even in the best of hands, laparoscopic completion of the operation is not always feasible due to patient comorbidities, hernia characteristics, or other intangible factors, and patients should be counselled as such. For example, in a randomized trial, Itani et al. compared laparoscopic and open hernia repairs, reporting a recurrence rate of 12.5% (8/72) in the laparoscopic arm, which included ten conversions with two recurrences [21]. Therefore, laparoscopically completed repairs had a recurrence rate of only 9.7% (6/62). Carlson and colleagues analysed over 6000 laparoscopic ventral hernia repairs reported in the literature and found an unweighted recurrence rate of 4.3% [48]. A further cause of bias, is that some surgeons only perform laparoscopic repair for smaller fascial defects, reverting to open repair if the defect is large. The reality is that while modern surgical techniques have reduced the likelihood of recurrence, it is unfortunately still common following ventral and incisional hernia repair.

Risk Factors for Recurrence

An important step in minimizing the risk of recurrence is identification of risk factors that may predict recurrence or complications in a particular patient [30, 49]. The defect size, mesh size, operative time, and complications all correlate with each other and together reflect the complexity of a repair but do not appear to increase the risk of recurrence in some series [44, 50, 51]. Despite mixed evidence, most surgeons agree that significant risk factors for recurrence include surgical site infections (discussed separately), previous recurrence history, and a complex interplay of mechanical factors such as obesity, hernia size, fixation methods, and mesh material.

In their retrospective review of 146 cases, Bencini et al. found significantly higher recurrence in patients with prior recurrences (67 vs. 16%) and smokers (58 vs. 23%), but the latter was not an independent predictor in their model [52]. In their analysis of 9 recurrences out of 505 laparoscopic repairs, Wassenaar et al. found that 8 of 9 patients had a first-time incisional hernia with no differences in age, sex, ASA score, OR time, mesh size, and hospital stay compared to the rest; seven of nine recurrences had no other postoperative complications. Approximately half of the recurrences had transfascial suture fixation; the others had tacks only [35].

Mesh selection, positioning, and fixation play a significant role in recurrence after laparoscopic hernia repair. The most popular and time-tested technique for intraperitoneal underlay synthetic mesh placement is transfascial suture fixation followed by tacks around the mesh perimeter [2, 53]. Variations of this technique as well as selection of mesh, sutures, and tacks are abundantly described in the literature. Berger and colleagues used sutures to position the mesh but secured solely with tacks, resulting in a 2.7% (4/147) recurrence at a mean follow-up of 15 months [53]. Several groups reported using no fixation sutures but a “double crown” (two circumferential rows) of tacks [33] resulting in 4.4% (12/270) recurrence rate at 44 months mean follow-up [31] and 3.5% (7/200) with 22.5 months follow-up. Bageacu et al. reported 15% (19/121) recurrence over a mean follow-up of 49 months and attributed the high recurrence rate to inadequate mesh fixation with metallic tacks alone [54]. In fact, the pull-off strength of suture fixation of the mesh to the abdominal wall is higher compared to the tacks [55]. In open repair, proper technique including fascial closure, the choice of whether to use mesh, and mesh positioning also affects recurrence rate. As discussed above mesh repair significantly reduces the risk of recurrence in ventral and incisional hernias as compared to suture repair [46].

Morbid Obesity

Obesity is a rapidly growing problem, and morbidly obese patients increasingly present for repair of ventral and incisional hernias. Body mass index >35 kg/m^2 is a strong predictor of postoperative wound complications, and BMI >40 kg/m^2 has been shown to increase the risk of recurrence almost fourfold [2]. The pathophysiology of this condition is complex, but increased intra-abdominal pressure, tissue laxity due to endocrine derangements, and large amounts of subcutaneous tissues contribute to the hernia repair failures [56, 57].

Pseudo-recurrence

Bulging and pain at the site of previous ventral hernia are sometimes noted by patients after a repair, especially after laparoscopic repair. These symptoms may be produced by seromas, hematomas, retained hernia contents, a true recurrence, or bulging of the mesh into the space formerly occupied by the hernial sac. The latter is termed a pseudo-recurrence and may mimic the symptoms of a true recurrence, without the risk of incarceration or strangulation. Wassenaar et al. reported mesh bulging in 4 of 505 patients (0.8%), which was corrected by placing a second, larger, well-stretched mesh at the site of the initial repair [44], although the necessity of surgical correction of eventrations has been challenged. Generally, the occurrence of such a phenomenon is probably due to the lack of appropriate tautness of the initial repair or insufficient fixation. Both of these can be prevented with proper technique.

Bowel Adhesions and Mesh Erosion

Peritoneal adhesions are common and will develop in nearly all patients with previous intra-abdominal surgery. Adhesions form as a result of an inflammatory reaction due to tissue dissection, mechanical shear, and certain prosthetic materials. One study used magnetic resonance imaging (MRI) in the evaluation of postoperative adhesions and found 49% of patients undergoing open ventral hernia repair developed adhesions (cf. 67% of laparoscopic repairs) [58]. While laparoscopic surgery minimizes direct tissue handling and generally results in fewer adhesions, intraperitoneal mesh placement always holds potential for adhesions. Mesh material is the principal determinant of the degree of adhesions, and dozens of mesh types have been developed over the last two decades as a result of extensive research. The original polypropylene mesh revolutionized hernia repair by providing a long-term durable reinforcement vis-a-vis an inflammatory process, which stimulates fascial ingrowth. Unfortunately, it also promotes intra-abdominal adhesions. In many cases the omentum provided the natural barrier protecting the bowel [19]; however, evidence quickly accumulated of the adverse effects of polypropylene on the bowel resulting in intestinal obstructions, erosions, and fistulas [59, 60]. With the advent of laparoscopy, the need arose for safe and effective intraperitoneal mesh prosthesis. Expanded polytetrafluoroethylene (ePTFE) mesh fell into favour as it produced minimal adhesions (although, PTFE may be more susceptible to infection than polypropylene).

The advent of large-pore composite mesh provided a more balanced option of sufficient fascial integration with low intra-abdominal adhesion characteristics [61]. However, all of the composite meshes still have the potential to result in adhesions albeit lower than non-composite meshes. Fixation of the mesh may also play a role in adhesion formation.

Most adhesions are quiescent. However, potential complications include pain and bowel obstruction, which can occur at a variable interval following surgical insult. The diagnosis is usually made in the context of previous surgery in addition to pain and obstructive symptoms. CT imaging may be required to exclude other causes of obstruction, such as hernia recurrence. Patients who develop adhesional pain or obstruction are usually managed conservatively. Surgery and adhesiolysis is only occasionally considered in patients who have failed to respond to conservative management and patients with evidence of significant sequelae such as bowel strangulation.

Readmission, Reoperation, and Mortality

Thirty-day readmission may be viewed as a composite indicator of serious postoperative complications. Hospital readmissions represent an increasing financial burden, with over 15 billion USD in annual expenditures according to the Medicare estimates. They are also associated with considerable patient morbidity. The rates are highly dependent on the surgical procedure and the patient population. Blatnik et al. found in their experience of 221 laparoscopic ventral hernia repairs a 5% readmission rate within 30 days of surgery [62]. They identified a number of risk factors including abdominal infection, defect size, and patient comorbidities. The primary reason for readmission was wound-related complications; open repair carried a much higher readmission rate of 20% (odds ratio 35:1). Blatnik et al. identified many potential predictors. Smoking is a strong predictor and a modifiable risk factor for wound complications [63], and many surgeons postpone elective hernia repairs in active smokers.

Mortality after an elective ventral hernia repair is uncommon, occurring in 0.2–0.7% of operations [20, 64, 65]. In the published literature, we identified 16 cases of postoperative mortality: ten due to intestinal perforation, three myocardial infarctions, one pulmonary embolism, mesenteric ischemia, and end-stage liver disease. Most deaths occurred within 3 days of the operation. Over 86% of studies on ventral hernia repair document no operative mortality [48].

Summary

Ventral and incisional hernia repair is a common operation performed throughout the world. With the widespread use of mesh, recurrence rates of less than 10% are typical, although the incidence is higher in long-term studies. Risk factors include smoking, obesity, defect size, previous recurrences, inadequate fixation, and mesh infection. With the refinement of bioprosthetics and surgical techniques, expedient recovery and postoperative quality of life have become the principal outcome measures for ventral and incisional hernia repairs.

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Abdominal Wall Mesh Infections

40

K.M. Coakley, B.T. Heniford, and V.A. Augenstein

Introduction

Ventral hernia repair is one of the most common operations in the world, with 765,000 repairs per year in Europe and the USA combined, as estimated by the Cochrane collaboration [1, 2]. In a recent publication in JAMA, Merkow demonstrated ventral hernia repair to be the second most common surgical procedure associated with readmissions in American College of Surgeons National Surgical Quality Improvement Program database [3]. In that particular study, 498,875 operations across six specialties were studied, and the only procedure associated with a higher percentage of readmissions than ventral hernia was lower extremity vascular bypass. One of the most common reasons for readmission were wound complications which occur in 29–66% of ventral hernia repairs [4–10]. Incidence of hernia formation after a laparotomy is 18–23% [11, 12]; the incisional hernia population is inevitably at a high risk for poor healing and wound complications as the vast majority of patients do not develop hernias.

Surgical techniques for ventral hernia repair vary, and, despite numerous studies on one of the most common surgical procedures in the world, there is little consensus regarding surgical technique, mesh type, and location of mesh placement. The benefit of using mesh, to repair ventral hernias, has been well established [13]. With 10-year follow-up, Burger et al. demonstrated a 32% recurrence rate for mesh compared to a 63% recurrence rate for suture-based repairs of singular small (<10 cm^2) midline incisional hernias [14]. In that particular study, mesh was used as a bridge; there have been multiple subsequent studies showing recurrence rates as low as 6.1% when performed with midweight polypropylene mesh [15, 16]. Additionally, Finan et al. showed the overall cost effectiveness of mesh placement after considering postoperative complications and recurrences. A systematic Cochrane review and literature summary [17, 18] reported that essentially all ventral hernias should utilize mesh to reduce the rate of hernia recurrence. This research has been largely heeded: in recent years, more than 85% of ventral hernia repairs utilize prosthetic mesh [19]. However, mesh becomes controversial as mesh infection rates increase [20]. A recent Danish study by Kokotovic et al. examined 3242 elective incisional hernia repairs with 100% follow-up and found mesh repair was associated with a lower risk of reoperation for recurrence compared with nonmesh repair over a 5-year follow-up period. However, although details regarding type of mesh, mesh placement, and patient BMI are not included, the analysis reported long-term mesh-related complications can partially offset benefits, showing the incidence of complications progressively increases with time [21]. While mesh implantation significantly reduces hernia recurrence, infection of the mesh is one of the most dreaded and challenging conditions in abdominal wall reconstruction. With the prevalence of synthetic materials used, the number of patients who will suffer such infections is likely to increase. Currently, there is no independent database tracking mesh-related complications, no mandate to follow patients for any set amount of time, and no guidelines regarding what type of mesh to use and when. This chapter focuses on mesh infections following ventral and incisional hernia repair—incidence, presentation, risk factors, microbiome, and treatment.

Incidence

Seventy percent of hernia repairs are performed via an open approach through a midline abdominal incision, with slightly lower rates of laparoscopic adoption worldwide [22, 23]. Any ventral hernia repair requiring a large incision and subcutaneous dissection carries increased risk of wound infection, and wound complication rates for complex hernia

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repairs vary between 28 and 66% [4–10]. Wound infections are correlated with a greater incidence of mesh-related infection. The reported rate of mesh-related infection following hernia repair is between 1 and 8% [24–31]. Literature shows mesh infection rates of less than 1% in laparoscopic surgery compared to 8% in open surgery [32, 33]; therefore, the laparoscopic approach is preferable in terms of risk for prosthesis infection. Two recent meta-analyses have shown the laparoscopic approach was associated with significantly lower surgical site infection rates, and there was a trend toward fewer infections requiring mesh removal [2, 34]. While a laparoscopic approach in morbidly obese patients undergoing ventral hernia repair minimizes the potential wound and mesh complications, there still exists an increased risk for recurrence with Tsereteli et al. finding recurrence following laparoscopic approach was four times higher in patients with a BMI >40 when compared to patients with lower BMI [35].

The variables involved in describing the hernia patient and technique of the hernia repair are numerous; furthermore, as shown above, there is quite a range in reporting wound and mesh infection rates. With no available national database to track each mesh recipient's outcome, the true incidence and outcome of wound infections and mesh infection are difficult to determine and likely underestimated. For several reasons, the true mesh-related infection rate may, in fact, be substantially higher than 8%. First, patients suffering from an infection or other complication may seek assistance from someone other than the operating surgeon. Of the hernia patients surveyed at our tertiary referral center, 57% reported having a complication related to their original hernia repair, and 100% had a hernia recurrence, yet only 44% of the primary surgeons knew of the complication or recurrence [36]. Second, studies suggest that the commonly used 30-day follow-up window may be inappropriately short to rule out the possibility of surgical complications, particularly mesh infections. In a review of mesh infections treated at our Hernia Center, the patients' mesh infection manifested itself between 6 days and 5 years after surgery, with a mean of 31 months post-implantation [37]. Thus, most mesh infections would be missed by a standard 30-day follow-up window. Ventral hernia repairs with mesh should be followed well beyond 30 days.

Presentation and Risk Factors

Mesh infections typically present with local erythema, tenderness, swelling, and warmth of the abdominal wall around the infected mesh. Generalized manifestations, such as pain, fever, malaise, chills, or rigors, are experienced by some patients [38]. Chronic mesh infections can present with a discharging sinus, enterocutaneous fistula (Fig. 40.1), and visible mesh (Fig. 40.2). Chronic mesh infections may manifest late after herniorrhaphy with skin erythema, wounds in the area of mesh, and ultrasound or CT imaging showing fistulous canals extending from skin to the infected prosthesis. Ultrasound and CT are not always helpful in determining diagnosis of mesh infection, and infection scintigraphy can be used not only to evaluate vascular and orthopedic prostheses, as commonly is done, but also to help evaluate prosthetic mesh [39]. Scintigraphy with 99mTc-antigranulocyte antibody has been utilized to differentiate between postoperative inflammation and infection following hernia repair with mesh [39].

The first step in the prevention of mesh infection is the surgeon's recognition of the relevant risk factors. Several risk factors increase the odds of a mesh infection: wound infection, smoking, obesity, enterotomy, concomitant

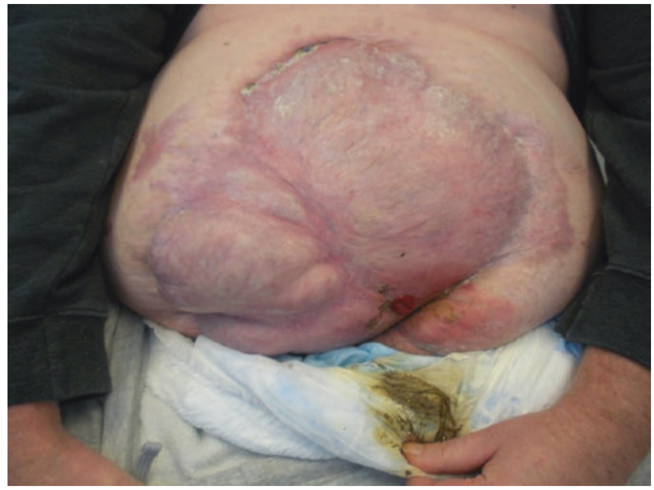

Fig. 40.1 This patient presenting with erythema as well as an enterocutaneous fistula has an underlying mesh fistula

Fig. 40.2 Another patient with mesh fistula presenting with exposed mesh

procedure, diabetes, and prolonged operative time [25, 40–42]. Despite well-known culprits for mesh infection, there is no standard of care for prevention or preoperative prehabilitation.

Reduction of medical comorbidities prior to surgery can have a significant effect of outcomes and medical costs. Martindale et al. clearly demonstrated that smoking cessation, diabetes management, and weight loss reduce complications and improve outcomes [43]. In a recent publication in JSR, Cox et al. demonstrated the compound effect of comorbidities; patients with comorbidities accrue more charges even without a complication when compared to patients without comorbidities and with a complication [44]. Preoperative optimization of preventable comorbidities such as diabetes, tobacco use, and obesity improves outcomes in ventral hernia repair [44]. A 2012 survey of ventral hernia surgeons revealed that surgeons are regarding morbid obesity as a relative contraindication for elective ventral hernia repair, with 43% of postponed or delayed elective ventral hernia repairs listing concomitant morbid obesity as the indication for case postponement [44, 45]. Surgeons are increasingly aware that patient's preoperative readiness for elective hernia repair should be based on a data-driven analysis of modifiable risk factors.

In an analysis of predictors of mesh infections, Liang et al. found the Ventral Hernia Working Group (VHWG) was an independent predictor of mesh explantation. VHWG is a four-level grading system designed to predict patients at high risk for surgical sight occurrence in ventral hernia [17] incorporating a variety of patient factors including comorbidities, surgical history, operative details, and degree of contamination. By comparison, The Center for Disease Control's four-tier classification of incisional wounds accounts for degree of contamination present in an incision [46, 47]. A Class I wound is an uninfected operative wound in which no inflammation is encountered and the respiratory, alimentary, genital, or uninfected urinary tract is not entered. Class II is an operative wound in which the respiratory, alimentary, genital, or urinary tracts are entered under controlled conditions. Class III is an open, fresh, accidental wound or an operation with major breaks in sterile technique or gross spillage from the gastrointestinal tract. And, lastly, Class IV wounds are defined as traumatic wounds with retained devitalized tissue or an existing clinical infection or perforated viscera [46]. Unlike the CDC classification, the VHWG incorporates comorbidities and patient history to define risk for wound complications. Grade 1 are low-risk patients with no history of wound infection; Grade 2 are patients who are active smokers, are obese, have diabetes, or are on immunosuppressive medications. Grade 3 are patients with previous wound infection, presence of an ostomy, or there is violation of the GI tract during the operation. Grade 4 are patients with active infection such as grossly infected mesh or septic dehiscence. It is important to keep in mind the differences in the two grading systems as, for example, an enterotomy is classified under a CDC Class II wound but a VHWG Grade 3 wound.

As hernia grade increases, the risk of mesh explantation increases. Additionally, the number of prior abdominal operations plays a role in mesh explantation as Liang et al. found that patients with four or fewer previous abdominal surgeries had 5% likelihood for an abdominal reoperation compared to those with five or more previous abdominal surgeries had 5- to 40-fold increased likelihood of needing a reoperation and mesh explantation [48]. The abdominal wall that has sustained multiple incisions is more likely to have altered vascularity, wound healing, or prior incisions that harbor latent bacteria.

Hawn et al.'s analysis of mesh explantation after ventral and incisional hernia repair found abdominal aortic aneurysm history was associated significantly with infection and explantation [26]. Similarly, Burger et al. found with 10-year follow-up risk factors for recurrence and infection included prior AAA repair [14]. Although corticosteroid use, tobacco smoking, coronary artery disease, COPD, a low preoperative serum albumin concentration, and long operative time have been shown to be independent predictors of SSI, these factors were not associated with mesh infection unlike a AAA history [26].

Carolinas Equation for Determining Associated Risk (CeDAR) is a prediction tool and a free mobile app which has been downloaded in over 140 countries around the world to estimate open ventral hernia patients' risk of postoperative wound complications. The statistically significant variables were enterotomy or presence of stoma (OR 2.65), previous ventral hernia repair (OR 2.64), advancement flaps (OR 2.28), tobacco use (OR 2.17), active infection at surgery (OR 2.07), uncontrolled diabetes (OR 2.01), anterior component separation (OR 1.91), and BMI >26 kg/m^2 (OR 1.08/unit BMI) [49]. These tools, through analysis of large databases and statistics, essentially predict high-risk patients and are specific to open ventral hernia patients. Colavita et al. found that the CeDAR equation predicts wound complications in a validation cohort of 915 open ventral hernias performed at a separate institution, Greenville Hospital System, from the 534 open ventral hernias analyzed to create the derivation cohort [50]. The model yielded an area under the curve of 0.78, demonstrating excellent statistical correlation and verifying it as a validated, effective, and user-friendly wound complication prediction tool for open ventral hernia repairs.

When predicting ventral hernia complications, the American College of Surgeons' Surgical Risk Calculator underestimates important outcomes. While the risk calculates can accurately predicted medical complications, reoperation, and 30-day mortality in ventral hernias, SSIs, serious complications, and LOS were significantly underestimated [51]. Several hernia specific tools are available to help surgeons quantitate preoperative risk factors and guide patient optimization. Liang et al. conducted a single institutional analysis of 407 open ventral hernia repairs with mesh to determine factors that lead to mesh explantation [48] and developed a Ventral Hernia Risk Score for predicting surgical site infection based on concomitant hernia repair, skin flaps created, American Society of Anesthesiologists (ASA) score ≥3, body mass index ≥40 kg/m, and incision class [52].

In addition to the preoperative factors mentioned above, nearly one in five patients develops an incisional hernia within 5 years of an abdominal organ transplantation [53]. Immunosuppressive medications given postoperatively impair wound healing and facilitate the development of a bacterial biofilm, leading to the resistance of microorganisms to antibacterial mechanisms [54]. There exists debate in the literature with Bueno-Lledo et al. finding corticosteroids to be a predictor of mesh infection but not explantation [55] and other series finding steroids not to be an independent predictor of mesh infection nor explantation [26, 48]. Certainly, this may yet be another variable to take into consideration when repairing ventral hernias in posttransplant patients.

By nature of the re-operative field, enterotomy during incisional ventral hernia repair is often unavoidable. Many patients have had multiple previous hernia repairs, intraperitoneal mesh, or tacks making adhesiolysis challenging. Hawn et al. found patients undergoing incisional hernia repair with concomitant intra-abdominal procedures or enterotomy have a greater than sixfold increased hazard of subsequent mesh explantation [25]. In addition, enteric gram-negative bacilli, including anaerobes, are more likely to be encountered in cases of enterotomy during the repair [25]. Bueno-Lledo et al. analyzed predictive factors associated with prosthesis infection after abdominal wall hernia repair and established patients undergoing a concomitant enterotomy with prosthetic repair were five times more likely to undergo subsequent mesh explantation [55]. The rate of enterotomies during open ventral hernias has been reported around 6.7% in randomized controlled trials [34]. When evaluating 1274 ventral hernias over 38-month follow-up, the author's data showed patients without a previous repair; the enterotomy rate was 1.4%, which increased to 3.6% if patients had even a single previous hernia repair. Mesh infection rates rose from 1.8% in those without enterotomy to 21.4% in patients with enterotomy [56]. Avoiding enterotomies and recognizing the downstream effect are important, and one should consider not using synthetic materials in high-risk patients.

The morbidity and cost associated with wound and mesh complications are significant. Colavita et al. found patients with wound or mesh complications experienced worse quality of life 6 months after surgery than those without complications [57]. Using the Carolinas Comfort Scale, patients who experienced a complication reported more discomfort (57.6 vs. 35.4%), greater limitations on activities (58.6 vs. 29.9%), and more mesh sensation (52.5 vs. 34.2%) than those without a complication. Patients who have complications required more office visits, placing a burden on the patients to travel to clinic appointments as well as additional time away from work. This increases a burden on the physician and the physician's staff, who now must see a higher number of patients, impacting both patient and physician quality of life. Additionally, Colavita's analysis showed that a patient who developed a mesh infection incurred inpatient hospital charges of $44,000, plus an additional $63,400 in follow-up costs, for a total average annual cost of $107,000 [57]. In comparison, a patient without hernia repair complications incurred 62% less in total charges (roughly $38,700 in hospital costs and $1400 in follow-up charges). This likely understates the actual increased expense from mesh-related infection, as this analysis does not include home nursing, antibiotic therapy, disability and rehabilitation, family-related time for care, time off work, and any charges incurred after 12 months, certainly making these underestimations [1]. Given the dramatic burden associated with mesh infection, reduction of any modifiable risk factors and avoidance of synthetic products in high-risk patients should be strongly pursued.

Microbiome

Staphylococcus aureus is the most common microorganism isolated from infected meshes [24], with over 80% of isolates displaying *S. aureus* [37, 55]. This is consistent with long-standing research indicating that the presence of a foreign body reduces the bacterial load required to induce *Staphylococcus* infection and abscess formation in healthy adults. Indeed, a single buried stitch can enhance the virulence of *Staphylococcus* by a factor 10,000 [58]. *S. aureus* can be difficult to treat, given its production of a network of exopolysaccharides, known as biofilm, that defends the bacteria from host immune response and antibiotics [54]. *S. aureus* is prone to attachment to surfaces and creation of biofilm. Biofilm's hydrated polymeric matrix is the root of persistent infection; studies of biofilms have revealed differentiated, structured groups of cells with community properties creating a protective film with an inherent resistance to antimicrobial agents. Biofilms have been established to be integral in the many human infectious diseases, including prosthetic joint infection, otitis media, cystic fibrosis, and endocarditis [38]. Additionally, bacterial biofilms are important contributors to complications associated with prosthetic mesh implanted in the abdominal wall, as in the presence of biofilm, Vancomycin is 1000–1500 times less effective in eradicating *S. aureus* [38]. Kathju demonstrated bacterial biofilms directly on mesh from patients with mesh infections were frequently polymicrobial and underappreciated by culture alone [38]. Egelsman's review of surgical mesh infection following abdominal wall reconstruction declared a surface biofilm is capable of resisting antimicrobial agents, and once a biofilm has formed, initiation of antibiotic treatment is too late, leaving the only option for treatment is removal of the implanted mesh [59].

Studies on the prevention of biofilm formation are mainly focused on increased mesh biocompatibility, as improved mesh tissue incorporation optimizes the host's protection of the mesh from microorganisms [59]. Kaplan and Ragunath have demonstrated in a dental study that enzymatic detachment of biofilms from synthetic surfaces results in increased ability for infection to be cleared by antibiotics in combination with the host immune response [60]. Enzymatic application in infected mesh for the eradication of biofilm is subject to ongoing research [38]. Sadava et al. have explored in animal models presoaking mesh in vancomycin solution to reduce methicillin-resistant S*taphylococcus aureus* bacterial growth [61]. They concluded presoaking with vancomycin may reduce the risk of mesh infection in clean-contaminated cases, although further investigation with human trials is still necessary.

Methicillin-resistant *Staphylococcus aureus*, or MRSA, is widespread in patients with infected mesh, and a MRSA history predisposes patients to future increased risk of mesh infection [61–64]. In the author's series of mesh infection patients, MRSA was present in 50.3% of cultured isolates [37]. Birolini et al.'s series of 41 mesh infections from Brazil showed a similar rate of MRSA infection with 47.1% of mesh infections cultures positive for MRSA [62]. It is the author's practice that any abdominal hernia patient who presents with signs and symptoms of a mesh infection should be placed on an antibiotic with activity against MRSA and gram-positive bacteria. While resistance of bacteria to antibiotics is a worldwide concern, it is important to consider when comparing international reports on mesh infections that MRSA incidence varies greatly internationally, with the USA showing 49% rate of MRSA isolates, compared to 10% in France, 5% in Canada, and 1% in the Netherlands [65, 66]. Bode et al. established nasal carriers of MRSA have a risk of healthcare-associated infection three to six times the risk among noncarrier and low-level carriers [67]. Blatnick et al. established in animal models that mesh types vary in ability to clear MRSA. In their study on animal models, they found monofilament unprotected polypropylene and polyester mesh can clear a large percentage of MRSA contaminants, whereas multifilament, composite anti-adhesive barrier meshes and laminar antimicrobial impregnated mesh are not able to clear bacterial contamination with MRSA [68]. Moreover, Polouse recently published data indicating that MRSA at any site increases the risk of surgical site occurrence long term [69]. Given this, it is the author's practice to decolonize nasal and extranasal sites on hospital admission with Bactroban in combination with a 4% chlorhexidine gluconate soap such as Hibiclens.

Escherichia coli, *Enterococcus*, and *Candida* are also encountered in mesh infections [40, 55, 64], with the presence of *E. coli* and *Enterococcus* bacteria often indicating a history of surgery with enterotomy or mesh fistula presence. The variety of organisms responsible for mesh infections underscores the importance of obtaining deep fluid cultures, via image guidance when possible, to guide antibiotic choice.

Treatment

Understanding and identifications of risk factors for mesh infections play a predictive role in likelihood of mesh explantation. Predictors for mesh explantation have been supported in many studies [25, 41, 48, 55].

In our analysis of mesh infections, we have seen that predictors of mesh explantation are fistulae, smoking, MRSA, and certain types of mesh such as composite, ePTFE, and polyester meshes. Bueno-Lledo et al. showed similar mesh explantation predictors to our analysis—type of prosthesis did not affect the rate of prosthetic infection but did influence the need for mesh explantation, with ePTFE and dual meshes requiring complete removal, compared to salvage rate of 36% for polypropylene meshes [55]. Leber et al. showed higher incidences of infection, enterocutaneous fistula formation, and small bowel obstruction with the use of multifilament polyester mesh compared to meshes made by other materials [70]. In Berrevoet's series of mesh salvage by use of topical negative pressure therapy, the only meshes that consistently had to be completely or partially removed because of ongoing infection and the lack of granulation tissue covering the mesh were multifilament polyester meshes [71]. Decreased likelihood of eradication of infection from polyester could be due to biofilm adherence, as Sadava established in animal models multifilament polyester mesh had more biofilm present on infected mesh when compared to monofilament polypropylene mesh [61]. Liang et al. showed when adjusting for covariates, ePTFE was associated with a threefold increase in the hazard of mesh explantation [48], consistent with a previous study by Hawn [25]. In a 2005 study examining FDA reported mesh complications, Robinson et al. stated mesh infections and intestinal fistulae were significantly more common with Composix-Kugel mesh, a mesh developed with both PTFE and polypropylene, when compared with meshes of polypropylene alone [72]. With more than 200 mesh types available in the USA [73, 74], mesh selection remains controversial [75, 76]. All mesh, especially synthetic, can become infected, and there is still debate in the literature in efforts to establish one material's clear superiority. Lightweight polypropylene meshes appear more prone to salvage with drainage and antibiotics alone compared to infected ePTFE which often requires complete excision [55].

The consideration of implanting a lightweight polypropylene mesh with wide pores was first studied in animals [77], and now the once prohibited idea of synthetic mesh in contaminated cases has been explored [78–80]. In a contaminated setting, a permanent prosthesis is commonly considered contraindicated because of high rates of mesh infection and removal, directly leading to hernia recurrence. These trials utilizing synthetic mesh in a contaminated field have been pursued in hopes of lowering incidence of infection while simultaneously avoiding the cost of biologic mesh; however, these studies are limited in sample size and length of follow-up. Deerenberg et al. placed synthetic in contaminated rat abdomens and found 15 of 16 rats receiving C-Qur, a polypropylene mesh, developed a mesh infections [81]. van't Riet et al. found when patients with postoperative wound dehiscence due to intra-abdominal infection had synthetic mesh placed, a high risk of complications resulted. Regardless of whether polypropylene or polyester was used, van't Riet et al. concluded over 49-month follow-up, synthetic mesh in a contaminated field should be avoided [82]. The potential of lightweight mesh has previously been humbled with long-term results revealing central fracture and a recurrence rate of 22.9% [28]. This high rate of recurrence in clean cases demonstrates an appropriate concern of lightweight mesh as an alternative to biologic mesh in high-risk patients.

As guidelines for treatment of mesh infections do not exist, the authors guide their treatment by established orthopedic replacement device infection algorithms [83], which, for example, strongly recommend determining the ESR and CRP, rigorous avoidance of any potential intraoperative contamination, and fluid aspiration and subsequent microbiological workup.

After failure of antibiotic or percutaneous drainage, in many cases, physicians attempt to salvage a patient's infected mesh through partial excision. Partial extraction of meshes has been advocated by some, driven by a belief that the remaining mesh can augment abdominal wall strength and that infection may be localized [62]. However, case reports indicate that there are significant complications with partial extraction, with over 60% of patients returning with wound complications and ongoing mesh infection [27, 84, 85]. Long-term salvage of an infected synthetic mesh is poor [55, 86], and the effects of chronic infection and inflammation have been associated with increased risks of cardiovascular disease, atherosclerosis, diabetes, and dementia [87]. Given the high ultimate failure rates and high complication rates in partial extraction, once mesh infection is identified, complete explantation should be attempted in patients who are good operative candidates and have feasible reconstruction options.

Conclusion

Increase in rates of obesity, diabetes, and resistant organisms poses further challenges for hernia surgeons. Mesh infection remains a costly and debilitating complication, and further studies are needed to confirm appropriate therapeutic strategies. Guidelines for treatment of mesh infections do not exist, but the type of bacteria, mesh, technique, and patient factors all influence outcomes and can help guide decision-making for this challenging group of patients. Incomplete removal of the mesh should be suspected in any case of persistent or recurrent signs of mesh infection, and complete excision when possible should be considered. Identifying patients at highest risk for infection, optimizing them before surgery, and making safe choices in the operating room when faced with known risk factors of mesh infection will help prevent infections. This in turn will prevent morbidity and save significant amounts of healthcare expenditures. Organized long-term follow-up for patients following a mesh implantation will help elucidate the optimal materials to use in various situations.

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Biographical Notes

Parviz Amid (1940-) *Director of Lichtenstein-Amid Hernia Institute. Fellow American College of Surgeons, Fellow Royal College of Surgeons of England, Fellow German Society of Surger*.

Parviz graduated from the University of Tehran School of Medicine in 1965 and undertook his residency at the Mount Sinai Hospital affiliated with Wayne State University and University of Michigan in 1972. He then entered private practice In Detroit until 1982 when he moved to Los Angeles where he joined the David Geffen School of Medicine at UCLA, later being appointed Professor of Clinical Surgery and Executive Director of the Lichtenstein-Amid Hernia Clinic at UCLA.

However, frustrated by the poor outcomes of hernia surgery, Parviz decided that making a difference in this field of surgery, plus his passion for the subject, necessitated limiting himself to abdominal wall surgery. This had a temporary but considerably negative effect on his financial situation, which committed him to penury for several years. Eventual success brought its just rewards to the three members of the Lichtenstein Institute—Irving Lichtenstein (q.v.), Alex Shulman and Parviz and international recognition followed. The decision by the Medical Faculty of UCLA to send residents for training at the Institute was the final seal of approval of the surgical fraternity.

Parviz was a founding member of the American Hernia Society, and through fundamental animal research, made the following contributions to the practice of Hernia surgery: described the optimal pore size of prosthetic materials to maximise tissue ingrowth; created and patented a bilaminar prosthesis that is incorporate into the abdominal wall and additionally preventing its adhesion to the intra- abdominal organs; demonstrate "shrinkage of mesh" and "meshoma" and its role in hernia recurrence; from cadavers described more precisely groin neuroanatomy and its role in postoperative inguinodynia; and thereby devised a one stage "triple neurectomy".

Since retirement and passing the reins of the Institute to one of the UCLA residents, Parviz has indulged his passion for philosophy, art, and music and studied at Wayne State University in Detroit and at UCLA.

Edoardo Bassini, MD (1844–1924) *Italian Senator; Professor of Surgical Pathology and subsequently of Clinical Surgery, University of Padua*.

Bassini travelled to receive postgraduate training in Vienna (Billroth), Berlin (Langenbeck), Munich (Nussbaum) and London (Lister) before embarking on a lifelong interest in applied anatomy. He advanced herniology in four important ways: (a) he ligated the peritoneal sac flush with the peritoneum; (b) he reconstructed the posterior wall of the inguinal canal, especially the fascia transversalis from the deep ring to the pubic tubercle, taking in the lateral margin of the rectus sheath medially; (c) he used non-absorbable (silk) sutures; (d) he performed adequate audit and follow-up of his patients—itself a major clinical advance. Bassini and his Italian pupils were quite explicit about his technique both in text and in diagram. Anyone seeking to check the anatomic details can refer to Catterina's English monograph. Bassini's reputation has suffered immensely at the hands of many English (and Irish) surgeons who have inadequately performed his operation and blamed him for their failure to read his work and follow his instructions. He appreciated the importance of the fascia transversalis and used non-absorbable sutures. Colleagues who neglect the fascia transversalis and use catgut should understand that they are not performing Bassini's operation.

Reinhard Bittner, PhD, MD, FRCS (1942-) *Director and Professor of Surgery of the Department of General and Visceral Surgery at Marienhospital Stuttgart, teaching hospital of the Medical University of Tübingen for 20 years, currently Director of the Hernia Center, Winghofer Medicum, Rottenburg. Founding President of the German Association of Minimal Invasive Surgery. Member of the Board of Directors of the German Society of Surgery and President of the German Society of General and Visceral Surgery*.

Reinhard Bittner was born in a small village east of the Oder river (today in Poland) as a son of a farmer who was killed in World War II. In 1945 together with his mother, brother and grandparents he had to leave his home and was settled in Eastern Germany, again in a small village north of Berlin. In 1959 he fled to Western Germany and finished High School in Frankenthal/Pfalz.

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Reinhard studied medicine at the University of Heidelberg and trained in General and Visceral Surgery at the University hospitals of Berlin and Ulm in gastrointestinal and pancreatic surgery. He is regarded as a leader in the field of laparoscopic surgery with over 60,000 laparoscopic procedures having been undertaken in his department. Patients (> 16,000 laparoscopic TAPP inguinal hernia repairs) during his 20 years as Chief of Surgery. All inclusive patient data has been recorded and analyzed with careful done follow-up. Standardization of the operation has greatly facilitated the popularization and teaching of the TAPP procedure, so that it can be routinely performed by all surgeons. His data has been widely published and he is regarded as the foremost expert and teacher of the TAPP operation, with numerous publications and a definitive textbook on the topic.

In 2008 he received the Rudolf Pichlmayer Medal, the highest award of German Society of General- and Visceral Surgery. In 2010 he received the Knight Cross awarded by the President of Germany.

Jean-Annet Bogros (1786–L825) Bogros was born in Messiex Auvergne, France, on 14 June 1786. He studied in Paris with Dupuymen and Bechard. In 1817 he was appointed Assistant in Anatomy. He obtained his MD in 1823. The doctoral thesis that established his name challenged and improved the technique of ligation of the epigastric and iliac vessels which had been put forward by Abernethy and Astley-Cooper. His thesis *Essai Sur L'Anatomie Chirurgicale De La Region lliaque* was published in 1823. Bogros' untimely death in 1825, probably of pulmonary tuberculosis, at the age of 39, deprived us of a fine pragmatic French surgeon.

Jean-Paul Chevrel (1933–2006) *Studied at the Faculty of Medicine of Paris, an dreceived postgraduate training at des Hôpitaux de Paris, and then entered the prestigious Laboratoire d'Anatomie de la Faculté Paris V to study anatomy. Attained the position of Attaché-Assistant and then Prosecteur d'Anatomie at the Faculty. In 1969 he became Assistant-Head of the Hospital and Head of Department and Professor in 1979. Until 1999 he was appointed Director of the General and Digestive Surgery Unit of the Avicenne Hospital in Bobigny, Paris. He was a member of and contributor to numerous scientific organisations*.

Chevrel made an enormous contribution to the globalization of hernia surgery. He was one of the Founders of the Groupe de Recherche et d'Etudes sur la Paroi Abdominale (GREPA) which in 1998 was re-named the European Hernia Society (EHS), and he subsequently created its official journal, *Hernia.*

As a teacher, he was renowned for his anatomy lectures, which depicted three-dimensional reconstructions of anatomical regions with blackboard and chalk. His enduring contribution to hernia surgery was his classic description of the onlay technique for repair of incisional hernias.

All who knew J-P Chevrel fell under the charm of his original and very endearing personality. Despite his sometimes misleading style and laid back cowboy allure, he was, as a matter of fact, a man of the utmost intellect.

William Bradley Coley, MD, Hon FRCS (1851–1936) *Surgeon-in-Chief, New York Hospital for Ruptured and Crippled*.

Much of Coley's surgical enterprise was to the management of bone sarcomas. By 1911 he was able to report successful management of 55 cases of inoperable sarcoma in which the tumour regressed after treatment. He used a mixed toxin (Coley's fluid), derived from erysipelas and *Bacillus prodigiosus*, and later combined with this X-ray therapy, Coley contributed to inguinal hernia surgerli reporting and following up techniques and –patients. Unfortunately he introduceJ suturing of the fascia transversalis ancl musculature lateral to the deep ring, "Coleyt stitch". This negated the sling/shutter mechanism of the deep ring and was inevitably followed by recurrence.

Abraham Colles, MD, FRCSI (1743–1833) *Professor of Anatomy, Physiology and Surgery to the Royal College of Surgeons in lreland and, subsequently twice President of that College; Surgeon to Dr. Steeven' Hospital, Dublin*.

Colles was educated at Trinity College, Dublin, and Edinburgh University. In 1797 he left Edinburgh to work as assistant to Astley Cooper (q.v.) at Guy's Hospital, London. He assisted Cooper in the dissections necessary for Cooper's monumentai work on hernias. There are many Colles eponyms—the fascia, the fracture, the law, the ligament and the space. 'We are concerned with the triangular ligament of Colles, known in moder:n nomenclature as the reflected part of the inguinal ligament: from the crest of the pubis, anteriorly to the insertion of the internal oblique and transversalis tendons, passing immediately behind the external abdominal tendon until it reaches the linea alba in which it terminates.

Astley Paston Cooper, Kt, FRCS, FRS (1768–1841) *Lecturer in Anatomy, Surgeons' Hall; Surgeon, Guy's Hospital; twice Hunterian Professor and twice President of the Royal Callege of Surgeons of England*.

In 1793, on the same day that Marie Antoinette was guillotined in Paris, Cooper was appointed Lecturer in Anatomy at Surgeons' Hall. This post entailed public dissections of recently executed criminals in the Old Bailey yard. Cooper performed well, was an entertaining lecturer and drew great crowds and much applause. In 1800 Cooper, now aged 32, was appointed to the staff at Guyst. In 1804 he published the first volume of his greatest work on hernias. He was assisted in the research and dissections for this by Abraham Colles (q.v.) who had come to London to study with him.

Hugh Brendan Devlin, CBE, MA, MD, MCh (Dublin), FRCS (England), FRCS (Ireland),FRCS (Edinburgh), FACS (1932–1998) *Consultant Surgeon, North Tees General Hospital, Stockton-on-Tees. Director, Surgical Epidemiology and Audit Unit, Royal College of Surgeons of England. Research Associate, Department of Surgery, University of Newcastle upon Tyne, Council Member, Royal College of Surgeons of England*.

Brendan pioneered the use of surgical audit. When he was appointed to Stockton-on-Tees in 1970 the hospital was run down and morale was low. Four years later, he commissioned the new North Tees General Hospital and worked hard to put it on the surgical map. This he did, by his reputation as a teacher and by his publications, which always dealt with common conditions. His first success was to organise better postoperative care for patients with colostomies. He became Chairman of the British Standards Institution Committee on Stoma Appliances and founded the British Colostomy Society.

Brendan's enduring interest however was in hernia and he was the most prominent exponent of the Shouldice tissue repair in the UK during the 1970s. Realizing that too often hernias were being repaired by partially trained juniors using techniques that had been proven to be inadequate, he set up a multi-centre audit of hernia surgery. This generated guidelines, innumerable publications and this classic textbook (initially a monograph), the second edition of which was written jointly with Andrew Kingsnorth (q.v.) and published shortly before his untimely death in 1998.

In 1982 together with John Lunn, Brendan set up the Confidential Enquiry into Perioperative Deaths (CEPOD). The study became a national one (NCEPOD), providing annual reports. The report on the management of emergency hernia surgery revealed preventable causes of perioperative deaths, such as lack of intensive therapy beds and lack of staff and resources at night. He was elected to the Council of the Royal College of Surgeons in 1986. There he set up and chaired the clinical audit committee. As Chairman of the examination committee he reformed FRCS examinations.

Brendan travelled widely to examine and to give lectures. He gave the Arris and Gale lecture in 1970, the Bradshaw lecture and oration in 1996, and a Hunterian oration in 1997. He was a member of many distinguished societies and on the editorial board of many prestigious surgical journals. He was appointed Commander of the British Empire (CBE) in 1994.

After his retirement he continued to work for the King's Fund on the commissioning of medical services in London and the organisation of audit.

Francis Sydney Alfred Doran, MD, FRCS (1910–1996) *Consultant Surgeon,. Worcester Hospital*.

Educated at Cambridge and Manchester Royal Infirmary Doran served in Burma during World War II. After the war he returned to Manchester where he was appointed Surgical Chief Assistant. He applied both anatomic and mathematical skills to the investigation of hernia repair techniques. He advocated the use of randomized trials in surgery and in the 1960s reported several trials using a thin, medium or heavy nylon net. The results were disastrous with a high incidence of chronic infection and sinus formation. This brought a deluge of criticism from the profession who largely abandoned the use of mesh in hernia surgery in the UK for the next two decades.

Eric Leslie Farquharson, MD FRCS Edin., FRCS Eng. (1905–1970) *Surgeon, Royal lnfirmary, Edinburgh. Council Member Royal College of Surgeons of England, and Edinburgh*.

Eric Leslie Farquharson was educated at Edinburgh Academy He obtained the FRCS Edin. in 1931 and MD in 1932.He then had a spell of postgraduate study in Paris, Vienna and Heidelberg. After War service in East Africa, Ceylon and India he returned to Edinburgh Royal Infirmary. He is most renowned for his textbook of operative surgery which first appeared in 1954 but which arose from his teaching of surgical anatomy. Many of the drawings were done by himself. His interest in hernia surgery with local anaesthesia arose from his experience of local anaesthesia for major abdominal surgery in Paris and his interest in early ambulation of hernia patients in the army in East Africa in 1940.

Alexander Hugh Ferguson (1853–1912) *Professor of Surgery, College of Physicians and Surgeons, Chicago*.

Ferguson was born in Ontario and qualified from the University of Toronto. He studied in London, Edinburgh and Berlin and then set up in surgical practice in Winnipeg in 1882. In 1894 Ferguson moved to Chicago and became a professor of surgery in the College of Physicians and Surgeons there. He was the first to abandon and openly speak out against the transposition of the cord advocated by Halsted.

Robert J. Fitzgibbons, Jr., MD, FACS (1949-) *Harry E. Stuckenhoff Professor and Chairman, Department of Surgery*.

Creighton University School of Medicine, Omaha, Nebraska, USA.

Bob Fitzgibbons was born in Omaha Nebraska and graduated from the Creighton University School of medicine in 1974. He did his surgical residency at Louisiana State University in New Orleans, followed by a Fellowship in general and oncological surgery at the Lahey Clinic in Boston. He returned to Creighton University in 1980 as an instructor in surgery, climbing through the ranks to ultimately attain the positions of endowed professor and Chairman of the department. His research efforts after returning to Creighton University focused initially on biliary tract issues but evolved into the developing field of minimally invasive surgery and therapeutic laparoscopic surgery especially as it relates to the management of the biliary tree and abdominal wall hernias.

Bob was Principle Investigator in two landmark randomized prospective multicenter trials dealing with the subject of inguinal hernia: (1)"Management of Groin Hernia: A multi-centered Clinical Trial", to determine if watchful waiting was a reasonable alternative to routine hernia repair for adult men with minimally symptomatic inguinal hernias. (2)" Tension-free Inguinal Hernia Repair: Comparison of Open and Laparoscopic Surgical Techniques". The results of these trials has greatly influenced the practice of hernia surgery.

Bob has held presidencies of the American Hernia Society and the Society of Laparoendoscopic Surgeons and is a member of numerous surgical societies including the American Surgical Association, and the Society of Surgeons of the Alimentary Tract. He has published widely and lectures regularly on subjects dealing primarily with minimally invasive surgery and abdominal wall reconstruction. He is currently Co-editor in Chief of the Journal "Hernia", The World Journal of Hernia and Abdominal Wall Surgery.

Henri Rene Fruchaud (1894–1960) *Professor of Clinical Surgery, Angers, Anjou, France*.

Fruchaud was a tiger who could work for hours on end. During World War I Fruchaud studied medicine in Paris and served as a corporal stretcher bearer and then as a *sous-aide-maior*, an assistant doctor at the front. After finishing his surgical training in 1924 he went on a world surgical tour of Germany (Berlin, Heidelberg and Hamburg), Austria (Vienna), England, Switzerland, Italy and Belgium. He was appointed professor of Surgery in 1937, his inaugural lecture 'Praise of Surgical Spirit' says all about him. He did not allow himself to be buried in the armistice of June 1940 so he joined DeGaulle in London and became chief surgeon of the *'Forces Francaises Libres'*. He served with elan during the War, in London, in Syria and in Italy. His written output covered five topics, surgical oncology and radiation therapy, the surgery of pulmonary tuberculosis, abdominal surgery war surgery and hernias. His 1956 books *L'Anatomie Chirurgical de la Region I'Aine* and *Le traitement Chirurgical des Hernies de I'Aine* were very important works on the anatomy and development of groin hernias. Fruchaud concept of the groin funnel, the abdomino-crural fascial funnel, through the myopectineal orifice drew together all the anatomy of the groin into one concept of repair.

William Edward Gallie, MD (Toronto), FRCS, FRCS (Canada), Hon FRCSE, FACS (1882–1959) *Professor of Surgery, Toronto; Hunterian Professor Royal College of Surgeons of England; President of theAmerican College of Surgeons*.

Gallie qualified from the University of Toronto in 1903and was only 39 when he was appointed Surgeon-in-Chief to Toronto Children's Hospital. Eight years later he was appointed Professor of Surgery in the University of Toronto. He developed the first co-ordinated surgical training scheme in Canada and in 1941, was elected President of the American College of Surgeons. Because of the War he held office for six strenuous years. Although he remained a general surgeon, his principal interests were in bone and joint surgeryand particularly in fascial healing. From 1921 to 1937 he published extensively on fascial grafts. With a colleague, Le Mesurier, he published his work on *'Living sutures in the treatment of Hernia'* in the Canadian Medical Journal. This description of the use of fascial strips on grafts in hernia repair was yery influential and was championed in Britain by Keynes.

Ralph Ger, MB. ChB, FRCS (1921-) *Professor of Surgery Albert Einstein College of Medicine 1973–84, later Professor of Surgery, SUNY Stony Brook, Chair of Surgery at Winthrop University Hospital, and Associate Chair of Surgery at Nassau County Medical Center*.

Ger was born in South Africa and graduated from the University of Cape Town Medical School in 1942. He served as a medical officer during World War II, following which he travelled to Britain for surgical training, and obtained the FRCS (England) and FRCS (Edin) in 1953. Returning to South Africa he held surgical appointments at the Groote Schuur hospital and allied hospitals. Becoming disillusioned with the political system of apartheid and losing favour with the authorities, these appointments were withdrawn. He decided to emigrated to the United States and in 1966 joined the surgery faculty of the Albert Einstein College of Medicine. He was a Founding Member of the American Association of Clinical Anatomists and one of the first co-editor of their journal, Clinical Anatomy.

In 1982 Ger proposed intraabdominal closure of the neck of the sac in certain abdominal hernias by application of metal clips. Later he published an experimental study with satisfactory results using a stapling instrument in dogs. A clinical study was then performed and reported in 1990. Accordingly Ger is attributed as the pioneer of laparoscopic hernia surgery.

Arthur I. Gilbert, MD, FACS (1932-) *In private practice at The Hernia Institute of Florida, Associate Clinical Professor University of Miami*.

Arthur Gilbert was born in Miami, Florida. Except for undergraduate study at Tulane University and a medical internship in Albany, NY he spent his entire life and career in Miami. After being a member of the second graduating class from the University of Miami Medical School in 1957, and straight medical internship at Albany Hospital, in 1962 he completed his general surgical training at the University of Miami, initially as a Clinical Instructor.

In 1976 Arthur visited the Shouldice Hospital in Toronto at the invitation of Dr. Nicholas Obney, its surgical director. That visit sparked Gilbert's future lifelong interest in abdominal wall hernia surgery. Over the following eight years by emulating the Shouldice approach and closely monitoring his results he recorded considerable improvement in his own surgical results. This revelation prompted him to make two important decisions: to organize the first ever three-day international symposium on hernia, and to give up his general surgery practice in favor of limiting his work to abdominal wall hernia surgery. In 1984, after evaluating presentations by Shockett and Lichtenstein at the first symposium, Advances and Improvements in Hernia Surgery (eventually there were five), Gilbert routinely incorporated a synthetic mesh patch in his repairs. This led him to use a mesh plug in the deep inguinal ring to repair indirect inguinal hernias, and eventually through the deep ring to accomplish his preperitoneal "sutureless repair". Gaining additional encouragement from Wantz and Stoppa he proffered a revised classification of inguinal hernias as a better communication tool and showed how the value of mesh repairs interfaced with the teachings of Fruchard's description of the potential defects in the multiple triangles of the myopectineal orifice.

As a consultant to Ethicon (Johnson & Johnson) he designed the Prolene Hernia System, a bi-layer connected mesh device and he organized and participated with other colleagues in multiple post-graduate hernia training programs. In 1997, along with eleven other surgeons he organized the American Hernia Society, a professional organization to promote teaching and research among surgeons worldwide and to provide for the formal association with multiple companies and industry in hernia work.

Arhtur retired from doing surgery in 2002 and turned the Hernia Institute of Florida over to Dr. Jerrold Young who has continued its successful operation. He continues to be involved in the benevolent work of Hernia Repair for the Underserved.

Frank Glassow, MD, FRCS, FRCS (Canada) (1917–2007) *Surgeon, Shouldice Hospital, Toronto, Canada; Hunterian Professor, Royal College of Surgeons of England*.

Glassow was educated at Cambridge University and Newcastle upon Tyne. During World War II he served with the 15th Scottish Infantry Division at the Normandy landings and afterwards in Northern Europe. After the war he joined the staff of Newcastle Royal Victoria Infirmary. He emigrated to Canada in 1952 and joined the staff of the Shouldice Hospital. A prolific author and lecturer, he has done much to increase awareness of the beneficial results of good surgery for all types of hernias.

Franz Kaspar Hesselbach, (1759–1816) *Hesselbach studied medicine at Wurzburg, working as a voluntary dissector at the Medical School. He revitalized the Anatomic Museum of the University*.

The area defined as Hesselbach's triangle is the home of the direct and external supravesical hernia; it has the inferior epigastric vessels as its superior or lateral border, the rectus sheath as its medial border, and the inguinal ligament as its latero-inferior border. This is the triangle as it is defined today, that originally described by Hesselbach was smaller. Hesselbach also described the so-called "corona mortis", a ring of vessels constituted by the epigastric artery and an aberrant obturator artery. Enlarged operations in cases of femoral hernia entail the risk of cutting it if dissection is conducted on nearby blood vessels.

Leif Israelsson, MD, PhD (1954-) *Associate Professor at the Department of Surgery and Perioperative Sciences at Umeå University 2001. Honorary member of the German Hernia Society 2014. Head of the Emergency Department at Sundsvall hospital (1995–2005). Head of the Department of Surgery, Urology and Oto-Rhino-Laryngology in the County of Västernorrland (2003—present)*.

Leif completed his surgical training at Sundsvall hospital (a teaching hospital of Umeå university, located on the east coast of northern Sweden) in 1985. He was accredited as Colorectal surgeon in 2000 and that year undertook an international trauma team training program in the Division of Traumatology and Critical Care at the University of Pennsylvania Medical Centre, Philadelphia, USA. His dissertation for the doctoral degree in 1995 was undertaken at the Department of Surgery, Lund University.

Leif's scientific focus has been on:

(1) Clarifying the role of suture technique in abdominal wall closure on the rate of subsequent complications. The outcomes of longitudinal clinical studies, randomizing nearly 2000 patients accessed through a midline incision, have been analyzed with long-term follow-up. These clinical trials, illustrated by parallel experimental animal studies, have shown that wounds should be closed with a suture-length-to-wound-length ratio of more than 4 (confirming a concept originally presented by TPN Jenkins [q.v.]), accomplished with small stitches. Other researchers have confirmed these results and this is now the recommended closure technique according to the Guidelines of the European Hernia Society.
(2) The use of a prophylactic mesh when constructing an end stoma. He performed the first randomized trial in Sundsvall (results since confirmed by others) and this technique has also become a recommendation in the Guidelines of the European Hernia Society.

Terence Percy Norman Jenkins, FRCS (1913–2007) *Surgeon to Guildford Hospitals, Surrey*.

Jenkins was educated at University College, London, and at University College Hospital. He served in the RAMC during World II. Jenkins' contribution to the understanding of fascial healing was gleaned from 27 years' experience of NHS hospital practice. His particular contribution was to the prevention of burst abdomen by the use of a continuous looped nylon suture, placed with centimetre bites, without tension, to achieve a suture-to-wound length of 4:1. The method had been introduced by Gordon Gill, his colleague, and the results were published in 1976.

Arthur Keith, Kt, FRS, DSc, MD, FRCS (1866–1955) *Curator of the Hunterian Museum, Royal College of Surgeons of England*.

Keith was born and received his initial education in Aberdeen. After qualifying, he first entered general practice in Mansfield. Then, seeking adventure, he went to Siam as medical officer to a gold mine. His work in Siam on the anatomy of Catarrhina monkeys brought him a Gold Medal.

After Siam he proceeded to University College, London, and thence to Leipzig for postgraduate experience. When he returned to England he launched his scientific career as anatomy demonstrator at the London Hospital. He was greatly interested in comparative anatomy, anthropology and embryology, subjects then fashionable and developing rapidly. In 1908 he was appointed Curator of the Hunterian Museum at the Royal College of Surgeons and remained in the post for 25 years. In May L941 the College was bombed, but Keith recovered the remains of the museum and built it up again after the War.

Geofftey Langton Keynes, Kt, MA, FRCS, FRCR FRCOG (1887–1982) *Surgeon, London Truss Society; Surgeon, St Bartbolomew's Hospital; Hunterian Professor, Royal College of Surgeons of England*.

The younger brother of the economist John Maynard Keynes, he became a scholar at Cambridge, where he took first-class honours, after which he read medicine at St Bartholomew's Hospital. During World War I he served in France and was mentioned in dispatches. His appointment as Surgeon ro the City of London Truss Society gave him a unique insight into working men and their problems with ruptures. He understood trusses and their disadvantages. Almost as a second life Keynes was a scholar, bibliophile, artist and litterateur. He wrote biographies of John Donne, John Evelyn, Bishop Berkeley and Williarn Blake and designed stage settings for Job. At the age of 90 he published his autobiography *The Gates of Memory*.

Irving Lichtenstein, MD, FACS (1920–2000) *Surgeon, Cedars-Sinai Hospital, Los Angeles*.

Lichtenstein received his medical training at Hahnemann Medical School, Pennsylvania. He founded the Lichtenstein Hernia Institute in Los Angeles in 1952 while a surgeon at the Cedars-Sinai Medical Center. His monograph in 1970 introduced four concepts: (1) hernia surgery can be performed as an outpatient procedure; (2) it is best performed by an experienced surgeon; (3) a 'tensionless' mesh procedure has enormous advantages; (4) local anaesthesia also has advantages. Early ambulation and return to unrestricted activity and labour is encouraged and brings economic advantages. In 1989 Lichtenstein reported 1000 consecutive cases without recurrence. He is considered an important and influential iconoclast.

Charles Barret Lockwood, FRCS (1856–1914) *Surgeon, St Bartholomew's Hospital; Hunterian Professor and Vice-President, Royal College of Surgeons of England*.

Lockwood was born in Stockton-on-Tees and attended Stockton Grammar School. After school he was apprenticed to a firm of surgeons in Stockton. ln 1874 he entered St Bartholomew's Hospital where he spent the remainder of his career, eventually retiring as a full surgeon in 1912. In 1914 he pricked his finger when operating for gangrenous appendicitis and died five weeks later from septicaemia.

George Lotheissen (1868–1941) *Surgeon at the Kaiser Franz Joseph Hospital, Vienna, Austria*.

Lotheissen was the first to recognise the entity of recurrent inguinofemoral hernia and the first surgeon to advocate the use of Cooper's ligament repair for recurrent femoral hernia (the Low Approach).

Just Lucas-Cbampionniere (1843–1913) *Studied medicine in Paris, receiving his medical doctorate in 1870. His career as a surgeon was associated with the hospitals Cochin, Lariboisière, Tenon, Saint-Louis, Beaujon and Hôtel-Dieu in Paris*.

Championniere's description in 1881 of incision of the external oblique, permitted complete exposure of the hernia sac, the cord and the inguinal floor, allowing dissection of indirect sacs to the deep internal ring and their differentiation from direct hernias. Total excision of the sac and visualization of the internal ring thus became possible.

William James Lytle, MB, FRCS (1896–1986) *Surgeon, Sheffield Royal lnfirmary*.

Lytle was born in Maghera, County Londonderry, and educated at Campbell College and Queen's University, Belfast. During World II he served in the Royal Navy. He was Consultant Surgeon, then Assistant Professor, then Postgraduate Dean in Sheffield. His work on the anatomy of the fascia tansversalis and, in particular, his fine colour film showing the "shutter mechanism" at the internal inguinal ring are very important contributions.

Charles Bidwell McVay, PhD, MD, FACS (1911–1987) *Professor of Surgery, University of south Dakota; Chief of Surgery, Yanktan Clinic, Yankton, Soath Dakota; Regent American College of Surgeons*.

McVay was born in Yankton, South Dakota, and initially educated there. He went to medical school in North Western University Chicago, and was a resident at the University of Michigan School of Medicine. He served in the US Army in Europe in World War II. McVay became Clinical Professor of Surgery and also Professor of Anatomy in the University of South Dakota. He was a Fellow of the American College of Surgeons. His contributions to the anatomy of the abdominal wall and herniology are numerous. Perhaps his most important contribution is his groin anatomy, based on the dissection of 500 body halves.

Rodney Honor Maingot, FRCS (1893–1982) *Surgeon, Royal Waterloo Hospital and Royal Free Hospital, London*.

Maingot was born in Trinidad of British parents and educated at Ushaw College, Durham. He studied medicine at St Bartholomew's in London and qualified with the conjoint diploma in 1916. He then joined the RAMC, serving in Egypt and Palestine, and was twice mentioned in dispatches. He returned to Bart's after the War and took the FRCS in 1920. He was appointed Consulting Surgeon to the Royal Waterloo Hospital and Southend General Hospital. Tn 1945 he joined the staff of the Royal Free Hospital. Maingot was a deft and meticulous surgeon whose major interest was in the abdomen. A prodigious writer and editor, his Abdominal Operations was first published in 1931 with himself as sole author. This classic textbook is still in print, but is now a multiauthor colossus. Sequential reading of thw editions will give a well-referenced and accurate summary of the development of each aspect of hemia surgery over the years.

Henry Orville Marcy, MD, AM, LLD (1837–1924) *Surgeon, Cambridge, Massachusetts; served in the Union Army 1861–65; President of the American Medical Association. Philanthropist*.

A graduate of Harvard, Marcy studied in Europe where he became a convert to Lister's doctrine of antisepsis and the use of carbolized catgut ligatures. He was the first surgeon to reconstruct the internal ring for inguinal hernia. "*In 1871 I first published two cases in which I closed the internal ring with interrupted sutures of carbolized catgut, followed by permanent cure*.' Marcy described his operation to the International Medical Congress in London in 1881 and Bassini (q.v,) was in the audience. Bassini improved on Marcy's technical advance by including division-reconstruction of the inguinal floor, and put to the test the innovative reconstruction of the fascia transversalis and the deep ring. Marcy's life was not only concerned with hernias; he was responsible for many civil engineering projects, including reclaiming the land to build the Massachusetts Institute of Technology and renovating the Charles River Basin in his native Cambridge, Massachusetts.

Austin Joseph Marsden, ChM, FRCS (1919–2004) *Surgeon, Liverpool and Ormskirk Hospitals; Research Associate, Liverpool University*.

Educated at Liverpool University, Marsden's contribution was to the follow-up and assessment of inguinal hernia results in the Liverpool hospitals during 1951–57. He had a long-standing interest in inguinal hernia and personally operated on, and followed up, over 3000 cases. His study of recurrent hernia using a "lace" technique, a relaxed *loose nylon darn* with meticulous technique, was a paradigm of observational and operative clinical surgery.

William James Mayo, MD (1861–1939) *Surgeon, Rochester, Minnesota*.

The brothers William and Charles Mayo, with their father, William Worall Mayo, were the triumvirate which founded The Mayo Clinic, Rochester, Minnesota.

William Mayo was born in Eccles, Lancashire, and studied medicine at Owen's.

College, Manchester. He emigrated to the USA and practised as a pioneer in Rochester. His sons, I7illiam James (born 1861) and Charles Horace (born 1865), qualified in medicine and devoted themselves to medicine, research and teaching. The Mayo Clinic was founded in 1894. They invested all their savings and energies in the enterprise, drawing a small salary only for themselves. \(hen the surgery in the clinic was divided up, Charles inclined to head and neck and prostatectomy and William to abdominal surgery. The brothers worked together all their lives and shared a common pocket notebook into which they wrote their share of day-to-day experiences and observations.

Erik Nilsson (1939-) *General surgeon Motala District Hospital* (1975–2005).

Erik received his surgical training in Linköping, Sweden and wrote a preclinical PhD thesis at the University of Lund. In 2005 he was appointed Professor of Surgery at the University of Umea. He was Head of the Swedish National Quality Register for Hernia Surgery, 1992–2003. Fellow of the Royal College of Surgeons of England.

Early in his career, Erik became interested in cost-utility of common surgical procedures, and found that results of hernia operations in general surgical practice differed significantly from outcomes reached by colleagues with particular interests in this field. Against this background he and collaborators initiated a National Quality Register for groin hernia surgery in 1992, and two Hernia Meetings with internationally well-known speakers were arranged in Motala. The register aimed to follow hernia surgery on a national basis concerning method of repair, postoperative complications and reoperation for recurrence, thereby stimulating local audit. Such a national register might facilitate epidemiological studies as each Swedish citizen (with due permission) can be followed through registers by means of a personal identity number. Initially eight hospitals participated in the register. In 2016, 98% of groin hernia operations performed in the country were recorded in the Swedish Hernia Register, www.svensktbrackregister.se. Through the register, the influence of patient gender, hernia anatomy, mode of admission, technique of operation may be scrutinized to the benefit of the ones most concerned, the hernia patients.

In 2007 in recognition of his lifetime contribution to medical science, Erik received the Ernst Reuterskiölds award of The Swedish Society of Medicine.

Lloyd Milton Nyhus, BA, MD, FACS (1923–2008) *Surgeon, Head of tbe Department of Surgery, University of lllinois College of Medicine; Surgeon-in-Chief,University of lllinois Hospital, Chicago. Chairman of the American Board of Surgery, President of the Central Surgical Association, President of the International Society of Surgery, President of the Chicago Surgical Society, President of the Society of University Surgeons, President of the Society for Surgery of the Alimentary Tract, First Vice President of the American College of Surgeons, First Vice President of the American Surgical Association, President of the Illinois Surgical Society, and President of the Warren H. Cole Society*.

Nyhus was born in Mt. Vernon, Washington, and gained his MD at the Medical College of Alabama in 1947. He did his surgical training at the University of Washington under his mentor, Dr. Henry Harkins, who ignited his interest in hernia and with whom he jointly edited, and subsequently inherited the influential textbook, *Hernia.*

Nyhus contributed extensively to the surgical literature on reflux oesophagitis and surgery of the stomach and duodenum, as well as on the subject of hernia. He was an important advocate of the preperitoneal approach to the groin; an important concept underpinning the management of recurrent groin hernia.

William Heneage Ogilvie, KBE, MCh, MD, FRCS (1894–1971) *Surgeon, Guy's Hospital, London; Hunterian Professor and Vice President of the Royal College of Swrgeons of England*.

Ogilvie was a powerful surgical character, imbued with a spirit of heterodoxy. He was a deft operator and skilled medical journalist. His views on hernia management were given full scope in World War II, during which he was Consulting Surgeon to the Mediterranean forces, with the rank of Major-General. His post-War book Hernia was the standard work of its day. Always outspoken, honest and combative, in 1949 while visiting the USA he caused consternation when he announced that he liked working in the British National Health Service.

Francois Poupart (1661–1708) *Obtained his doctorate in Reims, practiced for a period in the Hôtel-Dieu, and settled in Paris, where he became a member of the Académie des Sciences*.

Poupart was a surgeon-anatomist, naturalist and entomologist. In 1695 he gave an accurate description of the inguinal ligament The ligament had been previously described by Vesalius and Fallopius, and according to von Haller (1774), the description was neither original nor accurate, but the inguinal ligament is known throughout the world with his eponym.

Raymond Charles Read, MD, PhD, FRCS, FACS (1921–2016) *Surgeon-in-Chief, Veterans Administration Medical Center, and Professor of Surgery, Little Rock, Arkansas*.

Read was born in Beckenham, Kent. He was a Scholar at Cambridge, where he took his Tripos Part II in Anatomy and became interested in hernia. He was a Rockefeller Student at the University of Minnesota, where he received his surgical training. His studies of the causation of hernia, in particular his contributions on collagen failure, have led to the concept of 'metastatic emphysema'.

Jean Rives (1922–2012) *Chief of Surgery, Rheims University Hospital*.

Rives career began in Algiers, but due to civil unrest in 1962 he made the decision to leave the country. In 1964 he was appointed Chief of Surgery at Rheims University Hospital and founded a School of Surgery. He was a founding member with several other French surgeons of Groupe de Recherche et d'Etudes sur la Paroi Abdominale (GREPA). He was a highly innovative surgeon and between 1962 and 1966 developed an interest in hernia, developing three original operations:

1. Midline approach to inguinal hernias with placement of a "supple mesh" in the pre-peritoneal space. This technique was later popularised by Stoppa (q.v.) in France and by Wantz (q.v.) in America under the name of GPRVS (Giant Prosthetic Reinforcement of Visceral Sac).
2. Trans-inguinal approach to groin hernias with placement of a Mersilene mesh stitched to Cooper's ligament, which in recent years has been adopted by Schumpelick (q.v.) and given the name Trans Inguinal Pre-peritoneal Prosthesis (TIPP)
3. Retro muscular (sublay) prosthesis for the treatment of huge incisional hernias

These ideas more than any other have provided the basis for modern-day open hernia surgery. He was also active in disseminating this surgical knowledge through travel and the promotion of his faculty members to Chairs of Surgery throughout France.

Life was not always easy with Rives: he trained his residents like "commandos"—one of his favourite sayings was: "If the soldier is more frightened by the sergeant than by the enemy, he will win when facing the enemy". Rives was a good sergeant.

Volker Schumpelick (1944-) *Director of the Surgical University Clinic of RWTH Aachen University, Germany. President of the German Society of Surgery. President of the European Hernia Society*.

Born in Jena, Germany, Volker studied medicine between 1965 and 1970 in Munich, Berlin, Hamburg, Göttingen and New York, and qualified in Hamburg and entered completed his surgical training there in 1978 as a gastrointestinal surgeon. In 1985, he was appointed to the Chair of Surgery at the University Hospital of Aachen, which he held until his retirement in 2010.

Volker can be described as the outstanding European hernia surgeon of his generation, through his research, leadership and charisma. In addition to numerous scientific publications on hernia, Volker is a major contributor to the Konrad Adenauer Foundation's "Medical Ethics Law" series, which has been published for 10 years, in Cadenabbia, and since 2010 he has published three volumes of patient records under the title Unterm Messer and a volume of congress histories.

Of great international significant were the five Suvretta House meetings which he organized in Switzerland for the discussion of the State of the Art in hernia surgery from 1994 to 2008.

Volker has received many honours, including: Volkmann Medal 2010, Karl Schuchardt Medal 2011, Karl Schuchardt Bust 2013 (for his life's work).

Edward Earle Shouldice, MD (1890–1965) *Lecturer in Anatomy, University of Toronto*.

Shouldice was born in Ontario, Canada and graduated in medicine from the University of Toronto in 1916. He then served in the Canadian Forces in World War I. After the War he set up in private practice in Toronto and was appointed Lecturer in Anatomy in the University of Toronto. He became interested in hernia surgery during World War II when treating recruits for military service. After the war he opened a small private hospital for the surgical treatment of hernias, with the emphasis on local anaesthesia and early ambulation. He developed an eponymous tissue repair during the 1950s, which was first reported in the literature in the late 1960s. Since 1969 the hospital has moved to a large modern facility on the outskirts of Toronto. It has five operating theatres and several operating teams; 7000 hernia repairs are performed there annually. The Shouldice repair has become synonymous with the most effective inguinal hernia tissue repair and emulates the principles of Bassini's operation.

Maarten Simons, MD, PhD (1959-) *General and Trauma surgeon in OLVG Hospital Amsterdam. Specialist in abdominal wall surgery. Board member European Hernia Society. Coordinator Of the HerniaSurge Guidelines. Chairman of the Dutch Operation Hernia*.

Simons spent the best part of his youth in Spain and Tunesia. Thanks to a father in the Airlines business the family was in and out of airplanes travelling to all parts of the world. After a pilots training in the airforce he studied medicine in the University of Amsterdam and was trained as a surgeon in The Academic Medical Center and OLVG Hospital in Amsterdam and followed a fellowship in Seattle. During his surgical training he was enrolled in the first teaching programmes of evidence- based medicine in the Sackett school. He used this expertise to perform an RCT comparing a modified Bassini and a modified Shouldice operation. He authored the first systematic review on non mesh inguinal hernia repairs, concluding that Shouldice was probably the gold standard. Travels to the Shouldice Hospital and the Lichtenstein Hernia Institute started the contacts and friendships with the Hernia family. Attending the Suvretta meetings inspired him to dedicate his scientific career to abdominal wall surgery. This launched his career as an expert in the development of guidelines. He subsequently chaired the Dutch Guidelines in 2003, followed by the European Guidelines in 2009 and the International Guidelines in 2017. Bringing together hernia surgeons from around the world and improving quality of care is what really drives him. Whenever possible he uses magic to get things done. He was on 8 missions to Ghana with Operation Hernia teams and together with more than 30 surgeons has supervised more than 1000 operations in 8 different hospitals in Ghana.

René Stoppa (1921–2006) *Professor of Clinical Studies, University of Amiens Faculty of Medicine (Jules Verne University of Picardy) and Professor Emeritus and honorary Surgeon-in-Chief.*

Stoppa was born in a small fishing village of the Constantinois, and received his medical training at the University of Algiers' Faculty of Medicine (the only French University on the African continent). From 1942 to 1945 he enlisted as a volunteer in WWII and was assigned to active duty in France's First Army. After the War he resumed his post at the University and taught anatomy. In 1950, he was appointed intern in Paris Hospitals and in 1954 qualified in general surgery. By 1962 he was Chief of the Surgical Service of the University of Algiers Surgical Center. Civil unrest however prompted him to emigrate to France and in 1965 he was appointed surgeon-in-chief to the surgical service of the University of Amiens and in 1967 he became Professor of Clinical Studies.

In 1965, he designed, developed, and disseminated a personally developed technique in hernia repair—wrapping of the visceral (hernia) sac with a large synthetic sheet through a midline pre-peritoneal approach applicable to multiple recurrent groin hernias and incisional hernias. Several thousand cases of such hernias have been the subject of French and international publications.

He created the school of surgery of the University of Amiens and directed its teaching programs, with the objective of instituting national degrees in general surgery and, subsequently gastrointestinal surgery. He led and was associated with numerous scientific societies and in 2005 he was awarded the distinction of Honorary Member of the French Surgical Association, an exceptional honour awarded to French citizens. He had taught that a career could succeed only by application of hard work and not by a strict search for honours.

Ravindranath Rangnath Tongaonkar, MS (1939-) *Rural Surgeon. Founder member and Past-President, of Association of Rural Surgeons of India (ARSI), and International Federation of Rural Surgery (IFRS).*

Ravi was born and brought up in a small tribal town in a remote region of the state of Maharashtra, India, he pursued his medical education in B. J. Medical College, Pune. He had unbeaten academic career standing first in all the three MBBS Examinations and MS examination. Instead of settling in a big city, in 1967, he opted to settle in his native state, serving the poor, downtrodden masses.

In the year 2000, taking a clue from another Indian rural surgeon, Brahma Reddy, who was using mosquito-net (thinking it was nylon) for repair of hernia, Ravi undertook a detailed scientific study of the net, which later analysis proved it to be 'Low Density Polyethylene (LDPE). This net (LDPE mesh) could be bought in the local market, autoclaved and sterilized and was 4000 times cheaper than the commercial mesh.

Since year 2003 Tongaonkar started using LDPE mesh for all types of hernias and kept detailed records. He encouraged many Indian surgeons to use this mesh, sending it free of cost and collected data from over 30 centers, and 5 medical colleges which carried out clinical trials of using this mosquito-net mesh comparing with commercial costly meshes. The findings were published in the Indian Journal of Surgery. He then started presenting papers in many National and International conferences.

The turning point occurred in 2009, when Ravi was invited by Andrew Kingsnorth (q.v.), to present his paper in 4th World Congress of Hernia Surgery in Berlin. Together with Kingsnorth they started popularize the use of LDPE mesh in other low- and middle-income countries, by using the large quantities of mesh supplied by Ravi, free of cost, for the "Hernia International" missions in more than 28 countries. There were many publications in various International journals on the usefulness of LDPE mesh. This innovation was given first prize in the World Innovation Summit on Health (WISH) held in Doha (Qatar) in 2013.

Francis Cowgil Usher, MD (1908–1980) *Usher received his undergraduate degree from the University of Texas in 1930. After a residency in general surgery in 1940 at the Mayo Clinic, he served as an army surgeon in Germany and England as a Lieutenant Colonel from 1940–1945. In 1946 he moved to Houston, Texas as a general surgeon in private practice and joined the faculty at Baylor College of Medicine as a clinical associate professor in 1949*.

With his co-worker Wallace, Usher carried out extensive animal and clinical research to create a surgical mesh that would resist rigidity, fragmentation, loss of strength, and foreign body rejection. In 1958 they presented their observations with Marlex 50, a high density polyethylene (HDPE) material. Usher later patented a derivative of Marlex 50 mesh and a monofilament suture. Irving Lichtenstein (q.v.) used this material in the early years at his Institute, later converting to Prolene (polypropylene).

Cecil Pembrey Greay Wakeley, Bart., KBE, CB, DSc, FRCS (1882–1979) *Consultant Surgeon, King's College Hospital; Surgeon Rear Admiral, Royal Navy, President, Royal Callege of Surgeons of England*.

Wakeley served in the Royal Navy in both World Wars. During World War I he treated large numbers of burned men after the Battle of Jutland. He initiated treatment by exposure and early skin grafting and produced convincing evidence of the detrimental effects of the picric acid treatment, then in vogue as a first aid measure. During World War II he served as Rear Admiral in charge of surgical services at the Royal Naval Hospital, Haslar. An enthusiastic anatomist, he was, for 50 years' an anatomy teacher at King's College in the Strand. He was Consultant Surgeon at King's College Hospital from 1922 until his retirement in 1957. As Vice-President and then President of the Royal College of Surgeons of England he was the guiding hand behind the rebuilding of the Lincoln's Inn Fields premises after the War. He was Editor of the Annals for 20 years and Editorial Secretary of the British Journal of Surgery for 30 years! A prolific and enthusiastic surgical journalist, he contributed many articles on hernia, his most typical—combining anatomy with clinical observation and operative technique—being his classic on obturator hernia.

George E. Wantz, MD (1923–2000) *Clinical Professor of Sursery, Cornell University Medical College. Attending Surgeon The Nwi York" Hospital-Cornell Medical Center, New York, New York*.

Wantz was a founding member of the American Hernia Society. He was an advocate of the Shouldice (q.v.) operation and an early adopter of same-day discharge after hernia repair, local anesthesia for groin hernia repair and the use of mesh for recurrent groin and primary or recurrent incisional hernias. He introduced Rives' (q.v.) retro-rectus repair into the United States and helped to popularise the Lichtenstein (q.v.) repair by reporting a personal series of 1000 cases. His *Atlas of Hernia Surgery (1991)* is arguably the most beautifully illustrated (by Caspar Henselmann) hernia text to be produced and as such an irreplaceable teaching tool. It has been said that he taught a generation of American surgeons the art and science of modern hernia repair.

Karl Ziegler, PhD (1898–1973) *Director Max-Planck-Institute, 1949–1963*.

Ziegler was born in Helsa, Germany. He studied chemistry at University of Marburg, graduating in 1920 with a PhD. Only 3 years later, he published his landmark work "About the knowledge of the trivalent carbon—about tetra aryl-allyl radicals and their derivate"; with this work, Karl Ziegler had achieved the synthesis of the first free carbon radical.

In 1926, he was appointed director of the Institute of Chemistry at the Halle/Saale University and succeeded in developing "controlled polymerization". In 1943, he was appointed as director of the Kaiser-Wilhelm-Institute for Carbon Research (Kohlenforschung) and in 1949 assumed directorship of the illustrious Max-Planck-Institute. It was here that he succeeded in producing a high density polyethylene (HDPE), as opposed to the softer low density polyethylene (LDPE) produced by Imperial Chemical Industries (ICI) in England. In 1954 he patented his invention of HDPE, polypropylene and 1-Buten. In parallel. Giulio Natta, Piero Pino, and Giorgio Mazzanti filed two patents for their production of polypropylene. Ziegler and Natta together received the Nobel Prize for Chemistry in Stockholm in 1963. Their patents expired in 1995.

Today, more than 40 million tons of polypropylene and 30 million tons of polyethylene are produced annually worldwide. Hernia surgery has been a beneficiary—after a short episode with Marlex (HDPE), polypropylene rapidly found its way into clinical practice at the beginning of the 1960s.

Index

K.A. LeBlanc et al. (eds.), *Management of Abdominal Hernias*, https://doi.org/10.1007/978-3-319-63251-3