The SAGES University Masters Program Series
Editor-in-Chief: Brian Jacob

The SAGES Manual of Hernia Surgery

Second Edition

S. Scott Davis Jr.
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SAGES University MASTERS PROGRAM: Hernia Pathway

1

Daniel B. Jones, Linda Schultz, and Brian Jacob

The MASTERS Program organizes educational materials along clinical pathways into discrete blocks of content which could be accessed by a surgeon attending the SAGES annual meeting or by logging into the online SAGES University (Fig. 1.1) [1]. The SAGES MASTERS Program currently has eight pathways including: Acute Care, Biliary, Bariatrics, Colon, Foregut, Hernia, Flex Endoscopy, and Robotic Surgery (Fig. 1.2). Each pathway is divided into three levels of targeted performance: Competency, proficiency, and mastery (Fig. 1.3). The levels originate from the Dreyfus model of skill acquisition [2], which has five stages: novice, advanced beginner, competency, proficiency, and expertise. The SAGES MASTERS Program is based on the three more advanced stages of skill acquisition: competency, proficiency, and expertise. Competency is defined as what a graduating general surgery chief resident or MIS fellow should be able to achieve; proficiency is what a surgeon approximately 3 years out from training should be able to accomplish; and mastery is what more experienced surgeons should be able to accomplish after several years in practice. Mastery is applicable to SAGES surgeons seeking in-depth knowledge in a pathway, including the following: Areas of controversy, outcomes, best practice, and the ability to mentor colleagues. Over time, with the

Adopted from Jones, DB, Stefanidis D, Korndorffer JR, Dimick JB, Jacob BP, Schultz L, Scott DJ, SAGES University Masters Program: a structured curriculum for deliberate, lifelong learning. Surg Endoscopy, 2017, in press.

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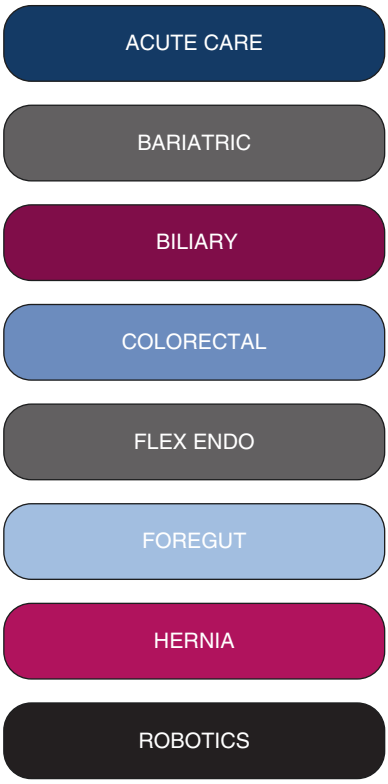
Fig. 1.1 MASTERS Program logo

Fig. 1.2 MASTER Program clinical pathways



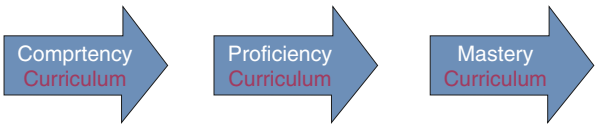


Fig. 1.3 MASTERS Program progression

utilization of coaching and participation in SAGES courses, this level should be obtainable by the majority of SAGES members. This edition of the SAGES Manual—Hernia Surgery aligns with the current version of the new SAGES University MASTERS Program Hernia Surgery pathway (Table 1.1).

Table 1.1 Hernia surgery curriculum

Curriculum elements	Competency
Anchoring Procedure—Competency	2
CORE LECTURE	1
CORE MCE 70%	1
Annual meeting content	2
Guidelines	1
SA CME Hours	6
Sentinel articles	2
Social Media	2
SAGES Top 21 video	1
FLS	12
PEARLS	1
Hernia task force tool	2
Sages manual	2
CREDITS	**35**

Curriculum elements	Proficiency
Anchoring Procedure—Proficiency	2
CORE LECTURE	1
CORE MCE 70%	1
Annual meeting content	5
FUSE	12
Outcomes database enrollment	2
SA CME Hours (ASMBS electives, SAGES or SAGES-endorsed)	6
Sentinel articles	2
Social Media	2
SAGES Top 21 video	1
PEARLS	1
CREDITS	**35**

Curriculum elements	Mastery
Anchoring Procedure—Mastery	2
CORE LECTURE	1
CORE MCE 70%	1
Annual meeting content	6
Fundamentals of Surgical Coaching	4
Outcomes database reporting	2
SA CME Credits (ASMBS electives, SAGES or SAGES-endorsed)	6
Sentinel articles	2
Serving as video assessment reviewer and providing feedback (FSC)	4
Social Media	6
SMART Enhanced Recovery	1
CREDITS	**35**

Hernia Surgery Curriculum

The key elements of the Hernia Surgery curriculum include a core lectures for the pathway, which provides a 45 min general overview including basic anatomy, physiology, diagnostic workup, and surgical management. As of 2018. all lecture content of the annual SAGES meetings are labeled as follows: Basic (100), intermediate (200), and advanced (300). This allows attendees to choose lectures that best fit their educational needs. Coding the content additionally facilitates online retrieval of specific educational material, with varying degrees of surgical complexity, ranging from introductory to revisional surgery.

SAGES identified the need to develop targeted, complex content for its mastery level curriculum. The idea was that these 25 min lectures would be focused on specific topics. It assumes that the attendee already has a good understanding of diseases and management from attending/watching competency and proficiency level lectures. Ideally, in order to supplement a chosen topic, the mastery lectures would also identify key prerequisite articles from *Surgical Endoscopy* and other journals, in addition to SAGES University videos. Many of these lectures will be forthcoming at future SAGES annual meetings.

The MASTERS Program has a self-assessment, multiple choice exam for each module to guide learner progression throughout the curriculum. Questions are submitted by core lecture speakers and SAGES annual meeting faculty. The goal of the questions is to use assessment for learning, with the assessment being criterion-referenced with the percent correct set at 80%. Learners will be able to review incorrect answers, review educational content, and retake the examination until a passing score is obtained.

The MASTERS Program Hernia Surgery curriculum taps much of the SAGES existing educational products including FLS, FUSE, SMART, Top 21 videos, and Pearls (Fig. 1.4). The Curriculum Task Force has placed the aforementioned modules along a continuum of the curriculum pathway. For example, FLS, in general, occurs during the Competency Curriculum, whereas the Fundamental Use of Surgical Energy (FUSE) is usually required during the Proficiency Curriculum. The Fundamentals of Laparoscopic Surgery (FLS) is a multiple choice exam and a skills assessment conducted on a video box trainer. Tasks include peg transfer; cutting; intracorporeal and extracorporeal suturing; and knot tying. Since 2010, FLS has been required of all US general surgery residents seeking to sit for the American

Fig. 1.4 SAGES educational content: FLS, FUSE, SMART

Board of Surgery qualifying examinations. The Fundamentals of Endoscopic Surgery (FES) assesses endoscopic knowledge and technical skills in a simulator. FUSE teaches about the safe use of energy devices in the operating room and is available at FUSE.didactic.org. After learners complete the self-paced modules, they may take the certifying examination.

The SAGES Surgical Multimodal Accelerated Recovery Trajectory (SMART) Initiative combines minimally invasive surgical techniques with enhanced recovery pathways (ERPs) for perioperative care, with the goal of improving outcomes and patient satisfaction. Educational materials include a website with best practices, sample pathways, patient literature, and other resources such as videos, FAQs, and an implementation timeline. The materials assist surgeons and their surgical team with implementation of an ERP.

Top 21 videos are edited videos of the most commonly performed MIS operations and basic endoscopy. Cases are straightforward with quality video and clear anatomy.

Pearls are step-by-step video clips of ten operations. The authors show different variations for each step. The learner should have a fundamental understanding of the operation.

SAGES Guidelines provide evidence-based recommendations for surgeons and are developed by the SAGES Guidelines Committee following the Health and Medicine Division of the National Academies of Sciences, Engineering, and Medicine standards (formerly the Institute of Medicine) for guideline development [3]. Each clinical practice guideline has been systematically researched, reviewed, and revised by the SAGES Guidelines Committee and an appropriate multidisciplinary team. The strength of the provided recommendations is determined based on the quality of the available literature using the GRADE methodology [4]. SAGES Guidelines cover a wide range of topics relevant to the practice of SAGES surgeon members and are updated on a regular basis. Since the developed guidelines provide an appraisal of the available literature, their inclusion in the MASTERS Program was deemed necessary by the group.

The Curriculum Task Force identified the need to select required readings for the MASTERS Program based on key articles for the various curriculum procedures. Summaries of each of these articles follow the American College of Surgeons (ACS) Selected Readings format.

Facebook™ Groups

While there are many great platforms available to permit online collaboration by user generated content, Facebook(™) offers a unique, highly developed mobile platform that is ideal for global professional collaboration and daily continuing surgical education (Fig. 1.5). The Facebook groups allow for video assessment, feedback, and coaching as a tool to improve practice.

Based on the anchoring procedures determined via group consensus (Table 1.2) participants in the MASTERS Program will submit video clips on closed Facebook

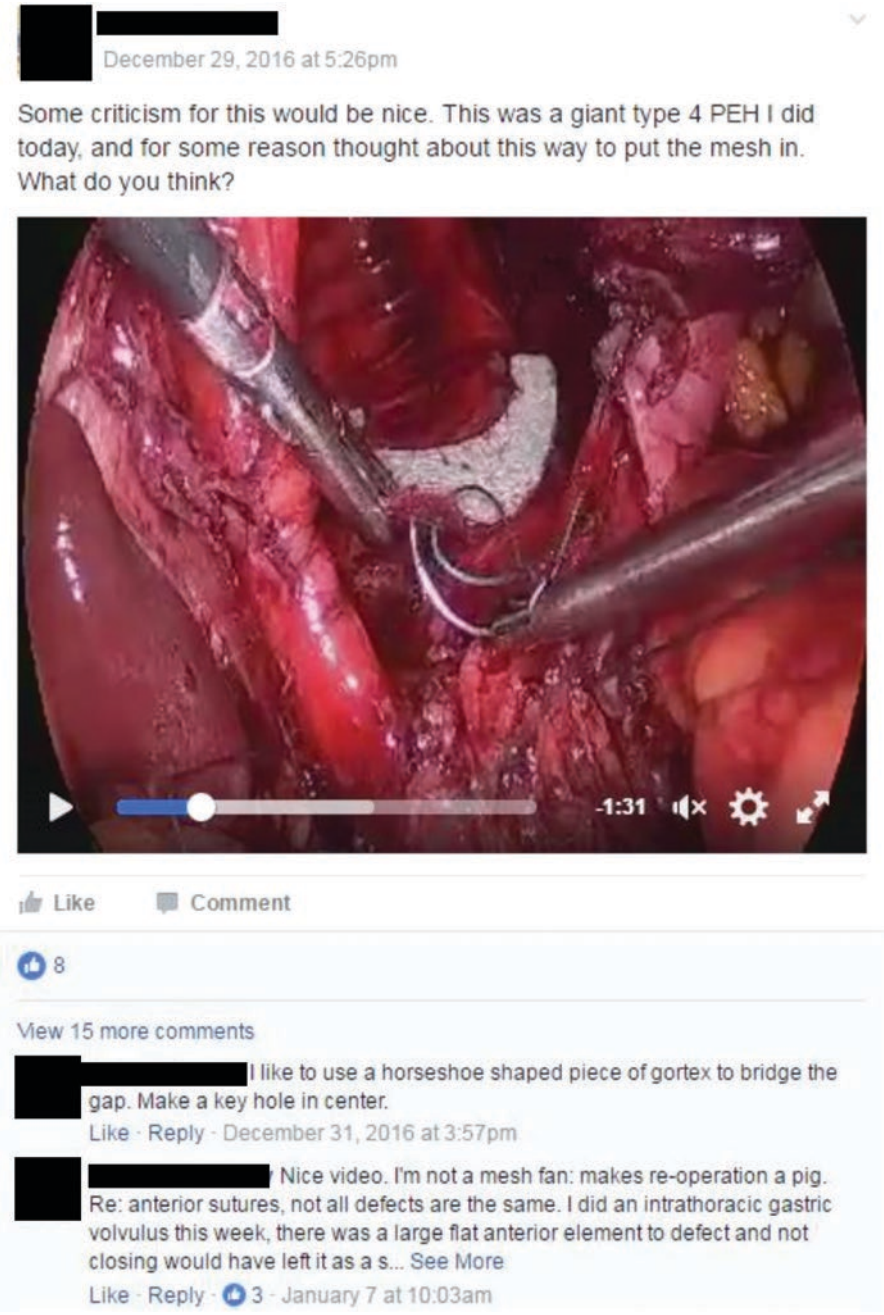


Fig. 1.5 Hernia Facebook group

Table 1.2 Anchoring procedures for Hernia Pathway

Anchoring procedure by pathway	Level
FOREGUT SURGERY	
Lap ventral hernia repair	Competency
Lap inguinal hernia repair	Proficiency
Lap redo inguinal	Mastery

Fig. 1.6 SAGES Robot Facebook group

groups, with other participants and/or SAGES members providing qualitative feedback. For example, for the Hernia Curriculum, surgeons would submit the critical views during a laparoscopic inguinal hernia repair with identification of the direct, indirect, and femoral hernia and triangle of pain. Using crowdsourcing, other surgeons would comment and provide feedback.

Eight, unique vetted membership-only closed Facebook groups were created for the MASTERS Program, including a group for bariatrics, hernia, colorectal, biliary, acute care, flexible endoscopy, robotics, and foregut. The Hernia Surgery Facebook group is independent of the other groups and will be populated only by physicians, mostly surgeons or surgeons-in-training interested in abdominal and inguinal hernia surgery (Fig. 1.6).

The group provides an international platform for surgeons and healthcare providers interested in optimizing outcomes in a surgical specialty to collaborate, share, discuss, and post photos, videos, and anything related to a chosen specialty. By embracing social media as a collaborative forum, we can more effectively and transparently obtain immediate global feedback that potentially can improve patient outcomes, as well as the quality of care we provide, all while transforming the way a society's members interact.

For the first two levels of the MASTERS Program, Competency, and Proficiency, participants will be required to post videos of the anchoring procedures and will receive qualitative feedback from other participants. However, for the mastery level, participants will submit a video to be evaluated by an expert panel. A standardized video assessment tool, depending on the specific procedure, will be used. A benchmark will also be utilized to determine when the participant has achieved the mastery level for that procedure.

Once the participant has achieved mastery level, he/she will participate as a coach by providing feedback to participants in the first two levels. MASTERS Program participants will therefore need to learn the fundamental principles of surgical coaching. The key activities of coaching include goal setting, active listening, powerful inquiry, and constructive feedback [5, 6]. Importantly, peer coaching is much different than traditional education, where there is an expert and a learner. Peer coaching is a "co-learning" model where the coach is facilitating the development of the coachee by using inquiry (i.e., open-ended questions) in a noncompetitive manner.

Surgical coaching skills are a crucial part of the MASTERS curriculum. At the 2017 SAGES Annual Meeting, a postgraduate course on coaching skills was developed and video recorded. The goal is to develop a "coaching culture" within the SAGES MASTERS Program, wherein both participants and coaches are committed to lifelong learning and development.

The need for a more structured approach to the education of practicing surgeons as accomplished by the SAGES MASTERS Program is well recognized [7]. Since performance feedback usually stops after training completion and current approaches to MOC are suboptimal, the need for peer coaching has recently received increased attention in surgery [5, 6]. SAGES has recognized this need and its MASTERS Program embraces social media for surgical education to help provide a free, mobile, and easy to use platform to surgeons globally. Access to the MASTERS Program groups enables surgeons at all levels to partake in the MASTERS Program Curriculum and obtain feedback from peers, mentors, and experts. By creating surgeon-only private groups dedicated to this project, SAGES can now offer surgeons posting in these groups the ability to discuss preoperative, intraoperative, and postoperative issues with other SAGES colleagues and mentors. In addition, the platform permits transparent and responsive dialogue about technique, continuing the theme of deliberate, lifelong learning.

To accommodate the needs of this program, SAGES University is upgrading its web-based features. A new learning management system (LMS) will track progression and make access to SAGES University simple. Features of the new IT infrastructure will provide the ability to access a video or lecture on-demand in relation to content, level of difficulty, and author. Once enrolled in the MASTERS Program, the LMS will track lectures, educational products, MCE, and other completed requirements. Participants will be able to see where they stand in relation to module completion and SAGES will alert learners to relevant content they may be interested in pursuing. Until such time that the new LMS is up and running, it is hoped that the SAGES Manual will help guide learners through the MASTERS Program Curriculum.

Conclusions

The SAGES MASTERS Program HERNIA SURGERY PATHWAY facilitates deliberate, focused postgraduate teaching and learning. The MASTERS Program certifies completion of the curriculum but is NOT meant to certify competency, proficiency or mastery of surgeons. The MASTERS Program

embraces the concept of lifelong learning after fellowship and its curriculum is organized from basic principles to more complex content. The MASTERS Program is an innovative, voluntary curriculum that supports MOC and deliberate, lifelong learning.

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Laparoscopic Ventral Hernia Repair

2

Alisa M. Coker and Gina L. Adrales

Laparoscopic ventral hernia repair (LVHR) was developed as a minimally invasive approach to the gold standard Rives-Stoppa repair. The Rives-Stoppa repair revolutionized abdominal wall reconstruction by markedly decreasing hernia recurrence with widely overlapping retromuscular mesh [1]. The first description of laparoscopic ventral herniorrhaphy was published by LeBlanc in 1993 [2]. By 1999, there were 40 manuscripts highlighting this advance in hernia repair and several comparative analyses noting reduced hospitalization and a decrease in wound complications and surgical site infection [3]. However, it was not until after 2000 that the technique was popularized with the publication by Heniford, Park, Ramshaw, and Voeller of a large multicenter series of laparoscopic ventral hernia repairs with a low complication rate and hernia recurrence rate of 3.4% [4]. While the landscape of ventral hernia repair has shifted remarkably since that landmark publication due to increasing patient complexity, obesity, and innovative technology, laparoscopic ventral hernia repair continues to play a major role in the care of ventral hernia patients.

Patient Selection and Preparation

The laparoscopic approach may be applied broadly to both initial and recurrent ventral and incisional hernias. Specifically, its benefits have been shown in the obese patient population among whom open repair is associated with a higher rate of wound complications and infection [5].

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A repair that is satisfactory for both surgeon and patient requires preoperative discussion of the patient's goals for repair. If skin excision is needed or primary fascial closure is not feasible for the patient lacking truncal support, a laparoscopic approach is not optimal. Other relative contraindications include contaminated cases and prohibitive intraperitoneal adhesions in the multiply recurrent incisional hernia patient.

Preoperative evaluation includes a comprehensive history and physical exam and review of prior operative reports. Knowledge of previous component separation, enterotomies, mesh type and positioning, and mesh fixation is critical for preoperative planning. Computed Tomography is a useful adjunct for most patients to assess the size and location of the hernia defect, proximity to bony structures, bowel involvement, and loss of domain. Imaging is particularly important for atypical ventral hernias, located away from the midline such as parastomal and subxiphoid hernias.

Modifiable risk reduction to improve perioperative outcomes and hernia recurrence is advisable in the elective setting. This includes smoking cessation, weight loss for patients with morbid obesity, glycemic control, treatment of chronic skin conditions, and MRSA clearance [6–9]. In the authors' experience, this is best achieved in partnership with the patient with utilization of educational resources and support from nurse educators, dieticians, and health coaches. Postoperative complications are an independent risk factor for hernia recurrence after laparoscopic hernia repair [10]. While not always possible in the setting of escalating hernia symptoms, such prehabilitation may break the "vicious cycle" of hernia repair complications and hernia recurrence [11].

Operative Setup and Instrumentation

Laparoscopic ventral hernia repair can be ergonomically challenging. Alignment of the surgeon, camera, and target anatomy will facilitate an efficient operation. As the majority of ventral hernias are located in the midline, the surgeon and assistant typically should stand at the patient's side and view the monitor on the opposite side of the patient (Fig. 2.1). Tucking both arms affords greater mobility of the surgeon about the patient and operative field. This includes moving to the contralateral side when needed for mesh fixation while avoiding working against the camera which can be difficult and time-consuming. All of the ventral hernias can be approached in this fashion, though one may consider lower abdominal port placement and surgeon placement between the split legs of the patient for the subxiphoid hernia. Likewise, mid- to upper abdominal port placement with the camera view of the pelvis is a more favorable ergonomic setup for the isolated suprapubic hernia, though the patient's chest may limit the range of motion of the instruments. Flexion of the table may ameliorate that limitation.

Standard sterile draping is used but should provide a wide operative field. This allows lateral port placement with adequate distance between the hernia defect and the ports. This also provides flexibility should additional ports be needed to conduct

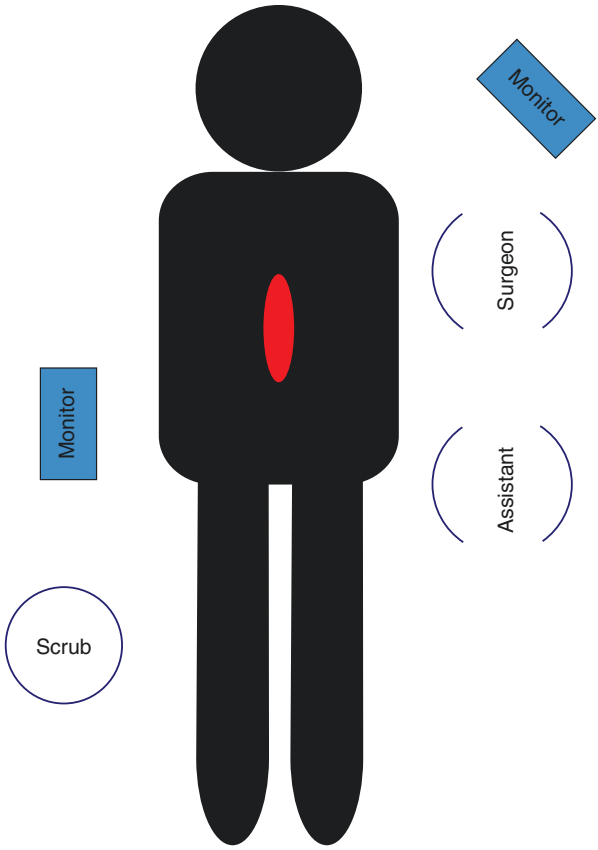

Fig. 2.1 Operative setup for laparoscopic ventral hernia repair of a midline incisional hernia

extensive adhesiolysis. Additional hernia defects are often discovered during the procedure, and a wide sterile prep ensures adequate space for working port placement away from the defects. A sterile occlusive drape may be used. While there is no evidence to suggest that this drape decreases the risk of surgical site infection, it facilitates mapping out the defect and mesh sizing on the drape and avoidance of contact of the mesh with the skin.

Laparoscopic ventral hernia repair requires a modest amount of instrumentation. Use of a 5 mm angled laparoscope allows movement of the laparoscope to various ports to maintain the best ergonomic advantage during adhesiolysis, mesh insertion, and mesh fixation. Basic instrumentation includes two to three blunt, bowel-safe, graspers, laparoscopic Metzenbaum scissors with monopolar cautery, and a suture passer. Finer grasper, clip applier, and suction/irrigation devices are useful secondary instruments. The selection of a more advanced electrosurgical instrument is based on the discretion and experience of the operating surgeon. Ultrasonic dissection is helpful in subxiphoid hernia repair in taking down the falciform ligament which is often associated with bleeding.

Abdominal Access and Port Placement

The method of abdominal access is based primarily on surgeon experience and preference. There is no substantial advantage of either closed Veress or Hasson open-access technique. Vascular and intestinal injuries can occur with either method [12, 13]. Optical trocar access without pre-insufflation is another option. The first site of peritoneal access should be made in an area away from previous incisions. For the Veress technique, Palmer's point below the left costal margin is the safest area of placement [14]. Ensuring full muscle relaxation and gastric decompression prior to insertion is important to lessen the risk of visceral injury. After access is established along with the first trocar placement, the abdomen should be inspected for bleeding and visceral injury, both of which would warrant further laparoscopic exploration or conversion to laparotomy if needed.

A minimum of three trocars are placed. For the midline hernia defect, three lateral trocars along the anterior to mid-axillary line are used including two 5 mm ports and one larger 10–12 mm port through which the mesh will be inserted. Alternatively, the larger trocar may be placed closer to or within the defect to allow coverage of the site with mesh. While caution should be exercised with assessment of the quality of the skin overlying the hernia defect for closure of the central port site, this method addresses the risk of trocar site hernia. The incidence of trocar site hernia, particularly in this population of patients who may have risk factors for hernia development, is likely underreported. While shorter-term retrospective series note an incidence of trocar site hernia after laparoscopy at 1–6%, the longer-term incidence associated with laparoscopic cholecystectomy is as high as 26% at 3 years [15].

The described lateral port placement provides camera visualization and two working ports to facilitate efficient adhesiolysis. An additional 5 mm trocar on the contralateral side allows better positioning for tack fixation on the side of the initial ports. In cases of extensive adhesions, two 5 mm trocars (working port and camera port) on the contralateral side may be needed for a different vantage point to complete the adhesiolysis and hernia contents reduction. Each of the ports should be placed under laparoscopic camera visualization.

Additional port placement is often required for atypically located ventral hernias. As mentioned previously, the trocar's arrangement should allow targeting of the camera and instruments toward the hernia site when possible. As patients can have incidentally found hernias at prior incisions, initial lateral port placement as described may be the most efficient to address all hernia defects.

Adhesiolysis Tips and Tricks

Adhesiolysis is often the lengthiest portion of ventral hernia repair. Adhesions should be expected during the course of incisional hernia repair as intra-abdominal adhesions are common after laparotomy, estimated to occur in almost 70–97% of patients [16–19]. The magnified view of the abdominal wall and the suspension of

adherent intestine created with the pneumoperitoneum facilitate safe adhesiolysis during laparoscopic repair. Adjustment of patient positioning and external pressure on the hernia sac can provide additional advantage. Except for thin, areolar adhesions, the majority of adhesions require sharp dissection. This should be performed with limited use of electrosurgery. One must be aware of the proximity of the surrounding intestine which may be hidden from view. Clips, rather than cautery or ultrasonic dissector use, provide hemostasis. The impact of the thermal spread in the closed working space of LVHR may be substantial. While the overall complication rate of LVHR is low, inadvertent enterotomy and, particularly, *missed* bowel injury are a significant cause of morbidity and potentially mortality [20].

A strategic plan for adhesiolysis enables safe dissection. Dissection at the hernia defect and hernia content reduction are achieved via atraumatic grasping of the hernia contents and hand-over-hand reduction (Fig. 2.2). Hernia sac adhesive bands are sharply divided as they are encountered. As adhesions are taken down and the contents are reduced, immediately afterward, the affected intestine and omentum should be inspected closely for hemostasis and bowel injury. Inspection should be performed at the end of the hernia repair as well. Documentation of this inspection and confirmation of lack of bowel injury are recommended.

The falciform ligament in subxiphoid hernias is divided to allow broad mesh overlap. The falciform ligament is vascular and should be clipped or divided with ultrasonic dissection. Peritoneal fat that would hinder intraperitoneal onlay mesh (IPOM) incorporation should be removed. For suprapubic hernias, the peritoneum is incised similar to transabdominal pre-peritoneal inguinal hernia repair. The bladder is mobilized down, and this allows secure mesh fixation at Cooper's ligament. Placement of a three-way Foley catheter allows filling of the bladder for identification and inspection for bladder injury.

Prior intraperitoneal mesh can pose a challenge. Removal of prior mesh allows better incorporation of the index mesh, but this is not always possible. When prior mesh removal is deemed too destructive to the abdominal wall, care should be taken to ensure wide overlap of the index mesh beyond the prior mesh with transfascial sutures through healthy abdominal wall. The intestine may be densely adherent to

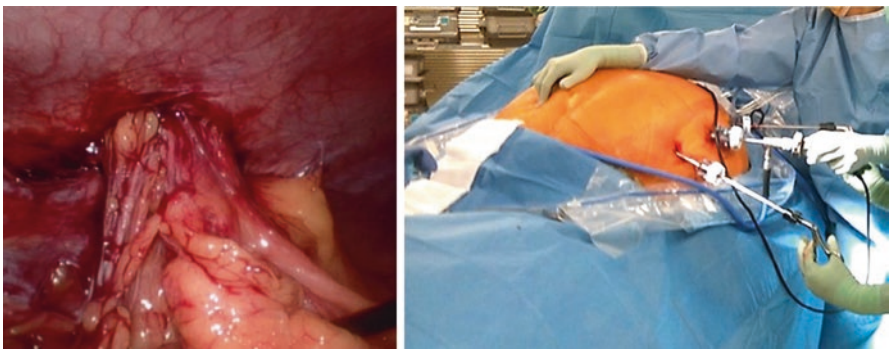

Fig. 2.2 Reduction of hernia contents

prior mesh. If there is no clear plane between the mesh and the intestine, a portion of the mesh should be excised and left adherent on the bowel rather than risking an enterotomy.

Hernia Defect Assessment

Accurate measurement of the fascial defect is an essential step in successful LVHR as this will allow an estimation of the appropriate-sized prosthetic to be placed. Extracorporeally, the defect can be defined by palpation, but this is often inaccurate. Laparoscopy, in contrast, allows a direct visualization of the defect. A measurement is then obtained by intracorporeal placement of a ruler or an umbilical tape with 2 cm markings [21]. Spinal needles, utilized to mark the edges of the defect, can assist in accurate measurement [5]. Alternatively, a suture is inserted and held across the distance between the two spinal needles and then is measured extracorporeally.

A significant advantage of LVHR over open repair is the ability to evaluate for additional defects that could not be palpated. Several studies have demonstrated high rates of these occult defects that are appreciated only at the time of LVHR [22, 23]. In this case, measurement should encompass all visible defects so that adequate mesh coverage can be achieved. In the case of incisional hernias, consideration should also be given to measuring and covering the entirety of the scar to prevent new hernias from forming [24].

Defect Closure

In its early conception, LVHR did not involve closure of the defect but was essentially a bridging repair. There are now several methods of defect closure described in the literature. A chapter in this book is devoted to the pros and cons of traditional IPOM versus that with defect closure, so it is mentioned only briefly here. Probably the most commonly applied method is the "shoelacing technique" described by Orenstein et al. This is an extracorporeal closure utilizing a suture passer to create a series of figure-of-eight stitches [25]. Intracorporeal closure and hybrid techniques for defect closure have been described as well [23, 26, 27]. Potential benefits of defect closure include reconstruction of a functional abdominal wall, closure of dead space that can lead to seroma formation, reduction in recurrence rate, and prevention of mesh eventration and bulging [27, 28].

Mesh Selection and Sizing

Many hernia surgeons are in favor of utilizing mesh for their open repairs in an effort to reduce recurrence rates. There are surgeons, however, who favor a primary repair and avoid the use of prosthetics when possible. There is no room for debate when it comes to laparoscopic hernia repair, as the technique can only be

accomplished with the use of mesh. The topic of which mesh could fill the pages of an entire book. Indeed, there are four chapters in this book devoted to the topic of prosthetics and mesh selection, so we will refer the reader to those for details regarding the subject. In brief, the principal selection criteria for a laparoscopic repair are based on whether the mesh will be directly exposed to the bowel. When performing an IPOM repair, the mesh is in direct contact with the bowel, and, thus, a mesh with an adhesion barrier is critical in the pursuit of avoiding complications of small bowel obstructions and fistulae [29]. Most manufacturers of polypropylene or polyester meshes offer a product with an adhesion barrier on the visceral side. Typically, this is a hydrophilic component that resorbs over time. Alternatively, expanded polytetrafluoroethylene (ePTFE) is less adhesiogenic, and thus prosthetics composed of this do not have an additional adhesion barrier [30]. In contrast, the parietal side of the mesh should facilitate tissue ingrowth to provide secure fixation. In an effort to achieve this ideal mesh, there are products composed of two different components available as well. If a transabdominal pre-peritoneal approach is utilized, a non-coated mesh is preferred. The peritoneum protects the viscera from the mesh, so no other barrier is needed, and some would argue anything else would interfere with ingrowth and potentially increase risk for seroma formation.

Whatever mesh is chosen, the size must provide adequate overlap of the defect. Obviously, this could be approached by choosing very large mesh for all defects. This, however, would be expensive, and the increased surface area requires more fixation and thus potential for complications such as chronic pain. The larger prosthetic would also be problematic if complications were to arise such as infection requiring explanation. The goal then is to utilize a mesh that provides enough overlap to account for potential shifting of the mesh as well as shrinkage. The increased surface area with overlap allows for more ingrowth and, thus, biologic fixation. Additional support occurs from the effect of intra-abdominal pressure on the increased surface area of a larger mesh [28].

There is little high-level evidence to dictate what the minimal amount of overlap should be for a LVHR. Studies are limited by variations in technique and small sample sizes [28]. One of the largest series of LVHR utilized a 3 cm overlap early in the series and then shifted to a 4 cm overlap [31]. Many surgeons now prefer a 5 cm overlap of the defect, and recurrence rates have been acceptable with this technique [5]. Thus, after measuring the defect size, 6–10 cm is added to the transverse and vertical dimensions to determine the minimum mesh size that should be utilized in the repair. There is general consensus that the larger the defect size, the larger the overlap should be [28].

As it becomes more common practice to close the hernia defect, there is some debate as to whether a smaller-sized mesh will suffice. Most commonly, a mesh size is selected based on the initial defect size as measured prior to closure. In doing so, if the fascial closure breaks down, one can be assured effective overlap remains.

Prior to inserting the mesh, the surgeon may wish to place marks in order to orient the mesh with more ease. Some manufactures have marking for this purpose. Most importantly, if adhesion barrier mesh is utilized, one must be able to identify which is the coated visceral side and which is the peritoneal side. If transfascial

sutures are to be used, part or all of these can be secured to the mesh prior to insertion as well.

Introducing the mesh to the abdomen can be accomplished by placing the rolled mesh directly through a trocar. This has the benefit of avoiding any skin contact with the prosthetic. This does, however, require a larger trocar as it would be a struggle to insert coated mesh through a 5 mm port. If the surgeon wishes to use only 5 mm trocars or needs to insert a very large mesh, this is accomplished by passing a grasper out directly through a trocar from the contralateral side. The trocar is then removed and the mesh pulled into the abdomen through the port site, prior to replacing the trocar.

Mesh Fixation

Positioning the mesh, especially larger sizes of mesh, is aided by the use of either a commercially available positioning device or simply by use of sutures placed prior to insertion. A suture passer is utilized to externalize the sutures and, thus, suspend the mesh. These can be subsequently removed, once methods of fixation are in place, or utilized as transfascial fixation points.

After the mesh is positioned, with appropriate overlap confirmed, the options for securing the mesh to the abdominal wall are tacks, transfascial sutures, glue, or some combination of these. The traditional technique involves placement of at least four transfascial sutures at equidistant points. Additional transfascial sutures may be placed, as deemed necessary, to secure larger prosthetics. The perimeter is then tacked to the posterior fascia at approximately 1 cm intervals [31]. The edge of the mesh should be secured close to the perimeter to avoid exposing bowel to the noncoated side of the mesh, if applicable. With any method of fixation, care should be taken to avoid injury to the epigastric vessels.

While suture is categorized as only absorbable or nonabsorbable, tacking options vary in design and material. Typically, tacks are helical or pronged, and available products vary in depth of penetration as well. There is evidence that, at least in short term follow-up, acute and chronic postoperative pain is not significantly different between the absorbable and nonabsorbable categories of tacks [32]. The tacking device can be utilized to secure the mesh around the perimeter between transfascial sutures, or can be utilized without transfascial sutures, often in a “double-crown” fashion. A randomized study evaluating acute postoperative pain found similar postoperative pain and quality-of-life findings between the double-crown technique with no sutures and transfascial sutures (either absorbable or nonabsorbable) with tacks. The same study noted decreased operative time in the group without transfascial sutures [33].

This is yet another controversial topic, and there is a paucity of high-level evidence regarding the best method to prevent recurrence and optimize the patient experience. Studies have demonstrated that suture fixation achieves the highest tensile strength in comparison to alternative devises and decreases mesh shrinkage [34, 35]. Still, this has failed to consistently demonstrate a reduction in recurrence rates.

A meta-analysis comparing only suture fixation, only tack fixation, and a combination of sutures and tacks failed to detect a significant difference regarding the recurrence rates at follow-up periods of at least 2 years [28].

Postoperative Care and Outcomes

Laparoscopic ventral hernia repair is associated with shorter hospitalization, decreased wound complications, and reduced surgical site infection rate compared to open repair [36–38].

In a systematic review and meta-analysis, the laparoscopic approach consistently reduced the risk of wound infection. (RR = 0.26; 95% CI 0.15–0.46; I(2)= 0%) [39]. While the minimally invasive approach may be associated with a longer operative time and higher operative cost, this lower risk of surgical site infection can reduce substantially the overall cost and burden on the patient associated with readmission and wound care.

Bowel Injury

The serious morbidity and mortality rate associated with LVHR is low. However, inadvertent enterotomy significantly increases the mortality risk. A literature review assessed that bowel injury occurs in almost 2% of patients, and large bowel injury comprises 8.3% of these cases. These injuries are identified and repaired approximately 80% of the time during the hernia repair. Enterotomy increased the mortality risk from 0.05 to 2.8% [20]. Despite the technical advances of magnified visualization, the rate of bowel injury remains higher for LVHR compared to open repair in at least two systematic reviews [38, 39].

Meticulous adhesiolysis to avoid thermal bowel injury as well as traction injury and close inspection for injury during laparoscopic repair are warranted. Identified injuries must be repaired immediately either laparoscopically or via laparotomy depending on the comfort of the surgeon. Gross contamination precludes permanent mesh placement. Postoperatively, patients may have significant incisional pain but should be hemodynamically stable. Fever, tachycardia, fluid sequestration, and erythema are all worrisome signs of a missed enterotomy.

Seroma

Seroma is common after laparoscopic ventral hernia but few require intervention [4, 31]. This can occur with transfascial sutures and with the double-crown technique of mesh fixation. The seroma is often within the old hernia sac but may occur as a retroprosthetic seroma in almost half of patients in the early recovery period [40]. Primary fascial closure reduces the seroma rate [41].

Pain Management

Enhanced recovery pathways with multimodal pain management reduce the narcotic usage and subsequent adverse effects such as ileus. Preoperative anti-inflammatory medication and acetaminophen as well as local anesthetic injection during the procedure may reduce postoperative pain. Pain has been associated with both transfascial sutures and tack fixation, without a demonstrable difference between absorbable and permanent tacks [42].

Hernia Recurrence

In a single series, the hernia recurrence rate after laparoscopic ventral hernia repair varies from 3 to 20%, though follow-up is limited. In a recent Cochrane review, the recurrence rate was comparable between laparoscopic and open repair, but the follow-up was shorter than 2 years in half of the included trials [39]. Mesh overlap of the defect is critical in reducing the rate of hernia recurrence. The risk of hernia recurrence is inversely correlated with increasing mesh overlap in laparoscopic repair. In laparoscopic procedures, the pooled estimation of risk for recurrence of hernia decreased with increasing area of mesh overlap (<3 cm, incidence rate 0.086; 3–5 cm, incidence rate 0.046; >5 cm, incidence rate 0.014) [43].

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Masters Program Hernia Pathway: Laparoscopic Inguinal Hernia

3

Jacqueline Blank and Matthew I. Goldblatt

Introduction

Laparoscopic inguinal hernia repair is among the most common procedures performed today by general surgeons. There is increasing data that laparoscopic surgery has the advantage of decreased postoperative pain and quicker return to normal daily activities, and it may even afford better visualization of a challenging anatomic region. However, there is considerable variety among general surgeons regarding the operative technique for laparoscopic inguinal hernia repair.

Laparoscopic inguinal hernia repairs may be performed via a totally extraperitoneal (TEP) approach or a transabdominal preperitoneal (TAPP) approach. The choice between a laparoscopic TEP and TAPP inguinal hernia repair is based on patient history and surgeon preference. Previous disruption of the preperitoneal space is a relative contraindication for a TEP repair, as is done with prostate surgery. A TAPP repair may be advantageous when performing with concurrent laparoscopic abdominal operations like a laparoscopic ventral hernia [1]. For repair of bilateral inguinal hernias, both TEP and TAPP are preferred over open repair. Laparoscopic repair is also ideal for recurrent inguinal hernia repair after open surgery, because the preperitoneal space has not yet been disrupted [2]. Lastly, laparoscopic femoral hernia repairs have been shown to have lower recurrence rates than open repairs of femoral hernias in women [3].

In the case where both TEP and TAPP are possible, the surgeon must consider the risks and benefits of each approach, as there is mixed data regarding the morbidity and mortality of each. A meta-analysis by Antoniou and colleagues examined

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over 500 patients that underwent TEP and TAPP laparoscopic repairs and found no difference in hernia recurrence or long-term pain or sensory deficits between the two approaches [4]. There was increased operative morbidity of TAPP when compared to TEP (OR = 2.15; 95% CI, 1.29 to 3.61; $P = 0.004$); however, this particular metric was heavily influenced by variable definitions of morbidity among studies [4]. Other studies also differ on results of early and late postoperative pain control for each approach [5, 6]. The decision between the TEP and TAPP approaches will be discussed in more detail in future chapters.

In this chapter, we will discuss preoperative and intraoperative techniques for laparoscopic inguinal hernia repairs (both TEP and TAPP), including relevant anatomy, operative dissection, mesh placement, and common complications.

Patient Preparation and Positioning

After appropriate medical evaluation and informed consent, the patient is placed in a supine position. Preoperative antibiotics are given within 1 h of the first skin incision. Venous thromboembolism (VTE) prophylaxis may be used for patients at moderate or higher risk of postoperative VTE according to the guidelines set forth by the American College of Chest Physicians (ACCP), which are endorsed by the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) [7]. Those at very low and low risk for postoperative VTE require only pneumatic compression devices and early postoperative mobilization for VTE prophylaxis [7].

Once general endotracheal anesthesia is initiated, the arm contralateral to the hernia is tucked. This allows the surgeon to stand at the patient's shoulder. If the patient has bilateral hernias, then both arms are tucked. Many surgeons place a urinary catheter; however, others may forego this step (discussed in Sect. 3.7). Hair in the operative field is removed using skin clippers. The abdomen is prepped from the costal margin to a few centimeters below the pubic symphysis and laterally to the posterior axillary lines. Drapes are then placed just above the umbilicus superiorly, the bilateral anterior superior iliac spines (ASIS) laterally, and the pubic symphysis inferiorly. The surgeon stands on the side contralateral to the hernia. For bilateral hernia, it is the surgeon's preference as to which side to start. A single monitor is positioned at the feet for the surgeon and assistant (Fig. 3.1) [8–10].

Laparoscopic Anatomy

The anatomy of the inguinal region can be challenging at first. Laparoscopic inguinal hernia repair requires thorough knowledge of the anatomy of the preperitoneal space. The distal aspect of the preperitoneal space is called the space of Retzius, which is located between the pubic tubercle and the urinary bladder. The lateral extension of the space of Retzius is the space of Bogros [11]. The preperitoneal space is bounded anteriorly by the abdominal wall, which forms the "ceiling" of the laparoscopic

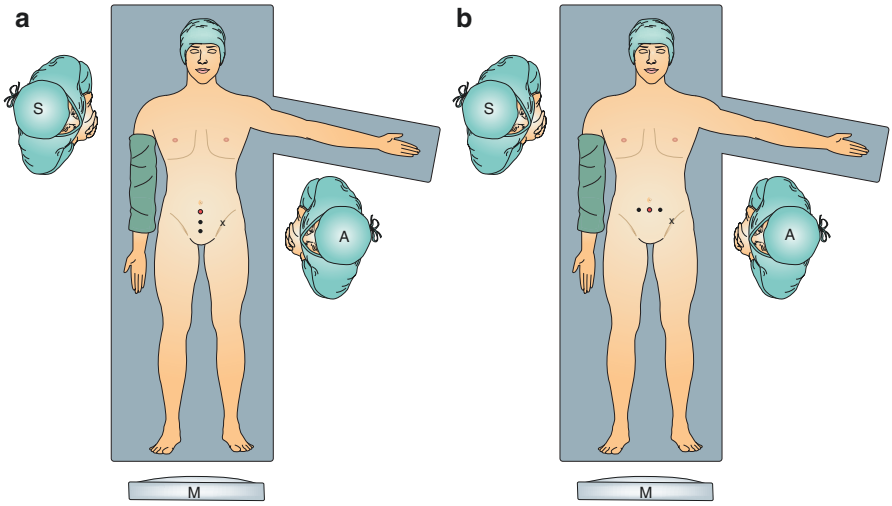

Fig. 3.1 Operating room setup and port placement for TEP repair (**a**) and TAPP repair (**b**) The surgeon stands contralateral to the hernia, and the arm contralateral to the hernia is tucked. The ipsilateral arm is left abducted for the anesthesiologist. *X* hernia, *S* surgeon, *A* assistant, *M* monitor. Open circle = 10- or 12-mm port. Closed circles = 5-mm ports

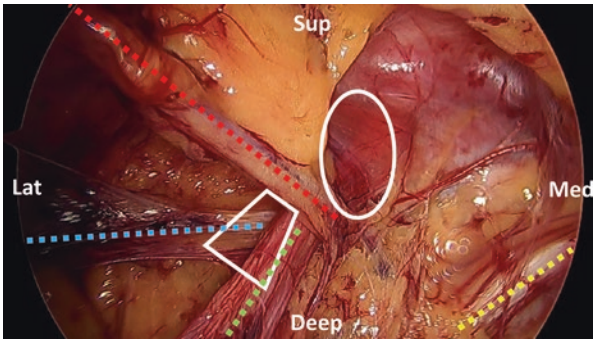

Fig. 3.2 Laparoscopic left inguinal hernia repair, with Cooper's ligament (yellow line), inferior epigastric vessels (red line), spermatic cord (green line), and the iliopubic tract (blue line). A direct hernia will be medial to the epigastric vessels, in the region of the white circle. An indirect hernia will be lateral to the epigastric vessels, in the region of the white polygon. *Med* medial, *Sup* superficial, *Lat* lateral

operating space. The inferior epigastric vessels should abut this wall when dissected properly (red line, Fig. 3.2). The posterior portion of the preperitoneal space is created by the peritoneum overlying the abdominal contents, which forms the "floor." The pubic tubercle is the medial landmark of the laparoscopic operating space, with the ASIS laterally. The inguinal ligament, or Poupart's ligament, runs from the ASIS to the pubic tubercle. The shelving edge of the inguinal ligament connects the

inguinal ligament to the iliopubic tract, an aponeurotic band overlying the superior pubic ramus (blue line, Fig. 3.2). The iliopubic tract also connects the ASIS to the pubic tubercle; it is connected to the inguinal ligament medially by Cooper's ligament (yellow line, Fig. 3.2) [10, 11]. The internal and external rings refer to the openings of the inguinal canal, through which the spermatic cord structures pass (green line, Fig. 3.2). The internal ring is visible on laparoscopy at the inferior portion of the field. It is formed by a hiatus in the transversalis fascia [9]. The external ring is not visible in the laparoscopic view; it is formed by a hiatus in the external oblique aponeurosis [9].

There are two triangular portions of the inguinal region that deserve special attention. The "triangle of pain" contains the lateral femoral cutaneous nerve, the femoral branch of the genitofemoral femoral, and the femoral nerves [9]. This triangle is bounded superiorly by the inguinal ligament, inferomedially by the spermatic cord, and laterally by the iliac crest [11]. Placement of staples or tacks in this area may predispose the patient to chronic pain or paresthesias in the inguinal region, testicle, or thigh [1, 10]. The "triangle of doom" contains the external iliac vessels and the deep circumflex iliac vein. This triangle is bounded by the vas deferens medially and the spermatic vessels laterally and may cause significant hemorrhage if violated [1, 11].

The three types of hernias that may be encountered in the inguinal region are indirect, direct, and femoral hernias. Often, these are indistinguishable on preoperative physical exam. Indirect hernias run with the spermatic cord and are found lateral to the inferior epigastric vessels (polygon, Fig. 3.2). Large indirect hernias may extend into the scrotum. Direct hernias protrude through Hesselbach's triangle, a triangle superior to the inguinal ligament and medial to the epigastric vessels, which forms the "floor" of an open inguinal hernia repair (Fig. 3.3; circle, Fig. 3.2). Femoral hernias occur inferior to the inguinal ligament within the femoral canal, medial to the femoral artery and vein [9, 11].

Indirect, direct, and femoral hernias all begin within the myopectineal orifice, first described in 1956 by Fruchaud [12]. This is a weakness in the transversalis fascia that is bounded by internal oblique and transverse abdominal muscles superiorly, the iliopsoas muscle laterally, and the rectus muscle medially [13]. The region

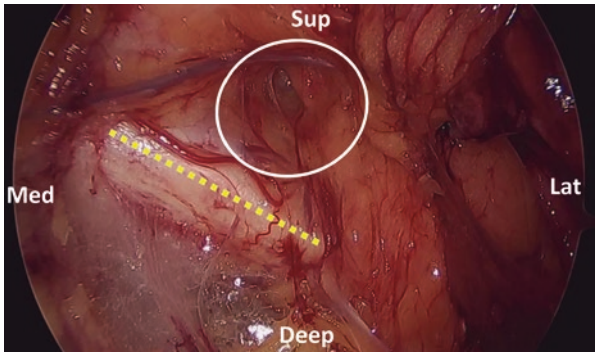

Fig. 3.3 Direct right inguinal hernia repair, with Cooper's ligament (yellow line), inferior epigastric vessels (buried in fat, under red line), and direct hernia medial to the epigastric vessels, in the white circle. *Med* medial, *Sup* superficial, *Lat* lateral

is divided in half by the inguinal ligament and contains the five major nerves of the region: the genital and femoral branches of the genitofemoral nerve, the femoral nerve, and the anterior and lateral femoral cutaneous nerves, from medial to lateral [14]. This region also contains the femoral vessels, as well as the round ligament in women and the spermatic cord in men [13].

Access to the Preperitoneal/Intraperitoneal Space: Laparoscopic Dissection

Access to the preperitoneal space for a totally extraperitoneal (TEP) or the intraperitoneal space for a transabdominal preperitoneal (TAPP) approach differs. We will first describe preperitoneal access in the TEP approach. Three laparoscopic ports are placed in the midline: one 10-mm or 12-mm port directly below the umbilicus and two 5-mm infraumbilical ports (Fig. 3.1a). Local anesthetic (the authors prefer a 50:50 mix of 0.5% bupivacaine and 1% lidocaine with epinephrine) is infiltrated in the patient's skin inferior to the umbilicus. The 10-mm/12-mm port incision is then made just inferior to the umbilicus, and the subcutaneous tissues are dissected down to the fascia. A 1-cm horizontal incision is made in the anterior rectus sheath, just off midline and ipsilateral to the inguinal hernia (the authors prefer the left side in bilateral inguinal hernias). The anterior rectus sheath is opened to expose the underlying rectus muscle, which is retracted anteriorly and laterally with an S-retractor.

A dissecting balloon is then placed in the preperitoneal space posterior to the rectus muscle and anterior to the posterior rectus sheath. The surgeon's finger may be used to develop a tunnel in the preperitoneal space prior to inserting the dissecting balloon [1]. The dissecting balloon is inserted to the pubic symphysis and inflated. For unilateral hernia repair, the assistant places pressure on the contralateral lower quadrant to prevent unnecessary tissue dissection (or a unilateral balloon may be used), and the balloon is gradually inflated under direct laparoscopic vision. For bilateral hernia repair, the dissecting balloon is fully inflated under direct laparoscopic vision to open the preperitoneal space bilaterally. Care must be taken to ensure that the balloon is dissecting posterior to the epigastric vessels. If the balloon begins to dissect between the rectus muscle and the epigastric vessels, inflation is halted, the balloon is removed, and the dissection is performed manually.

After deflation, the dissecting balloon is removed, and a 10-mm or 12-mm Hasson trocar is placed in the same incision. The preperitoneal space is then insufflated to 12 mmHg pressure. This insufflation pressure is lower than that required for a TAPP repair to avoid barotrauma to the peritoneum. The two 5-mm trocars are then placed in the midline under direct vision, one trocar two fingerbreadths below the umbilicus and one trocar five fingerbreadths below the umbilicus. Alternatively, some surgeons prefer their trocars closer to the pubic symphysis [8]. The dissection is initially carried out in a medial to lateral fashion. A laparoscopic Kittner or blunt dissecting forceps is used to remove the loose areolar tissue from the pubic symphysis and Cooper's ligament, and gentle dissection proceeds laterally toward the

ASIS. Care is taken to ensure that the epigastric vessels remain anterior. In some patients, the transversalis fascia continues inferiorly, and the plane posterior to the transversalis fascia must be created starting inferiorly near the cord structures.

Once at the ASIS, the dissection is carried medially toward the internal ring, which is skeletonized using blunt dissection to reveal the structures of the spermatic cord: the vas deferens, pampiniform venous plexus, autonomic nerve fibers, and testicular artery. An indirect hernia or a cord lipoma may be found running with the cord structures into the internal ring; this may be reduced with gentle traction, and the peritoneum should be pushed posteriorly. A large indirect hernia sac can be divided just distal to the internal ring and the remainder of the sac left in situ to avoid trauma to the spermatic cord [1].

Dissection continues medially, where a direct inguinal hernia may be seen superior to the inguinal ligament, within Hesselbach's triangle. This triangle is formed by the inguinal ligament inferiorly, the inferior epigastric vessels laterally, and the lateral edge of the rectus sheath medially. Hernias found in this region may be gently reduced with a laparoscopic Kittner or blunt graspers. A femoral hernia may also be visualized inferior to Hesselbach's triangle and may be reduced by the same technique. There is typically lymphatic tissue medial to the external iliac vein, which should not be mistaken for a femoral hernia.

The dissection is now complete, and the following structures are clearly visualized: the pubic symphysis or tubercle medially; the ASIS laterally; the skeletonized internal ring with the vas deferens entering medially and the spermatic vessels entering laterally; the epigastric vessels approximately halfway between the pubic tubercle and ASIS, overlying the anterior abdominal wall; and the peritoneum posteriorly. At this point, the surgeon may proceed with mesh placement.

Access to the peritoneal cavity for a TAPP approach begins with infiltration of local anesthetic as above and placement of an optical trocar or Hasson trocar just inferior to the umbilicus into the peritoneal cavity. The abdomen is insufflated to 15 mmHg pressure, and the abdominal contents are inspected for visceral injury or other diseases. The patient may be placed in Trendelenburg position to allow the bowel to fall cephalad out of the pelvis to aid in visualization of the inguinal region [1]. Two additional 5-mm trocars are then placed under direct vision in the right and left mid-abdomen, along the mid-clavicular line (Fig. 3.1b).

The peritoneum is then scored using cautery or scissors approximately 6–7 cm cephalad from the pubic symphysis or 2 cm above the superior edge of the hernia defect [1]. The peritoneal flap is created by gently pulling the peritoneum posterior toward the abdominal contents. This is performed in a medial to lateral fashion, from the median umbilical ligament to the ASIS, preserving the medial umbilical ligament to avoid inadvertent bleeding from a remnant umbilical artery [10]. The preperitoneal space is developed using a laparoscopic Kittner or blunt graspers for dissection in the avascular plane between the peritoneum and transversalis fascia [10]. In some patients, the peritoneum does not separate from the transversalis fascia, and so in order to dissect laterally, the dissection must go to the pretransversalis

plane. The surgeon should then identify the previously discussed structures: the pubic tubercle and Cooper's ligament medially, the ASIS laterally, and the internal ring with the vas deferens and spermatic vessels. Indirect hernias will be visualized with the spermatic cord and may be gently reduced. Direct hernias will again be seen in Hesselbach's triangle, and femoral hernias will be visible at the femoral canal, inferior to the inguinal ligament. At this point, the surgeon may proceed with mesh placement.

Mesh Placement

A variety of types of mesh may be used for inguinal hernia repairs and will be discussed in later chapters. Regardless of the type of mesh and operative approach, it is imperative that the mesh cover the regions of indirect, direct, and femoral hernias. The authors prefer a 2-cm overlap across the midline and under the pubic symphysis to ensure proper mesh coverage.

The mesh is rolled in a caudal to cranial orientation prior to placement into the preperitoneal space. Once rolled up, the mesh is placed through the 10-mm/12-mm trocar. It is then unrolled in a cranial to caudal fashion, ensuring a 2-cm overlap of the midline, until the most inferior portion of the mesh covers the pubic symphysis (Fig. 3.4). The mesh must cover all three potential hernia spaces. A non-adherent mesh may then be secured with tacks to the anterior abdominal wall, taking care to avoid the epigastric vessels and the triangles of doom and pain. Tacks are placed at the medial aspect of the pubic tubercle into Cooper's ligament. Additional tacks can be placed along the anterior abdominal wall, typically one medially and one laterally. Absorbable tacks are preferred by the authors. The assistant's hand may be placed on the abdominal wall to palpate the tacking device and ensure that all tacks are placed superior to the iliopubic tract, to avoid the triangle of pain. Approximately 10 mL of 0.5% bupivacaine is then instilled into the field. The mesh is held in position and the field is desufflated. If a TAPP approach has been chosen, the peritoneum is now placed over the mesh and stapled or sewn in place.

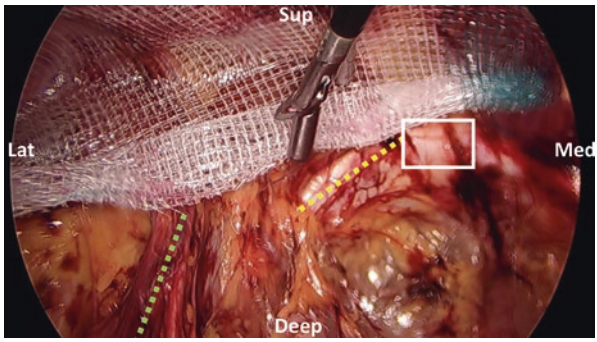

Fig. 3.4 Left inguinal hernia repair. Unrolling mesh in a cranial to caudal direction, ensuring at least 2-cm overlap of the pubic tubercle. Shown here are Cooper's ligament (yellow line), spermatic cord (green line), and the pubic tubercle (rectangle). *Med* medial, *Sup* superficial, *Lat* lateral

Closure

The trocars are removed, and attention is directed to the 10-mm/12-mm trocar site. The fascia is closed using a 0 Vicryl in a figure-of-eight fashion. The skin and the remaining 5-mm port sites are closed using 4-0 Monocryl in a subcuticular fashion, and incisions are covered with Steri-Strips. After sufficient recovery, the patient may be discharged home on the same day.

Complications

Many surgeons still feel that placement of a urinary catheter is paramount to preventing bladder injury. This complication is rare, occurring in less than 1% of all laparoscopic inguinal hernia repairs, and is more common in TAPP repairs than TEP repairs [15, 16]. Still, patients who have undergone previous surgery in the space of Retzius are at high risk for bladder injury [1]. An open repair should be seriously considered for these patients. If a bladder injury does occur, it should be repaired anteriorly to prevent mesh placement near the repair [1]. The authors have their patients void immediately before going to the OR and have stopped using urinary catheters, except in those patients with significant benign prostatic hypertrophy (BPH).

Urinary retention is also a recognized complication of laparoscopic inguinal hernia repair, with a wide variation of incidence (1–22% [17]) in the literature. The use of Foley catheterization has not been extensively studied in this instance, and it is unknown whether this intervention would improve on the rate of postoperative urinary retention. In fact, a retrospective review by Patel and colleagues [18] suggested that Foley catheter placement may induce urinary retention due to detrusor muscle injury during placement. This study also described significant variables that influence the rate of postoperative urinary retention, including age over 50 years, bilateral hernia repair, and increased use of postoperative narcotics [18].

Vascular injury usually involves the inferior epigastric and spermatic vessels, as well as the iliac veins, and is more common in TEP than TAPP [1, 16, 19, 20].The overall incidence of vascular injury during laparoscopic inguinal hernia repair is low, at 0–3% [16, 19, 20]. The use of a Hasson trocar for entrance into the abdomen as well as identification of vascular landmarks may help decrease the incidence of these injuries [1]. Aberrant vasculature, specifically the *corona mortis*, may also be injured during dissection (Fig. 3.5). This vascular anomaly may be present as a branch of the external iliac artery or the inferior epigastric artery and passes over the pubic tubercle on the way to the obturator region [11]. The *corona mortis* is present in approximately 15–40% of cases [20].

Chronic nerve pain is a common complaint after both open and laparoscopic inguinal hernia repair. Patients may complain of burning pain or numbness to the

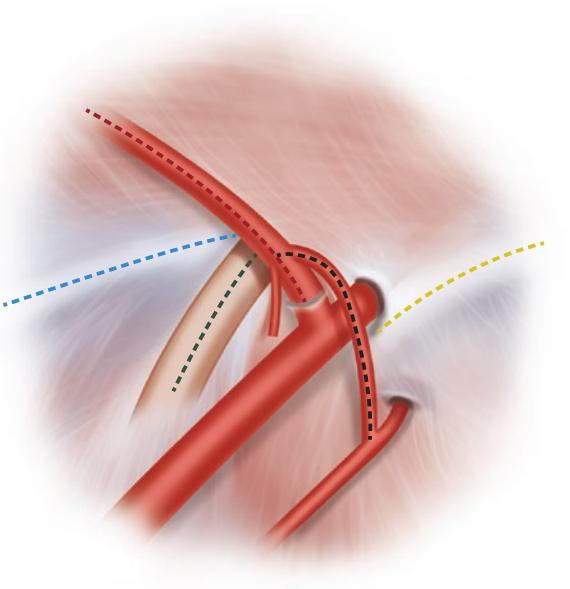

Fig. 3.5 Aberrant branch of the obturator artery, the *corona mortis* (black line), connects the inferior epigastric artery (red line) to the obturator artery. The external iliac artery is deep to the operative field but shown here for reference. Again shown are Cooper's ligament (yellow line), the spermatic cord (green line), and the iliopubic tract (blue line)

inguinal region, testicle, or thigh. Delayed onset of symptoms usually signifies a self-limiting condition. However, if symptoms occur in the recovery room, immediate return and re-exploration should be considered, especially if tacks were used [1]. Violation of the triangle of pain greatly increases the risk of chronic nerve pain.

Recurrence of inguinal hernia after both open and laparoscopic repair is another recognized complication. A meta-analysis of over 6000 patients who underwent either open or laparoscopic inguinal hernia repair found a significantly increased risk of recurrence for laparoscopic inguinal hernia repair (RR = 2.06). Subgroup analysis revealed no difference between TAPP and open inguinal hernia repairs, but TEP repairs were associated with a significantly increased risk of recurrence when compared to open (RR = 3.72) [21]. Another meta-analysis confirms these results, with a recurrence rate of 2.7% for open repairs and 5.5% for laparoscopic repairs [22]. Many surgeons agree that the learning curve for TEP repairs is high and the number of cases to achieve mastery may be over 250.

Conclusion

We have presented our preferred operative technique for laparoscopic TEP and TAPP inguinal hernia repairs. Laparoscopic inguinal hernia repair is a viable alternative to open inguinal hernia repair, and the complex anatomy of the region requires intraoperative vigilance in order to avoid morbidity and mortality for our patients.

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Hernia Materials: Fundamentals of Prosthetic Characteristics

4

Corey R. Deeken and Spencer P. Lake

For nearly 80 years, biomaterials have been utilized to reinforce hernia repairs, beginning with silver and tantalum meshes in the early 1940s [1, 2] and progressing to permanent synthetic polymer meshes in the late 1950s [3]. In more recent years, advancements in biomaterial technology have led to rapid expansion of this field with nearly 150 hernia repair materials now available [4]. This seemingly ever-expanding array of biomaterials has recently been classified by our group in a hierarchical fashion (Fig. 4.1) [4] that better reflects the nuances of recent designs compared to previous classification schemes [5, 6].

In the Deeken & Lake Mesh Classification System [4], hernia repair materials are first grouped according to the composition of the underlying structural scaffold material, forming three broad groups: permanent synthetic polymers, resorbable polymers, and biological tissue-derived materials (Fig. 4.1). Hernia repair materials are then further subdivided based on the presence of a coating, barrier layer, or reinforcing material. Coatings and barriers are used to minimize tissue attachment by separating the abdominal viscera from the mesh when utilized in the intraperitoneal position. Coatings are applied to the surface of the individual mesh fibers and do not span across the pores of the mesh, while a barrier layer is applied continuously across the surface of the mesh, spanning the pores and creating a distinct layer. Barrier layers are additionally characterized as composite or noncomposite. Composite barrier layers are constructed of a distinct anti-adhesion layer that is

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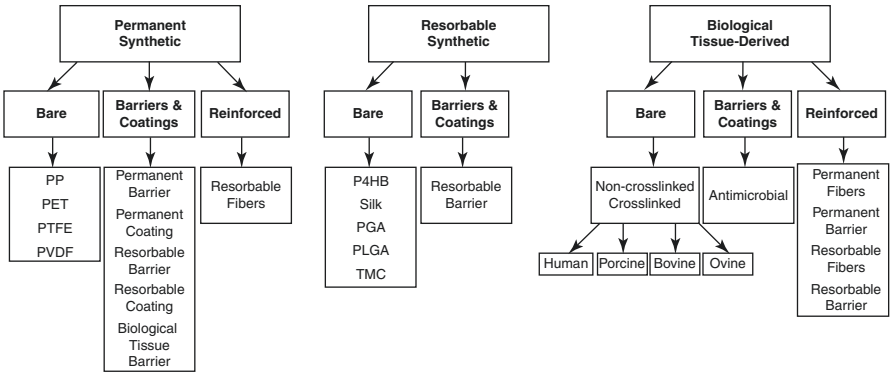

Fig. 4.1 Deeken & Lake Mesh Classification System hierarchy encompassing three main categories that are further distinguished by the presence, type, and composition of complementary barriers, coatings, or reinforcing materials. Terms of Use: This figure was adapted from the original figure licensed under a Creative Commons Attribution 4.0 License (https://creativecommons.org/licenses/by/4.0/) attributed to Corey Deeken and Spencer Lake. The original version can be found here: https://doi.org/10.1016/j.jmbbm.2017.05.008. The content of the figure is reprinted with minor modifications to the original work [4]

sewn or vacuum-pressed onto the structural mesh component. Noncomposite barriers are formed from a single sheet of scaffold material that possesses side-specific features: anti-adhesive (e.g., smooth surface or smaller pores) or tissue attachment properties on the sides of the biomaterial intended to be placed in contact with the viscera and the abdominal wall, respectively. Reinforcing materials, which can be permanent or resorbable, are often included to optimize initial mechanical support of the defect and facilitate handling during implantation. To date, both permanent synthetic and biological tissue-derived scaffold designs have incorporated reinforcing materials, creating many unique combinations in which part or all of the scaffold resorbs over time, gradually transferring the load back to the host tissue in the process.

The first broad category of hernia repair materials in the Deeken & Lake Mesh Classification System [4] consists of permanent synthetic polymers such as polypropylene (PP), polyester (PET), polytetrafluoroethylene (PTFE), polyvinylidene fluoride (PVDF), and various combinations of these polymers (Table 4.1). Many of the products in this category are available as bare meshes, without coatings, barriers, or reinforcements (Table 4.1, column 1). However, several designs contain anti-adhesion barriers that may be classified as permanent, resorbable, or biological tissue derived. These barriers are further subdivided into noncomposite or composite barriers (Table 4.1, column 2). In the permanent barrier, noncomposite group, the anti-adhesion barriers of all current designs are comprised of expanded PTFE (ePTFE). In the permanent barrier, composite group, the anti-adhesion barriers of all current designs are also comprised of ePTFE, except for one design comprised of silicone (Surgimesh® XB, Aspide/BG Medical, Barrington, IL). In the permanent coating group, the anti-adhesion coatings of all current designs are comprised of titanium (TIMESH product line, Biomet Biologics/GfE Med. GmbH).

Table 4.1 Permanent synthetic meshes for hernia repair subdivided by the presence/absence of a barrier, coating, or reinforcing material

Bare	Barriers and coatings	Reinforced
Polypropylene (PP) 3D Max (Bard/Davol Inc.)[a] 3D Max Light (Bard/Davol Inc.)[a] Bard Mesh (Bard/Davol Inc.) Bard Soft Mesh (Bard/Davol Inc.) DynaMesh-PP Light (FEG Textiltechnik mbH) DynaMesh-PP Standard (FEG Textiltechnik mbH) EASY PLUG PATCH SYSTEM (Aspide/BG Medical)[a] Freedom Octomesh (Insightra Medical) Kugel Patch/Modified Kugel Patch (Bard/Davol Inc.) Marlex (Bard/Davol Inc.) MK Hernia Patch (Bard/Davol Inc.) Optilene Mesh (B Braun) Optilene Mesh Elastic (B Braun) Optilene Mesh LP (B Braun) Optilene Mesh Plug (B Braun) Parietene (Covidien) PerFix Light Plug (Bard/Davol Inc.)[a] PerFix Plug (Bard/Davol Int.)[a] Polysoft Hernia Patch (Bard/Davol Inc.) Premilene Mesh (B Braun) Premilene Mesh Plug (B Braun) PROLENE 3D Patch (Ethicon Inc.)[a] PROLENE Mesh (Ethicon Inc.) PROLENE Polypropylene Hernia System (Ethicon Inc.)[a] PROLENE Sort Mesh (Ethicon Inc.) ProFlor (Insightra Medical)[a] ProLite Mesh (Atrium Medical Corp.) ProLite Ultra Mesh (Atrium Medical Corp.) ProLoop Mesh (Atrium Medical Corp.)[a]	**Permanent** **Permanent barrier, noncomposite** **Expanded polytetrafluoroethylene (ePTFE)** CRURASOFT Patch (Bard/Davol Inc.) DUALMESH Biomaterial (W.L. Gore & Assoc. Inc.) DUALMESH PLUS Biomaterial (W.L. Gore & Assoc. Inc.) DULEX Mesh (Bard/Davol Inc.) MYCROMESH Biomaterial (W.L. Gore & Assoc. Inc.) MYCROMESH PLUS Biomaterial (W.L. Gore & Assoc. Inc.) Reconix Reconstruction Patch (Bard/Davol Inc) **Permanent barrier, composite** **PP + ePTFE** Composix (Baid/Davol Inc.) Composix E (Bard/Davol Inc.) Composix F/X (Bard/Davol Inc.) Composix Kugel Patch (Bard/Davol Inc.) Composix L/P (Bard/Davol Inc.) CK Parastomal Hernia Patch (Bard/Davol Inc.) Ventralex Hernia Patch (Bard/Davol Inc.) VENTRIO Hernia Patch (Bard/Davol Inc.) **PP + silicone** SURGIMESH XB (Aspide/BG Medical) **Permanent coating** **PP + Titanium** TIMESH Extralight (Biomet Biologics/GfE Med. GmbH) TIMESH Light (Biomet Biologics/GtE Med. GmbH) T1MESH Strong (Biomet Biologics/GfE Med. GmbH) **Resorbable**	**Resorbable** **Fibers** **PP + glycolide/ε-caprolactone** SERAMESH PA (Serag Wiessner) ULTRAPRO Hernia System (Ethicon Inc.)[a] ULTRAPRO Mesh (Ethicon Inc.) ULTRAPRO Plug (Ethicon Inc.)[a] **PP + glycolide/lactide** VYPRO Mesh (Ethicon Inc.) VYPRO II Mesh (Ethicon Inc.)

(continued)

Table 4.1 (continued)

Bare	Barriers and coatings	Reinforced
SURGIMESH WN (Aspide/BG Medical) Surgipro Polypropylene Monofilament (Covidien) Surgipro Multifilament Polypropylene (Covidien) Surgipro Polypropylene Open Weave (Covidien) VISILEX Mesh (Bard/Davol Inc.) VITAMESH™ (Proxy Biomedical.) VITAMESH™ BLUE (Proxy Biomedical) **Polyester (PET)** MERSILENE Mesh (Ethicon Inc.) Parietex Anatomic Mesh (Covidien) Parietex Flat Sheet 2D Weave (TEC) Mesh (Covidien) Parietex Flat Sheet 3D Weave (TET) Mesh (Covidien) Parietex Folding Mesh (Covidien) Parietex Easegrip Mesh (Covidien) Parietex Lightweight Monofilament Polyester Mesh (Covidien) Parietex ProGrip Self-Fixating Mesh (Covidien) Parietex Plug and Patch System (Covidien)[a] Versatex (Covidien) **Polytetrafluoroethylene (PTFE)** **Condensed PTFE** Omyra Mesh (B Braun) **Macroporous PTFE** INFINIT Mesh (W.L. Gore & Assoc. Inc.) MotifMesh (Proxy Biomedical) **POLYVINYUDENE FLUORIDE (PVDF)** DynaMesh-CICAI (FEG Lextiltechnik mbH) DynaMesh-ENDOLAP (FEG Textiltechnik mbH) DynaMesh-Lithtensteiri (FEG Lextiltechnik mbH)	**Resorbable barrier, composite** **PP + glycolide/ε-caprolactone** PHYSIOMESH (Ethicon Inc.) **PP + glycolide/caprolactone/trimethylene carbonate** Parietene DS Composite Mesh (Medtronic) **PP + sodium hyaluronate/carboxymethylcellulose/polyethylene glycol** Sepramesh (Bard/Davol Inc.) Sepramesh IP COMPOSITE (Bard/Davol Inc.) Ventralex ST Hernia Patch (Bard/Davol Inc.) VENTRALIGHT ST Mesh (Bard/Davol Inc.) VENTRIO ST Hernia Patch (Bard/Davol Inc.) **PP + oxidized regenerated cellulose** PROCEED Surgical Mesh (Ethicon Inc.) PROCEED Ventral Patch (PVP) (Ethicon Inc.) **PP + polyvinylpyrrolidone/polyethylene glycol** Adhesix (Cousin Biotech) **PP + omega**-3 **fatty acid** C-QUR Mesh (Atrium Medical Corp.) C-QUR Mosaic Mesh (Atrium Medical Corp.) C-QUR TacShield (Atrium Medical Corp.) C-QUR V-Patch (Atrium Medical Corp.) **PET + type 1 collagen** Parietex Composite (PCO) Mesh (Covidien) Parietex Composite Hiatal (PCO 2H) Mesh (Covidien) Parietex Composite Open Skirt (PCO OS) Mesh (Covidien) Parietex Composite Parastomal (PCO) Mesh (Covidien) Parietex Composite Ventral Patch (Covidien) Symbotex (Covidien) **PTFE + polyglycolic acid/trimethylene carbonate** Gore Synecor Biomaterial (W.L Gore)	

Bare	Barriers and coatings	Reinforced
Combinations **PTFE + PP** Rebound HRD(MMDI) Rebound HRDV(MMDI) **PVDF + PP** DynaMesh-IPOM (FEG Textiltechnik mbH)	Gore Synecor Preperitoneal Biomaterial (W.L. Gore) **Resorbable coating** **Omega-3 fatty acid** C-QUR FX Mesh (Atrium Medical Corp.) C-QUR Lite Mesh (Atrium Medical Corp.) C-QUR CENTRIFX (Atrium Medical Corp.)[a] **Biological tissue-derived** **PP + non-crosslinked porcine small intestine submucosa** Zenapro^{T} (Cook Medical)	

[a]Available in preformed shapes

Permanent synthetic meshes are also commonly paired with resorbable composite barriers, resorbable coatings, or biological tissue-derived barriers (Table 4.1, column 2). Resorbable composite barriers are comprised of a variety of substances, including: sodium hyaluronate/carboxymethylcellulose/polyethylene glycol hydrogel, omega-3 fatty acid, glycolide/caprolactone/trimethylene carbonate, type I collagen, oxidized regenerated cellulose, glycolide/ε-caprolactone, polyvinylpyrrolidone/polyethylene glycol, and polyglycolic acid/trimethylene carbonate. Omega-3 fatty acid coating represents the only resorbable coating currently available (C-QUR™ FX Mesh, C-QUR Lite™ Mesh, and C-QUR™Centrifix Mesh, Atrium/Maquet Getinge Group (Hudson, NH)). In addition, a permanent synthetic base scaffold (polypropylene) has recently been combined with a biological tissue-derived anti-adhesive barrier (non-crosslinked porcine small intestine submucosa), creating a "hybrid" mesh construct that spans both synthetic and biological realms (Zenapro® Hybrid Hernia Repair Device, Cook Medical, Bloomington, IN). Finally, permanent synthetic meshes have also been combined with resorbable fibers (Table 4.1, column 3) such as glycolide/ε-caprolactone or a co-polymer of glycolide and lactide that provide initial mechanical support at the defect site and then gradually resorb, transferring the load back to the native tissue and leaving a permanent scaffold for long-term mechanical support.

The second major category of hernia repair materials includes resorbable polymers such as poly-4-hydroxybutyrate, ultra-pure fibroin derived from silk, polyglycolic acid, a co-polymer of glycolide and lactide, aco-polymer of polyglycolic acid and trimethylene carbonate, and a co-polymer of glycolide, lactide, and trimethylene carbonate (Table 4.2). The majority of scaffolds in this category are available as bare meshes, without coatings, barriers, or reinforcements (Table 4.2, column 1) and are designed to provide initial mechanical support to the defect without the long-term

Table 4.2 Resorbable meshes for hernia repair subdivided by the presence/absence of a barrier, coating, or reinforcing material

Bare	Barriers and coatings
Poly-4-hydroxybutyrate (P4HB) Phasix™ Mesh (Bard/Davol Inc.) **Ultra-pure fibroin from silk** Seri Scaffold (Sofregen Medical) **Polyglycolic acid (PGA)** Safil Mesh (B Braun) **Co-polymer of glycolide and lactide** DEXON Mesh (Covidien) VICRYL Knitted/Woven Mesh (Ethicon Inc.) **Co-polymer of polyglycolic acid and trimethylene carbonate** BIO-A Tissue Reinforcement (W.L. Gore & Assoc. Inc.) BIO-A Hernia Plug (W.L. Gore & Assoc. Inc.) **Co-polymer of glycolide, lactide, and trimethylene carbonate** TIGR Matrix Surgical Mesh (Insightra Medical)	**Resorbable barrier, composite** **P4HB + hydrogel (sodium hyaluronate, carboxymethylcellulose, and polyethylene glycol** Phasix™ ST Mesh (Bard/Davol Inc.)

presence of a permanent implant. There is currently a single fully resorbable composite mesh with a resorbable barrier layer (Table 4.2, column 2) that deserves mention as a particularly unique design. This device is comprised of a biologically derived resorbable base scaffold of poly-4-hydroxybutyrate paired with a resorbable composite barrier layer containing a hydrogel of sodium hyaluronate/carboxymethylcellulose/polyethylene glycol (Phasix™ ST Mesh, C. R. Bard, Inc./Davol, Warwick, RI).

The third fundamental category of hernia repair materials encompasses biological tissue-derived scaffolds, which are comprised of extracellular matrices (ECM) derived from dermis, pericardium, rumen, and small intestine submucosa of human, porcine, bovine, and ovine sources (Table 4.3). The tissues are subjected to several processing steps including decellularization and sterilization to remove native cells and improve biocompatibility. Some of these materials are also intentionally crosslinked in an effort to improve the mechanical strength of the scaffold and resistance to enzymatic degradation. As with the other categories described above, the majority of scaffolds in this category are bare meshes, without coatings, barriers, or reinforcements (Table 4.3, column 1). However, there are two unique designs that warrant discussion. The first is comprised of a non-crosslinked porcine dermis scaffold combined with an antimicrobial coating of rifampin/minocycline (Table 4.3,

Table 4.3 Biological tissue-derived scaffolds for hernia repair subdivided by the presence/absence of a barrier, coating, or reinforcing material

Bare	Barriers and coatings	Reinforced
Non-crosslinked	**Non-crosslinked**	**Non-crosslinked, ovine rumen**
Bovine (fetal) dermis	**Porcine dermis + antimicrobial coating (rifampin/minocycline)**	**Permanent fibers (polypropylene)**
SurgiMend Collagen Matrix (TEI Biosciences Inc.)	XenMatrix™ AB Surgical Graft (Bard/Davol Inc.)	OviTex Reinforced BioScaffold with Permanent Polymer (TELA Bio)
Bovine pericardium		**Permanent fibers + barrier (polypropylene)**
Veritas® Collagen Matrix (Insightra)		OviTex 1S Reinforced BioScaffold with Permanent Polymer (TELA Bio)
		OviTex 2S Reinforced BioScaffold with Permanent Polymer (TELA Bio)
Human dermis		
AlloDerm Tissue Matrix (LifeCell Corp.)		**Resorbable fibers (polyglycolic acid)**
AlloMax Surgical Graft (Bard/Davol Inc.)		OviTex Reinforced BioScaffold with Resorbable Polymer (TELA Bio)
FlexHD Acellular Dermis (MTF/Ethicon Inc.)		
DermaMatrix Acellular Dermis (Synthes Inc.)		**Resorbable fibers + barrier (polyglycolic acid)**
		OviTex 1S Reinforced BioScaffold with Resorbable Polymer (TELA Bio)
		OviTex 2S Reinforced BioScaffold with Resorbable Polymer (TELA Bio)
Porcine dermis		
Fortiva (RTI Biologics)		
Strattice Reconstructive Tissue Matrix (LifeCell Corp.)		
XCM Biologic Tissue Matrix (Ethicon)		
XenMatrix™ Surgical Graft (Bard/Davol Inc.)		
Porcine liver		
Miromesh Biologic Matrix (Miromatrix Medical Inc.)		

(continued)

Table 4.3 (continued)

Bare	Barriers and coatings	Reinforced
Porcine mesothelial matrix Medeor Matrix (Kensey Nash Corp.) Meso BioMatrix Scaffold (Kensey Nash Corp.) **Porcine small intestine submucosa** Surgisis/Biodesign Hernia Grafts (Cook Medical) Surgisis FM/Biodesign Hernia Grafts (Cook Medical) **Porcine urinary bladder** MatriStem (ACell, Inc.) **Crosslinked** **Bovine pericardium** Peri-Guard Repair Patch (Synovis) Supple Peri-Guard Repair Patch (Synovis) **Porcine dermis** CollaMend Implant (Bard/Davol Inc.) CollaMend FM Implant (Bard/Davol Inc.) Permacol Surgical Implant (Covidien) **Porcine pericardium** XI-S+™ (Colorado Therapeutics LLC)		

column 2) designed to reduce or inhibit microbial colonization (XenMatrix™ AB Surgical Graft, C. R. Bard, Inc./Davol, Warwick, RI). The second is a series of ovine rumen ECM-based products that are reinforced with permanent or resorbable polymer fibers, with or without barrier layers (Table 4.3, column 3) (OviTex™ product line, TELA Bio, Malvern, PA). These "hybrid" mesh constructs span both synthetic and biological realms, and as such, provide unique characteristics and benefits. In the case of the OviTex™ Core Reinforced BioScaffolds with Permanent Polymer, four ovine rumen ECM layers are reinforced with a sewn 6 mm pattern of

permanent synthetic polypropylene fibers. To this, the OviTex™ 1S and OviTex™ 2S Reinforced BioScaffolds with Permanent Polymer designs (TELA Bio, Inc., Malvern, PA) add two additional layers of ECM with a 25 mm pattern on either one or both sides for a total of 6 or 8 layers per implant, respectively. The additional layers serve as barriers. In these designs, the biological tissue-derived matrix is eventually remodeled, leaving behind only the permanent polypropylene fibers or layer. Alternatively, the ovine rumen ECM is reinforced with resorbable polyglycolic acid fibers in the OviTex™Core Reinforced BioScaffolds with Resorbable Polymer design. Here again, the OviTex™ 1S and OviTex™ 2S Reinforced BioScaffolds with Resorbable Polymer designs (TELA Bio, Inc., Malvern, PA) add two layers on one or both sides, creating fully resorbable, reinforced constructs. This design strategy seeks to optimize initial support of the defect without the disadvantages of a long-term, permanent implant.

In addition to composition, surgeons must also understand the physical and mechanical characteristics associated with these materials in order to inform mesh selection. Physical characteristics such as pore size/filament diameter, thickness, and area density are typically determined through morphometric analysis, laser micrometry, and the use of an electronic balance, respectively [7, 8]. The physical properties of hernia repair materials have previously been defined along a continuum of increasing foreign material in order to unify the terminology used to describe these biomaterials and to provide insight into the amount of foreign material in a given design [7, 8]. Pore size was previously defined as microporous (diameter: <100 μm; area: <0.008 mm^2), small pores (diameter: 100–600 μm; area: 0.008–0.28 mm^2), medium pores (diameter: 600–1000 μm; area: 0.28–0.79 mm^2), large pores (diameter: 1000–2000 μm; area: 0.79–3.14 mm^2), or very large pores (diameter: >2000 μm; area: >3.14 mm^2). Fiber diameter was defined as very large (>200 μm), large (175–200 μm), medium (150–175 μm), small (125–150 μm), or very small (<125 μm). Thickness was defined as extra thick (>1.5 mm), thick (1.0–1.5 mm), medium (0.75–1.0 mm), thin (0.5–0.75), or very thin (<0.5 mm). Finally, area density was defined as heavy-weight (>90 g/m^2), medium-weight (50–90 g/m^2), light-weight (35–50 g/m^2), and ultra-light-weight (<35 g/m^2). Multiple clinical studies have documented improved abdominal compliance with less restriction, pain, and foreign body sensation with increasing pore size and decreasing area density [9–11]. These results are confirmed in the preclinical literature: Klinge et al. reported improved tissue integration with less inflammation associated with an ultra-light-weight, large pore mesh compared to a heavy-weight, small pore mesh in a rat model [12]. Similarly, Lake et al. reported a significant impact of pore size and shape in a porcine study of prototype meshes with varying pore size, shape, and area density [13]; tissue ingrowth strength, as well as neovascularization and fibrosis, were significantly improved in meshes with larger pores, particularly those of a hexagonal shape.

In addition to physical characteristics, mechanical characteristics play an important role in hernia repair. Mechanical properties of mesh materials are determined through a variety of techniques, including suture retention, tear resistance, ball burst, uniaxial tensile, and planar biaxial tensile testing [7, 8, 14]. Suture retention

testing is performed by passing a suture surrogate, typically a stainless steel wire, through the material 1 cm from the edge and applying tension to the material until failure occurs. Suture retention strength is defined as the maximum load sustained prior to failure [7, 8]. Tear resistance testing is typically performed in an effort to understand the resistance that a material provides against the propagation of a tear once a tear has been initiated. To accomplish this, a small tear of a defined length (typically 2.54 cm long) is created in the mesh, leaving two tabs on either side of the tear. Tension is applied to the tabs, and the force required to fully propagate the tear across the mesh is recorded as the tear resistance strength [7, 8]. Ball burst testing is another common method of material characterization. In ball burst testing, the mesh is clamped in a test fixture, and a stainless steel ball is applied against the mesh in compression until failure occurs and the ball bursts through the mesh [7, 8]. Uniaxial tensile testing is accomplished by subjecting a strip of mesh to tension in a single direction, while planar biaxial tensile testing applies tension in two, orthogonal directions [7, 8, 14]. Material properties such as ultimate tensile strength, stiffness, and strain can be calculated from ball burst testing. In addition to these properties, tensile testing can also quantify anisotropy (i.e., direction dependence of the mechanical response). Planar biaxial testing realistically simulates the conditions of the human abdomen and provides additional insight into properties such as nonlinearity and hysteresis, providing a significant advantage over other methods of testing.

Guidelines for appropriate mechanical properties of biomaterials utilized for hernia repair applications have been derived from the results of both preclinical studies and theoretical calculations. In a bench top study in which hernia repair materials were attached to porcine abdominal wall tissue with various fixation devices, Melman et al. reported that a single polypropylene suture resisted a maximum load of 20 N when the mesh-tissue construct was subjected to lap shear testing [15]. Failure occurred in the porcine tissue, while the mesh remained intact. It was therefore recommended that hernia repair materials withstand at least 20 N at each suture point in order to reinforce the tissue to which it is attached. This rationale was also extended to guidelines for tear resistance values. In another series of studies, the human abdomen was modeled as a thin-walled pressure vessel [7, 8]. A range of possible tensile stress values were calculated when intra-abdominal pressure and abdominal circumference were varied to account for a range of possible patient scenarios. The largest abdominal circumference with the greatest intra-abdominal pressure resulted in the greatest tensile stress on the human abdomen (47.8 N/cm); a threshold value of 50 N/cm (ball burst strength) was selected to account for this theoretical scenario. Specimens of abdominal wall tissue obtained from human cadavers exhibited strain values in the range of 10–30% during tensile testing, leading Junge et al. to recommend this range of values for hernia repair applications [16].

The physical and mechanical characteristics of over 50 hernia repair materials have been comprehensively characterized by our group [7, 8, 14, 17–22] and others [12, 23–41] and are summarized in Tables 4.4 and 4.5 [4]. These tables demonstrate the wide range of both physical and mechanical properties available in current hernia repair materials, with the greatest variation apparent in the values reported for

Table 4.4 Summary of the physical properties of a subset of available hernia repair materials, including pore size/filament diameter, thickness, and area density

	Diameter of pores (mm)	Area of pores (mm^2)	Diameter of fibers (μm)	Thickness (mm)	Density (g/m^2)	References
Permanent synthetic						
Bare						
Bard Mesh		0.44–0.58	185.7	0.73–0.76	102.4–105	[8, 27]
Bard Soft Mesh	2.5				44	[28, 29]
Dyna-Mesh		4.16			36	[23]
INFINIT		4	116.2	0.16	65.6–70	[8, 23]
Marlex	0.46			0.63	95	[12, 29–31]
MERSILENE Mesh	1.0				33–40	[29, 32, 33]
Optilene Mesh	1.0	7.64			36–48	[23, 28, 29, 34]
Parietene	1.0–1.6			0.53	77–78	[29, 30, 35]
Parietene Light	1.5–1.7			0.36	36–38	[28–30, 36]
Parietex Flat Sheet 2D Mesh (TEC)	2.0	1.75	338.8	0.52–0.53	100–119.2	[8, 30]
Parietex (TECR)	2.0			0.53	120	[30]
PROLENE Mesh	0.8–1.6	0.39	130.4	0.51–0.53	79.5–108	[8, 29–32, 37]
ProLite Mesh	0.8	0.33	151.2	0.47	85–90	[8, 29, 31, 38]
ProLite Ultra Mesh		0.34	99.0	0.39	50.1	[8]
Serapren	0.08–0.1				116	[29, 37]
Surgipro	0.8	0.26		0.57	84–110	[23, 29–31]
Trelex	0.35–0.6				95	[29, 32, 38]
Permanent barrier, non-composite						
DUALMESH Biomaterial	0.003/0.022	n/a	n/a	1.18	320–420	[7, 29, 39, 41]
MYCROMESH	0.025/0.3					[29, 40]
Permanent barrier, composite						
Composix E/X		0.43	183.70	0.89	255.80	[7]
Composix L/P		6.07	163.20	0.69	187.40	[7]
Permanent coating						
TIMESH Extralight	1.24			0.21	16	[30]
TIMESH Light	1.24			0.29	33	[30]
Resorbable barrier, composite						
C-QUR Mesh		0.33	151.2	0.56	321.0	[7]
Parietex Composite (PCO)		3.68	160.20	0.76	155.90	[7]
PROCEED		5.46	96.85	0.57	189.50	[7]

(continued)

Table 4.4 (continued)

	Diameter of pores (mm)	Area of pores (mm^2)	Diameter of fibers (μm)	Thickness (mm)	Density (g/m^2)	References
Sepramesh IP Composite		0.40	155.70	0.82	240.60	[7]
Resorbable coating						
C-QUR Lite Mesh (≤6 in. size mesh)		0.34	99.00	0.28	69.19	[8]
C-QUR Lite Mesh (>6 in. size mesh)		0.33	151.20	0.46	128.70	[8]
Reinforced—resorbable fibers						
ULTRAPRO	2.28	3.45–4.10	102.5	0.44–0.5	28–58	[8, 23, 30]
VYPRO	3.0			0.34	26	[30]
VYPRO II	2.6			0.39	40	[30]
Resorbable synthetic						
Bare						
BIO-A Tissue Reinforcement			33.8	1.57		[22]
TIGR Matrix Surgical Mesh		1	~13	~0.5		[22, 23]
VICRYL			13.1	0.07		[22]
PHASIX Mesh		0.26		0.51	182	[27]
Biological tissue-derived						
Bare						
AlloDerm Tissue Matrix	n/a	n/a	n/a	2.02	n/a	[64]
AlloMax Surgical Graft	n/a	n/a	n/a	1.29	n/a	[64]
CollaMend Implant	n/a	n/a	n/a	1.22	n/a	[64]
CollaMend FM Implant	n/a	n/a	n/a	1.34	n/a	[64]
FlexHD Acellular Dermis	n/a	n/a	n/a	1.15	n/a	[64]
Peri-Guard Repair Patch	n/a	n/a	n/a	0.47	n/a	[64]
Permacol Surgical Implant	n/a	n/a	n/a	0.91	n/a	[64]
Strattice Reconstructive Tissue Matrix	n/a	n/a	n/a	1.76	n/a	[64]
SurgiMend Collagen Matrix	n/a	n/a	n/a	0.84	n/a	[64]
Surgisis/ Biodesign Hernia Grafts	n/a	n/a	n/a	1.37	n/a	[64]

Table 4.4 (continued)

	Diameter of pores (mm)	Area of pores (mm^2)	Diameter of fibers (μm)	Thickness (mm)	Density (g/m^2)	References
Veritas Collagen Matrix	n/a	n/a	n/a	0.80	n/a	[64]
XenMatrix Surgical Graft	n/a	n/a	n/a	1.95	n/a	[64]

Physical characteristics vary widely between designs, and many designs have yet to be evaluated

Table 4.5 Summary of the mechanical properties of a subset of available hernia repair materials derived from suture retention, tear resistance, ball burst, uniaxial, and planar biaxial testing

		Suture retention (N)		Tear resistance (N)		Uniaxial tensile strength (MPa)		References
		L	T	L	T	L	T	
Permanent synthetic meshes								
Bare								
Bard Mesh		50.78	66.8	46.84	38.36	11.64	0.16	[8, 14]
Bard Soft Mesh								[14]
Dyna-Mesh								[23]
INFINIT		26.71	32.36	14.29	16.35	13.6	7.36	[8, 14, 23]
Optilene Mesh								[23]
Parietex Flat Sheet 2D Mesh (TEC)		51.4	58.38	32.66	28.6	6.63	15.51	[8]
PROLENE Mesh		61.2	70.49	33.66	39.33	0.76	16.06	[8, 14]
ProLite Mesh		48.75	57.71	33.35	33.10	11.64	0.16	[8, 14]
ProLite Ultra Mesh		36.07	23.89	19.27	17.84	11.40	4.90	[8, 14]
Surgipro								[23]
Permanent barrier, noncomposite								
DUALMESH Biomaterial		65.18	72.95	30.47	41.28	7.52	5.52	[7, 14]
Permanent barrier, composite								
Composix E/X		70.47	60.28	30.14	48.75	1.44	10.74	[7]
Composix L/P		34.04	48.58	32.76	16.96	6.10	1.48	[7]
Resorbable barrier, composite								
C-QUR Mesh		41.78	62.75	25.79	30.79	1.73	4.74	[7, 14]
Parietex Composite (PCO)		28.15	36.32	19.74	16.21	2.56	1.03	[7, 14]
PHSIOMESH								[14]

(continued)

Table 4.5 (continued)

		Suture retention (N)		Tear resistance (N)		Uniaxial tensile strength (MPa)		References
		L	T	L	T	L	T	
PROCEED		34.06	41.62	19.84	20.19	4.44	4.78	[7, 14]
Sepramesh IP Composite		99.22	85.89	51.07	54.18	4.38	2.64	[7]
Ventralight ST								[14]
Resorbable coating								
C-QUR Lite Mesh (≤6 in.)		22.86	33.83	19.36	18.35	1.11	2.56	[8]
C-QUR Lite Mesh (>6 in.)		61.83	40.00	35.04	42.77	13.75	3.52	[8]
Biological tissue-derived barrier								
OviTex 1S		~60						[26]
OviTex 2S		~75						[26]
Resorbable fibers								
ULTRAPRO		15.08	16.	10.47	5.07	13.52	0.08	[8, 14, 23]
Resorbable Synthetic								
Bare								
BIO-A Tissue Reinforcement		~45		16.6		~4.5		[22]
TIGR Matrix Surgical Mesh		~45	59.0	~30	33.3	~7	0.2	[22, 23]
VICRYL		39.4		~25		145.2		[22]
PHASIX Mesh		59.2	49.1	30.3	29.5			[18]
Biological tissue-derived								
Bare								
AlloDerm Tissue Matrix		127.2		84.73		20.32		[64]
AlloMax Surgical Graft		29.09		16.86		14.36		[64]
CollaMend Implant		47.90		17.13		11.48		[64]
CollaMend FM Implant		37.53		13.21		10.65		[64]
FlexHD Acellular Dermis		55.34		31.05		14.36		[64]
Peri-Guard Repair Patch		30.54		14.34		21.51		[64]
Permacol Surgical Implant		23.75		10.1		8.22		[64]
Strattice Reconstructive Tissue Matrix		63.76		27.54		9.92		[64]
SurgiMend Collagen Matrix		87.85		27.86		28.54		[64]
Surgisis/Biodesign Hernia Grafts		50.29		32.13		2.53		[64]
Veritas Collagen Matrix		23.92		15.06		9.38		[64]
XenMatrix Surgical Graft		99.74		24.5		11.95		[64]
Reinforced								
Permanent fibers	OviTex Reinforced BioScaffold with Permanent Polymer	~42						[26]

Table 4.5 (continued)

		Suture retention (N)		Tear resistance (N)		Uniaxial tensile strength (MPa)		References
		L	T	L	T	L	T	
Resorbable fibers	OviTex Reinforced BioScaffold with Resorbable Polymer	~42						[26]

		Ball burst		Planar biaxial tensile			
		Tensile strength (N/cm)	Strain (%)	Stiffness (N/cm)	Stiffness (N/cm)	Anisotropy index	References
Permanent synthetic meshes							
Bare							
Bard Mesh		157.7	10.76	75.69	37.53	2.03	[8, 14]
Bard Soft Mesh				124.53	52.89	2.36	[14]
Dyna-Mesh				190.1	100.1	1.84	[23]
INFINIT		9.25	n/a	168.40-479.1	119.83-139.7	1.42-3.3	[8, 14, 23]
Optilene Mesh				191.1	100.1	1.82	[23]
Parietex Flat Sheet 2D Mesh (TEC)		112.90	3.49				[8]
PROLENE Mesh		156.60	5.27	180.04	143.42	1.26	[8, 14]
ProLite Mesh		138.00	9.61	106.19	82.97	1.29	[8, 14]
ProLite Ultra Mesh		50.72	16.35	92.24	76.36	1.21	[8, 14]
Surgipro				148.7	128.5	1.18	[23]
Permanent barrier, noncomposite							
DUALMESH Biomaterial		97.76	10.24	137.59	125.97	1.08	[7, 14]
Permanent barrier, composite							
Composix E/X		237.8	9.62				[7]
Composix L/P		76.77	11.06				[7]
Resorbable barrier, composite							
C-QUR Mesh		144.30	9.07	177.00	177.78	1.00	[7, 14]
Parietex Composite (PCO)		38.87	6.46	178.13	119.34	1.50	[7, 14]
PHSIOMESH				168.91	151.62	1.12	[14]
PROCEED		52.60	7.25	129.72	128.34	1.01	[7, 14]
Sepramesh IP Composite		200.7	3.68				[7]
Ventralight ST				123.57	50.82	2.43	[14]
Resorbable coating							
C-QUR Lite Mesh (≤6 in.)		50.53	13.22				[8]
C-QUR Lite Mesh (>6 in.)		170.00	11.32				[8]
Biological tissue-derived barrier							
OviTex 1S							[26]
OviTex 2S							[26]
Resorbable fibers							
ULTRAPRO		35.50	16.23	98.63-171.2	53.01-79.6	1.87-2.17	[8, 14, 23]

(continued)

Table 4.5 (continued)

		Ball burst		Planar biaxial tensile			
		Tensile strength (N/cm)	Strain (%)	Stiffness (N/cm)	Stiffness (N/cm)	Anisotropy index	References
Resorbable synthetic							
Bare							
BIO-A Tissue Reinforcement		74.9	7.3				[22]
TIGR Matrix Surgical Mesh		86.5	<10	409.2	272.4	1.47	[22, 23]
VICRYL		~70	5.8				[22]
PHASIX Mesh		140.7	15.4				[18]
Biological tissue-derived							
Bare							
AlloDerm Tissue Matrix		1028.00	17.02				[64]
AlloMax Surgical Graft		290.80	26.22				[64]
CollaMend Implant		110.3	5.85				[64]
CollaMend FM Implant		86.18	13.58				[64]
FlexHD Acellular Dermis		929.50	21.20				[64]
Peri-Guard Repair Patch		99.05	20.05				[64]
Permacol Surgical Implant		66.23	13.1				[64]
Strattice Reconstructive Tissue Matrix		270.5	9.59				[64]
SurgiMend Collagen Matrix		432.4	6.41				[64]
Surgisis/Biodesign Hernia Grafts		200.2	13.57				[64]
Veritas Collagen Matrix		128.6	25.6				[64]
XenMatrix Surgical Graft		377.0	11.59				[64]
Reinforced							
Permanent fibers	OviTex Reinforced BioScaffold with Permanent Polymer						[26]
Resorbable fibers	OviTex Reinforced BioScaffold with Resorbable Polymer						[26]

Many current mesh materials meet or exceed the threshold mechanical strength values previously recommended by our group, but it remains unclear whether these characteristics represent the optimal match to the nuanced and complex mechanical properties of the human abdominal wall

anisotropy, nonlinearity, and hysteresis [14]. Guidelines for these parameters have not yet been established, and studies in this area represent the next significant advancement in understanding and optimizing the mechanical match of hernia repair materials to repair-site tissue. Additionally, direct comparisons across studies are limited due to differences in specimen dimensions/orientation, testing rate, and equipment setup, as well as differences in data analysis and reporting. While it is clear that many current mesh materials meet or exceed the threshold values previously recommended by our group—suture retention and tear resistance strength >20 N, ball burst strength >50 N/cm, and strain in the range of 10–30%—it is unclear whether these characteristics represent the optimal match to the nuanced and complex mechanical properties of the human abdominal wall. Furthermore, mechanics of human tissue are likely to vary with patient demographics (i.e., age, gender, BMI) and clinical state (i.e., healthy, fibrotic, herniated), thereby increasing the challenge of matching mesh mechanical properties to specific properties of individual patients.

Many factors such as mesh-defect overlap [42–45], surgical technique (e.g., closure of the anterior myofascial layer) [42–45], fixation strategy [45, 46], and wound healing/inflammatory response [47–50] have been identified as factors impacting the success of a particular hernia repair, yet, the impact of a mechanical match between the implanted device and the properties of the human abdominal wall is nearly devoid of research. We have previously presented a comprehensive review of the anatomy and mechanics of both animal and human abdominal wall tissues in an effort to understand the potential mismatch of mechanical properties between tissues and biomaterials [4]. A full discussion is outside the scope of the current chapter; however, a few key points are summarized here. When human abdominal tissues were tested in a longitudinal (i.e., cranial-caudal) orientation, the linea alba exhibited greater compliance [51], the intact abdominal wall exhibited greater strain [16], and the rectus sheath and umbilical fascia both exhibited greater stiffness compared to tissues tested in a transverse (i.e., medial-lateral) orientation [52–57]. When tested in the transverse orientation, the linea alba sustained greater stresses than the longitudinal orientation [52, 58, 59]. Taken together, these findings suggest that meshes should be oriented in the body with the most compliant axis in the longitudinal orientation and the strongest axis in the transverse orientation. As mentioned previously, the impact of mismatched anisotropy is currently unknown, but it cannot be ignored that anisotropy ratios of 8–9 have been reported for human abdominal wall tissues [60] compared to values of 1–3 reported for many biomaterials [4, 14]. This represents an area of potential mechanical mismatch between mesh and tissue which should be explored in future studies. Studies have also shown that tissues such as linea alba [52, 58–60], rectus sheath [53, 54, 61], and the intact abdomen [16, 62, 63] exhibit many differences in mechanical properties, suggesting that implantation location may also play a key role in the success or failure of a biomaterial. In summary, the mechanical characteristics of both the human abdominal wall and hernia biomaterials are incompletely understood, and additional studies are warranted to establish guidelines for the ideal characteristics of these biomaterials, such as anisotropy, compliance, strength, and hysteresis.

Conclusions

Hernia repair materials have advanced over the past 80 years to include over 150 designs at present. The structural scaffold element of these biomaterials includes permanent synthetic polymers, resorbable polymers, and biological tissue-derived materials, and various designs also contain coatings, barrier layers, or reinforcing materials. Physical characteristics such as pore size/filament diameter, thickness, and area density vary widely between designs and have previously been classified along a continuum of increasing material to provide insight into the amount of material in a given design. Although many current mesh materials meet or exceed the threshold mechanical strength values previously recommended by our group, it is unclear whether these characteristics represent the optimal match to the nuanced and complex mechanical properties of the human abdominal wall. It is unlikely that any single biomaterial design encompasses all of the ideal physical and mechanical characteristics required to fully match the properties of the human abdominal wall. A complete set of guidelines, including strength, compliance, anisotropy, nonlinearity, and hysteresis should be established through continued testing of human abdominal wall tissue specimens and sophisticated modeling efforts.

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Permanent Prosthetics: Polypropylene, Polyester, ePTFE, and Hybrid Mesh

5

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Introduction

While primary suture repair remains an option for select hernias, mesh prosthetics have shown to greatly reduce the incidence of hernia recurrence [1, 2]. Because of this significant benefit, the vast majority of modern hernia repairs utilize some form of mesh reinforcement. Surgeons strive to find and utilize the "ideal" mesh. Up until relatively recently, little has changed over the last half century with regard to the evolution of mesh. Dr. Francis Usher popularized the use of polypropylene mesh in the 1950s, [3] while Dr. René Stoppa and Dr. Jean Rives published their use of polyester meshes in the 1980s, among other great surgeons using various mesh prosthetics [4]. Currently, polypropylene and polyester remain the most commonly utilized materials in modern meshes, with a reduction in the use of expanded polytetrafluorethylene (ePTFE). Newer synthetic materials have been developed, including polyvinylidene fluoride (PVDF); however, long-term data is still being accrued. A variety of composite and hybrid meshes have also been developed that share characteristics of different materials to aid in mesh integration, impede adhesion formation, and/or provide some degree of resorption.

Mesh prosthetics strengthen hernia repairs and reduce hernia recurrences via two principal mechanisms: structural support and as a scaffold for ingrowth. The first mechanism is obvious—the mesh acts as a physical barrier to prevent herniation of contents. But, it also acts as a load-bearing structure, taking tension off the hernia upon fascial closure. Additional strength of the repair is aided by cellular ingrowth within the mesh. By allowing an influx of cellular components, the mesh facilitates fibroblast proliferation with neovascularization, followed by fibrotic scar formation, thus assisting with mesh incorporation and overall strength of the repair. While this

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process is mostly beneficial, excessive fibrosis can be a detriment, with resultant encapsulation, mesh shrinkage, increased stiffness, and undesirable symptoms for the patient [5]. Conversely, insufficient cellular ingrowth and fibrosis can lead to poor mesh integration, mesh folding, central mesh failure, and ensuing hernia recurrence. This chapter will review commonly used meshes and their various characteristics, including material, density, and porosity, among other attributes that contribute to incorporation of the mesh upon implantation.

Synthetic Mesh Characteristics (Table 5.1)

Most prosthetic materials, although chemically inert, generate an intense host inflammatory reaction upon implantation. The host response to implanted prosthetic biomaterials follows a typical sequence of events, namely, coagulation, inflammation, neovascularization, fibroplasia, matrix deposition, and wound contraction. Exaggerated inflammatory responses with its downstream effects can lead to significant clinical sequelae, including excessive fibrosis and persistent foreign body response. In the long term, such acquired rigidity of implanted meshes can contribute to changes in compliance of both the hernia site and the entire abdominal wall. Clinically, this decrease in compliance can lead to a sensation of stiffness and result in both physical discomfort and limitations in the activities of daily living for some patients. The deleterious foreign body effects of synthetic meshes are related to the amount of foreign body implanted. As a result, a goal of modern mesh manufacturers has been the development of prosthetic implants that are able to meet the tensile demands of the abdominal wall while limiting the foreign body burden at the site of the repair. As a theme of modern meshes, a reduction of the overall density/weight of the mesh implant has been shown to be associated with an increase in biocompatibility of the prosthetic [5].

Material

Polypropylene (PP) remains the most commonly utilized polymer of hernia meshes, and is manufactured by most companies that produce surgical meshes, even if they manufacture other materials. It has the longest track record of any mesh material, being used for over 60 years, and has demonstrated long-term durability. Polypropylene remains popular due to its high tensile strength, durability, pliability, and ease of use at time of repair. However, traditional (heavyweight) polypropylene can induce a strong inflammatory reaction. Excessive inflammation can lead to high levels of fibrosis, loss of pliability, chronic pain, as well as intolerance to infection. Modern lightweight polypropylene meshes obviate many of these drawbacks, with reduced inflammation and its sequelae (discussed below). Also, if exposed to viscera, uncoated polypropylene can lead to significant adhesive disease and/or fistulae.

Table 5.1 Synthetic mesh characteristics

Material	Mesh product	Manufacturer	Mesh characteristics
Standard Permanent meshes			
Polypropylene (PP)	Surgipro™	US Surgical/ Covidien/ Medtronic	Heavyweight—110 g/m^2 Microporous—0.6–0.8 mm
	Prolene™	Ethicon	Heavyweight—105 g/m^2 Microporous—0.8+ mm
	Prolene Soft™	Ethicon	Lightweight—45 g/m^2 Macroporous—2.4 mm
	Marlex	CR Bard	Heavyweight—95 g/m^2 Microporous—0.5 mm
	Bard Mesh™	Bard-Davol	Heavyweight—95 g/m^2 Microporous—0.46 mm
	Bard Soft Mesh™	Bard-Davol	Lightweight—44 g/m^2 Macroporous—2.5 mm
	Trelex®	Boston Scientific	Heavyweight—95 g/m^2 Microporous—0.6 mm
	ProLite™	Atrium	Medium weight—85 g/m^2 Microporous—0.8 mm
	ProLite Ultra™	Atrium	Medium weight—50 g/m^2 Microporous—0.75 mm
	Parietene™	Covidien/ Medtronic	Medium weight—78 g/m^2 Microporous—1.0–1.6 mm
	Parietene™ Macroporous	Covidien/ Medtronic	Medium weight—46 g/m^2 Microporous—2.0–2.4 mm
	DynaMesh®-PP standard	DynaMesh	Medium weight—72 g/m^2 Macroporous—1.4–1.8 mm
	DynaMesh®-PP light	DynaMesh	Ultralightweight—36 g/m^2 Macroporous—1.6–2.6 mm
Polyester (PET)	Parietex™	US Surgical/ Covidien/ Medtronic	3-D multifilament PET mesh Medium weight—78 g/m^2 Macroporous—1.0–1.6 mm
	Mersilene	Ethicon	2-D multifilament PET mesh Lightweight—33–40 g/m^2 Macroporous—1.0 mm
	Parietex™ Lightweight	Covidien/ Medtronic	Monofilament PET mesh Medium weight—46 g/m^2 Macroporous—1.5 mm
	Versatex™	Medtronic	Monofilament PET mesh Medium weight—64 g/m^2 Macroporous—2.1–3.0 mm
Polytetrafluoroethylene (PTFE)	Infinit	WL Gore	Medium weight—65–70 g/m^2 Macroporous—unknown mm[a]
Polyvinylidene fluoride (PVDF)	DynaMesh®	DynaMesh	Density—unknown[a] Porosity—unknown[a]

(continued)

Table 5.1 (continued)

Material	Mesh product	Manufacturer	Mesh characteristics
Partially resorbable composite meshes			
Polypropylene with poliglecaprone	Ultrapro™	Ethicon	Ultralightweight—28 g/m^2 (~40 g/m^2 out of package before poliglecaprone resorption) Macroporous—2.0–4.0 mm
Polypropylene with polyglactin	Vypro II	Ethicon	Lightweight—35 Macroporous—3.4 mm
Polyester with polylactic acid (PLA) microgrips	ProGrip™	Covidien/ Medtronic	Monofilament polyester with PLA microgrips Medium weight—38 g/m^2 (73 g/m^2 out of package before PLA microgrip absorption) Macroporous—1.1–1.7 mm
Polyester with polylactic acid (PLA) microgrips	ProGrip™ Laparoscopic	Covidien/ Medtronic	Monofilament polyester with PLA microgrips Medium weight—49 g/m^2 (82 g/m^2 out of package before PLA microgrip absorption) Macroporous—1.8 mm
Anti-adhesion and coated composite meshes			
Expanded polytetrafluoroethylene (ePTFE)	DualMesh®	WL Gore	(solid laminar sheet) 2-sided: micro- and macroporous[a]
	Dulex™	Bard-Davol	(solid laminar sheet) 2-sided: micro- and macroporous[a]
Polypropylene mesh and ePTFE	Composix E/ X™	Bard-Davol	Heavyweight, microporous polypropylene (abdominal wall surface) and microporous ePTFE (anti-adhesion)
	Composix L/ P™	Bard-Davol	Lightweight, macroporous polypropylene (abdominal wall surface) and microporous ePTFE (anti-adhesion)
	Ventralex™	Bard-Davol	Patch designed for smaller defects (e.g., umbilical, port site hernias) Weight/pore size—unknown[a]
Polypropylene and polyglycolic acid (PGA) mesh + carboxymethylcellulose-sodium hyaluronate-polyethylene glycol (CMC-HA-PEG) coating	Sepramesh™	Bard-Davol	Medium weight Macroporous polypropylene Heavyweight—102 g/m^2 Pore size—unknown[a]
	Ventralex ST™	Bard-Davol	Patch designed for smaller defects (e.g., umbilical, port site hernias) Weight/pore size—unknown[a]
	Ventralight ST™	Bard-Davol	Medium weight Macroporous polypropylene Weight/pore size—unknown[a]

Table 5.1 (continued)

Material	Mesh product	Manufacturer	Mesh characteristics
Polypropylene mesh + poliglecaprone coating	Physiomesh™	Ethicon	Light or ultralightweight—(estimated 28–40 g/m^2)[a] Macroporous—unknown mm[a]
Polypropylene and polydioxanone (PDS) mesh + oxidized regenerated cellulose (ORC) backing	Proceed™	Ethicon	Lightweight—45 g/m^2 Macroporous—unknown mm[a]
Polypropylene mesh + omega-3 fatty acid coating	C-Qur™	Atrium	Medium weight—85 g/m^2 Microporous—0.8 mm
	C-Qur Lite™	Atrium	Medium weight—50 g/m^2 Microporous—0.75+ mm
3-D Polyester + collagen-polyethylene glycol (PEG) coating	Parietex™ Composite	Covidien/ Medtronic	Medium weight—78 g/m^2 Macroporous—1.8 × 1.5 mm
Monofilament polyester + collagen film	Symbotex™ Composite	Medtronic	Medium weight—66 g/m^2 Macroporous—2.3–3.3 mm
Polyvinylidene fluoride (PVDF) + polypropylene	DynaMesh® IPOM	DynaMesh	Medium/ heavyweight—60/108 g/m^2 (PP-60/PP + PVDF 108 for overall effective density of both materials) Macroporous— >1 mm
Polypropylene + titanium (vapor deposition of titanium)	TiMesh™ strong	PFM Medical	Medium weight—65 g/m^2 Macroporous— >1 mm
	TiMesh™ light	PFM Medical	Ultralightweight—35 g/m^2 Macroporous— >1 mm
	TiMesh™ extralight	PFM Medical	Ultralightweight—16 g/m^2 Macroporous— >1 mm
Hybrid Meshes			
Polyester + small intestine submucosa (SIS)	Zenapro®	Cook	Braided polyester backbone with SIS laminate Weight/pore size—unknown[a]
PTFE + PGA:TMC	Synecor	WL Gore	Monofilament PTFE backbone with PGA:TMC 3D matrix and PGA:TMC anti-adhesion film Weight/pore size—unknown[a]

This table represents a summary of commonly utilized hernia meshes. Not every mesh manufactured has been included due to lack of information available, low utilization, etc. Some meshes have been listed for reference that are currently not in use. Information was obtained from manufacturer material as well as published literature. Please note that there are discrepancies among various published values, and manufacturer information was used as the primary source, when available.

Weight/density units, g/m^2. Pore size units, millimeters

[a]Information not available at time of publication

Polyester (polyethylene terephthalate (PET)) is a hydrophilic polymer that, like polypropylene, has a long track record of effectiveness for hernia repair. Traditional polyester meshes are multifilament, based on 2-dimensional (flat) or 3-dimensional constructs. Newer polyester-based meshes have switched to monofilament polyester fibers with the overall goal of increasing biocompatibility. Traditional multifilament polyester meshes are noted to be highly pliable, allowing the surgeon to easily manipulate and conform the mesh to variations of the abdominopelvic walls. Like polypropylene, polyester can lead to significant inflammatory response with ensuing heavy fibrosis, visceral adhesions, and fistulae.

Polytetrafluoroethylene (PTFE) is a carbon- and fluorine-based synthetic hydrophobic polymer. Most people associate PTFE with nonstick cookware (e.g., Teflon). PTFE has been made in two main forms for hernia repair, with most common application in a laminar sheet, or "expanded" PTFE form (ePTFE). However, knit fiber-based PTFE meshes have been developed as well. DualMesh (WL Gore, Newark, DE, USA) is the most widely used solid laminar ePTFE mesh, containing a smooth side as an anti-adhesion barrier and a corrugated side to facilitate ingrowth. ePTFE use has diminished significantly over the last several years, likely due to its lack of resilience in the setting of infection as well as a significant fibrotic and encapsulation response to it. A silver chlorhexidine-impregnated version has also been produced to help reduce infectability.

Polyvinylidene fluoride (PVDF) is a polymer that, despite having been described for well over a decade, [6] it's use within the United States is very limited, with greater utilization in Europe (DynaMesh, Aachen, Germany). One of the principal described benefits of PVDF is the ability to withstand hydrolysis and degradation compared to other materials such as PP or PET, and additional studies have demonstrated reduced foreign body response to PVDF [6, 7].

Regarding the biologic study of mesh implants, although tissue reactions of biomaterials vary greatly throughout the literature, experience in animal studies demonstrates that polyester-based meshes are a significant inducer of inflammation and appear to induce a severe chronic foreign body reaction [5]. While polypropylene meshes also demonstrate significant inflammation and some degree of foreign body response, the severity is strikingly less when compared to polyester-based implants. Compared to the fiber-based mesh constructs, integration of laminar ePTFE mesh within tissues was met more with heavy fibrosis and encapsulation instead of integration. This has been seen in in vivo studies and clinically with excised samples of previously implanted ePTFE demonstrating significant heavy fibrosis. In addition, decreased ability for inter-mesh neovascularization may predispose ePTFE mesh to diminished biocompatibility. Heavy fibrosis and encapsulation often leads to mesh shrinkage. Overall, of the more commonly used polymers, polypropylene exhibits the highest degree of tissue biocompatibility followed by ePTFE and polyester. The clinical implications of these findings are not entirely clear, and no randomized controlled trials have evaluated these materials in a comparative fashion.

Weight/Density

Mesh density, most commonly termed "weight," is an important determinant of overall structural strength of the mesh. Typically measured in grams per meter squared (g/m^2), mesh weight/density is generally categorized as lightweight, medium weight, and heavyweight, though other terms have been described (e.g., ultralightweight). While various density ranges have been described, commonly published density/weight ranges include [8]:

Heavyweight— >90 g/m^2
Medium weight—50–90 g/m^2
Lightweight—35–50 g/m^2
Ultralightweight— <35 g/m^2

Studies have shown that traditional heavyweight meshes may have been overengineered, with Marlex-type meshes (heavyweight polypropylene) displaying 4–6 times the tensile and burst strength of the native abdominal wall [9]. Such heavyweight meshes induce a significant inflammatory reaction and ensure exaggerated fibrotic response, leading to mesh contraction and excessive hardening of the mesh and surrounding tissues which can lead to chronic pain symptoms [5]. This excessive granulomatous reaction around the mesh fibers led to the development of lighter, less dense mesh, with a combination of smaller caliber fibers and larger spaces (pores) between the mesh fibers (see "Porosity" section below) [9]. Such reductions in prosthetic weight result in reduced inflammatory reaction, less fibrosis, and mesh contraction, as well as improved compliance and flexibility. However, with all the fervor of producing reduced-weight meshes, manufacturers may have swung the pendulum too far and produced meshes too lightweight. Such lightweight meshes may result in central mesh failure, whereby a mechanical failure develops within the mesh, resulting in fatigue fracture and subsequent hernia recurrence [10]. Therefore, caution should be used with some lightweight meshes for ventral hernia repair, especially in the setting of bridged repairs, and a heavier weight mesh should be considered.

The scientific and clinical evidence for the benefits of mesh density is evolving. Animal studies as well as clinical studies support the notion that limiting density/weight results in marked reduction in foreign body response and overall biocompatibility [11]. A prospective randomized trial of inguinal hernia repair demonstrated elevated inflammatory markers and oxidative stress in the heavyweight mesh group compared to lightweight implantations [12]. While other studies support the clinical benefits of lightweight mesh [13], a long-term study negated such findings, with equivalence seen at 2 years post-TEP inguinal hernia repair [14]. Despite a variety of studies, the majority of studies demonstrate that the implantation of lightweight polypropylene mesh results in decreased chronic discomfort and reduced restriction of physical activities while providing sufficient strength for the reinforcement of hernia repairs.

Porosity

Along with reducing the fiber thickness and density, allowing more empty space between the mesh fibers also aids in reducing the overall foreign body footprint of the mesh. Following implantation, each mesh fiber is surrounded by a granulomatous reaction, with some degree of inflammation and fibrosis [5, 9]. Because microporous meshes typically contain thicker fibers and limited interfiber spacing, such heavyweight microporous meshes (e.g., Marlex) induce a significant inflammatory and fibrotic response. The ensuing "bridging" fibrosis results in excessive scar plate formation, mesh contraction, and loss of pliability [9]. Macroporous meshes, commonly with light or medium density, allow for reduced bridging fibrosis with less mesh contraction. Also, larger pore size permits greater fluid transport across the mesh, theoretically reducing seroma formation. For perspective, heavyweight polypropylene (e.g., Marlex) is an example of a microporous mesh with a pore size of 0.6 mm, compared to typical lightweight macroporous meshes commonly having pore sizes in the 2–4 mm range. Importantly, reduced weight macroporous monofilament meshes demonstrate an important finding of greater tolerance in the setting of some degree of contamination (Note: greater tolerance, not resistance, to contamination). Early data support the use of permanent lightweight macroporous polypropylene meshes in contaminated settings, [15] though there is a lack of consensus for this among hernia surgeons.

Filament Design

Meshes are created using materials arranged in either multifilament or, more commonly, monofilament design. Multifilament meshes, containing bundles of mesh fibrils, are benefited by increased flexibility at time of implantation. However, they can induce heightened inflammatory and foreign body reaction. Of more importance is the inability for multifilament meshes to withstand contamination and commonly require mesh explantation if infected [16]. This intolerance of multifilament meshes to contamination is thought to be due to bacteria being trapped between the small interstices of the mesh fibrils, with insufficient neovascularization and inability of immune cell access to such small spaces where the pathogens reside [17]. Conversely, monofilament meshes tend to be more stiff and rigid upon implantation. However, they demonstrate reduced inflammatory and foreign body responses compared to their multifilament counterparts, as well as having reduced bacterial adherence [16]. And, while any mesh has the potential for infection and need for mesh explantation, monofilament (macroporous lightweight) meshes have demonstrated greater tolerance in the setting of contamination, as discussed in the previous section.

As already mentioned traditional polyester-based meshes such as Parietex (Medtronic, Minneapolis, MN, USA) are composed of multifilament fibers. However, newer polyester meshes have been designed with monofilament fibers, including Versatex, Symbotex, and ProGrip (Medtronic), which are manufactured

with similar monofilament polyester fibers. The overall goal of monofilament forms is to increase biocompatibility upon implantation and perhaps increase tolerance to contamination/infection and allow greater vascularity between mesh fibers. However, as Petro et al. point out, the use of monofilament polyester meshes requires some degree of caution, as central mesh failures and subsequent hernia recurrence were seen with an unusually high rate with the use of a monofilament polyester-based mesh [10].

Anti-adhesion Barriers

Because of the inflammatory response to foreign materials, the abdominal cavity creates varying degrees of adhesions to implanted prosthetics. In an effort to reduce adhesion formation, mesh manufacturers have developed composite meshes that greatly reduce adhesions and allow intra-abdominal placement of meshes. Common design strategies for intra-abdominal meshes include one side containing some form of tissue-separating barrier designed to impede ingrowth of viscera and adhesions, while the opposite side contains a porous, or a rougher, surface to facilitate ingrowth from the peritoneum.

Various anti-adhesive polymers have been developed including hyaluronic acid (Ventralight ST; Sepramesh, Bard-Davol), polyethylene glycol (Parietex, Medtronic), collagen film (Symbotex, Medtronic), oxidized regenerated cellulose (Proceed), omega-3 fatty acids (C-Qur, Atrium), and poliglecaprone (Physiomesh, Ethicon), among others. These mesh coatings are intended to persist until the abdomen has created a neoperitoneum over the visceral side of the mesh, typically within 10–14 days after mesh implantation. Of note, the design of Physiomesh (Ethicon, Somerville, NJ, USA) differed greatly from other meshes for use within the abdominal cavity. Instead of only a single-sided coating of poliglecaprone (i.e., Monocryl), both sides contained the poliglecaprone anti-adhesion barrier. This design flaw impeded adequate ingrowth from the peritoneal side and was likely a contributing factor in reported failures and its eventual removal from the market.

ePTFE is very effective as an anti-adhesion barrier. A common use of ePTFE (e.g., DualMesh, WL Gore, Flagstaff, AZ, USA) is as a bilaminar mesh, with fusion of a “macroporous” rough/corrugated layer to promote tissue ingrowth from the peritoneum, and a smooth “microporous” layer, which impedes adhesions on the visceral surface. Similarly, other meshes have utilized ePTFE as an anti-adhesion barrier, with bare polypropylene serving as the peritoneal, ingrowth side, while the ePTFE impedes adhesions on the visceral size (e.g., Composix, Davol, Warwick, RI, USA). One potential issue with such composite meshes is the differing rates of fibrosis and contraction of the two completely different materials. ePTFE tends to induce significant fibrous encapsulation leading to greater shrinkage of this layer compared to the polypropylene side. This may result in mesh curling and possible exposure of polypropylene fibers, leading to worse adhesions, or perhaps hernia recurrence, and may require mesh explantation.

Composite and Hybrid Meshes

Many of the meshes described above are composed entirely of permanent polymer fibers. However, there are varieties of permanent meshes that also contain resorbable or other materials. The addition of temporary fibers adds initial structural integrity at time of implantation and then resorbs as tissue infiltrates the mesh. One commonly used example is Ultrapro (Ethicon, Somerville, NJ, USA), which is an ultralightweight polypropylene mesh containing interwoven fibers of poliglecaprone (i.e., Monocryl, Ethicon) that add initial stiffness to the mesh. Ultrapro starts out at ~40 g/m^2 out of the package but ends up ~28 g/m^2 following complete resorption of the poliglecaprone fibers, hence the ultralightweight designation. Similarly, Vypro (Ethicon, Somerville, NJ, USA) consists of both polypropylene fibers and polyglactin (i.e., Vicryl) to add initial strength which resorbs (~2–3 months) following implantation. An example of a hybrid/composite mesh for intra-abdominal use is Ventralight ST (Bard-Davol, Warwick, RI, USA), which is a barrier-coated medium weight polypropylene mesh that also contains interwoven polyglycolic acid (PGA) fibers. The use of PGA fibers allows temporary "thickness" of the mesh, which facilitates adherence of the anti-adhesion hydrogel to the mesh fibers. TiMesh (PFM Medical, Nuremberg, Germany) is an interesting polypropylene-based mesh with covalently bound titanium atoms around each mesh fiber. The stated benefits of the titanium coating include a reduction in inflammation and foreign body response, thus improving biocompatibility as well as allowing for intra-abdominal use.

Newer laminate hybrid meshes have been developed that incorporate both a permanent mesh fiber backbone combined with biologic or synthetic-based resorbable components. While the literature is very limited for such products, early data demonstrate safety and efficacy [18]. Zenapro (Cook Medical, Bloomington, IN, USA) is a laminate synthetic-biologic hybrid consisting of a lightweight macroporous polypropylene mesh with layered small intestine submucosa (SIS). The biologic SIS acts to "shield" the polypropylene fibers upon implantation, allowing for intra-abdominal placement as well as limiting potential contamination of the permanent mesh fibers. Synecor (WL Gore) is another hybrid mesh that consists of three different materials: a macroporous monofilament PTFE mesh fiber backbone surrounded by Gore's Bio-A resorbable synthetic polyglycolic acid and trimethylene carbonate (PGA/TMA) matrix, with a PGA/TMA film on one side to reduce visceral adhesions. The Bio-A matrix facilitates ingrowth, lasting approximately 3–6 months. At time of publication, there are no studies evaluating the use of Synecor.

Additional Mesh Considerations

Self-Fixating Mesh

One of the challenges of mesh placement during hernia repair is mesh fixation. There are multiple methods and devices utilized to fixate the mesh area of concern, with sutures and tacks being the most prevalent fixation sources. Such fixation

methods have the potential drawbacks of increased pain, bleeding, as well as chronic foreign body and granulomatous reactions. In an effort to reduce fixation-related complications, manufacturers have developed meshes that utilize a built-in form of fixation. The most widely used self-fixating mesh, ProGrip (Medtronic, Minneapolis, MN, USA), utilizes monofilament polyester-based mesh that is covered with numerous absorbable polylactic acid (PLA) micro-hooks, akin to a burr found in nature. The microscopic hooks promote adherence to the surrounding tissue upon implantation and then absorb over ~18 months as the mesh allows ingrowth for long-term fixation. Much literature on ProGrip has been published, with over 40 studies over the last 8 years, mostly involving inguinal hernia repair. While several case series are supportive of the efficacy of ProGrip with potential for reduced pain, several randomized studies and a recent meta-analysis are not as supportive [19–21]. The higher-level data point to the principal advantage of self-fixating mesh as reduced operative time and found equivalence of pain with traditional inguinal hernia repair methods. One randomized controlled trial (RCT) found a significantly higher recurrence rate with the use of ProGrip for open inguinal hernia repair [20]. Very little data exist for self-fixating mesh and ventral hernia repair, and no RCTs have been published. Other self-gripping and self-adhering meshes are actively being researched and have been developed with early use in various parts of the world. Though, there is limited access to other self-adhering meshes in the Unites States at this time.

Anisotropy

Various material properties of meshes contribute to the overall mechanical behavior of the repair of hernias. While the differing elasticity of meshes when pulled in different directions (i.e., anisotropy) has not been well defined to date, studies have shown that many commonly used meshes have up to 20-fold differences in their "stretchability" when pulled in perpendicular directions [22]. This may factor into the success of abdominal wall repairs, as the native abdominal wall is roughly twice as elastic in the vertical (craniocaudal) axis versus the transverse/horizontal axis. As a result, mesh implantation may need to be strategic in order to address the differences in both the textile properties of the prosthetic and the physiologic properties of the abdominal wall [22, 23]. Interestingly, mesh labeling or descriptions of anisotropic behavior from manufacturers are lacking for nearly all products on the market today.

Conclusion

Surgical meshes have demonstrated their usefulness for hernia repair over many decades, with significant reductions in hernia recurrence upon implantation. A variety of permanent synthetic surgical mesh prosthetics have been developed, which offer immediate structural support as well as provide a scaffold for ingrowth, thus facilitating long-term integration with the body at the site of hernia repair. Many mesh products have been produced over the years, with polypropylene, polyester, and ePTFE being the most common materials utilized for

mesh manufacturing. Each material has its own benefits and limitations, with overall structural stability and biocompatibility acting as crucial components to ensure a successful hernia repair.

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Biologic and Absorbable Prosthetic: When, Why, and Where Are We Going

6

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Introduction

The need for tissue reinforcement in hernia repair was recognized as early as the 1800s and was finally realized in the advent of synthetic mesh in 1958 with the introduction of polyethylene mesh by Usher [1]. The benefit of using mesh to repair ventral hernias has been well established [2]. The principle of mesh repair hernia surgery is to reinforce native tissues and provide a scaffold for the cellular and vascular ingrowth and deposition of proteins necessary to integrate the mesh into host tissues. Tissue deposition and ingrowth occurs over the surface of the mesh, allowing distribution of the lateralizing forces of the abdominal wall over the entire area rather than at isolated points of fixation. This has helped significantly decrease hernia recurrence [3].

Synthetic mesh has become a routine part of hernia repair when used for fascial reinforcement. Improved outcomes, with regard to reduction in hernia recurrence, and low rates of wound complication and mesh infection are well documented with use in the appropriate setting [4–6]. However, the use of nonabsorbable synthetic mesh in high-risk patients comes with increased risk and is often warned against by mesh manufacturers. Complications such as wound infections, hernia recurrence, visceral erosion that can result in enterocutaneous fistulae, and chronic mesh infection are possible and significantly more so in high-risk patients [7–9]. The Ventral Hernia Working Group (VHWG) warns surgeons against using nonabsorbable synthetic mesh in the presence of contamination. Prosthetic materials may act as a reservoir for bacteria, biofilm creation, and inhibited clearance of infection by the

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immune system; this in turn leads to chronic infection, inflammation, pain, wound dehiscence, draining sinuses, cellulitis, abscesses, and hernia recurrence. Risk factors for mesh infection and explantation include obesity (high body mass index), chronic obstructive pulmonary disease, prior surgical site infection, longer operative time, enterotomy, or enterocutaneous fistula [10].

Nonpermanent materials for abdominal wall reinforcement can provide an alternative in high-risk patients. In theory, biologic and absorbable synthetic meshes provide mechanical support and reinforcement as well as a temporary scaffold for cellular infiltration during the early critical period in wound healing. Hernia repair with these products should be accompanied by primary closure of overlying fascia whenever possible. As there are many absorbable synthetic and biologic meshes currently on the market, the aim of this chapter is to describe the most commonly used products and existing data. The financial burden of complex hernia repair is significant; defining the value of different meshes is the critical factor determining the continued ability to provide optimal surgical care to these patients.

Biologic Mesh

Biologic meshes, first introduced in the late 1990s, are derived from decellularized, collagen-rich tissues from cadavers and animals. Biologics have been shown to have a lower rate of infection ($p < 0.00001$) and a similar rate of recurrence compared to synthetic meshes, supporting the use of biologic meshes in high-risk patients [8]. Biologic grafts are generally derived from human, porcine, and bovine tissue. Grafts are further divided into categories of cross-linked and non-cross-linked meshes; cross-linked meshes appear to be more stable against degradation but have reduced vascularization and tissue integration. Cross-linked meshes act more like synthetics and are more prone to infection and possible explantation [2, 11, 12]. Infection of non-cross-linked tissue-derived grafts appears to result in accelerated degradation of the collagen scaffold, which can take place before sufficient healing has occurred and has led to concerns regarding hernia recurrence [13]. Despite this, non-cross-linked meshes have been considered an option as they may be less likely to harbor contamination by supporting rapid neovascularization and may decrease the risk of postoperative complications [14]. Furthermore, several publications have suggested a benefit to biologic mesh in complex cases, but there is currently no Level 1 evidence supporting the decision to use either synthetic or biologic in these patients [3–7, 9, 14–17].

Biologic grafts often require specific storage, transport, or pretreatment protocols to preserve the integrity and function of the product. Given that these must be harvested and processed from human or animal tissues and subsequently undergo various methods of sterilization and packaging, variability of the different products is inevitable, and new data are emerging that better characterize the variation in biologic grafts [18]. Biologic meshes are not FDA approved for use in contaminated settings, although this has become their most advocated and prevalent application. These meshes have succeeded in filling a gap in the options available for abdominal wall closure and reconstruction in high-risk patients and have made one-stage repair

Table 6.1 Market available biologic mesh

	Strattice™	XenMatrix™	FlexHD®	Permacol™
Manufacturer	LifeCell Corporation	C.R. Bard, Inc./ Davol Inc.	Ethicon, Inc.	Medtronic Corporation
Cross-linked	Non-cross-linked	Non-cross-linked	Non-cross-linked	Cross-linked
Species	Porcine dermis	Porcine dermis	Human dermis	Porcine dermis
Thickness (mm)	1.76 ± 0.012	1.95 ± 0.012	1.15 ± 0.043	0.91 ± 0.008
Tear resistance (N) [24]	>20 N	>20 N	>20 N	≤20 N
Approximate cost per cm^2 (20×30 cm^2) (USD)	$20–30	$20–30	>$30	$20–30
Registered clinical trials	NCT01987700 NCT01083472 NCT02587403 NCT02121743	NCT02587403 NCT01305486 NCT02691962 NCT02228889	NCT01987700 NCT03145337 NCT02372305	NCT01268514 NCT01644695 NCT02703662

possible, thus improving the chance that of avoiding multiple laparotomies [19]. Although high recurrence rates and cost are often attributed to biologics, supportive studies such as Garvey et al.'s recently reported a hernia recurrence of 8.3% at 5 years in high-risk patients who underwent mesh-reinforced abdominal wall reconstruction with acellular dermal matrix [20]. In that study, human acellular dermal matrix was an independent risk factor for recurrence and porcine performed significantly better [20]. A summary of the most commonly used biologic mesh grafts is included in Table 6.1.

Strattice™

Strattice Reconstructive Tissue Matrix (LifeCell Corporation, Branchburg, NJ) is a non-cross-linked acellular porcine dermal matrix. The manufacturer has published some details of their processing technique and results using 0.25% trypsin and 0.1% sodium dodecyl sulfate prior to incubation in 0.25% trypsin, followed by 560 units/l dispase at 25 °C. According to the manufacturer, evaluation of this tissue processing technique demonstrated "most of the original type I collagen" [21]. Histologic biopsies at 1 month, 6 months, and 36 months demonstrate rapid neovascularization and preserved extracellular matrix for collagen deposition and minimal foreign body reaction. Furthermore, when compared to two other biologic grafts in a nonhuman primate mode, this process resulted in Strattice™ having less susceptibility to collagenase degradation, improved stability, and less inflammatory response when compared to its competitors [22]. Strattice™ has been extensively studied in humans, and the recent publications by Garvey and Huntington show promising results and recurrence under 10% in high-risk patients [18, 20].

XenMatrix™

XenMatrix™ surgical graft (C.R. Bard, Inc. [Davol], Warwick, RI, USA) is a non-cross-linked porcine dermal scaffold with an added antibacterial coat of minocycline and rifampin. According to the manufacturer, their process results in an increased pore size in the tissue scaffold, which may improve cell adhesion and infiltration [23]. In vitro performance data have demonstrated XenMatrix™ to have equivalent or higher suture retention strength, tear resistance, and tensile strength and integrity [24]. A study from Baker et al. examined 74 patients undergoing ventral hernia repair with XenMatrix™AB. They included patients with modified VHWG grade 1 17.6%, grade 2 66.2%, and grade 3 14.9% and reported a surgical site infection rate of 6.8% [25]. They reported a hernia recurrence rate of 5.4% within their 6-month follow-up period.

FlexHD®

FlexHD® Structural Acellular Hydrated Dermis (Ethicon, Inc., Somerville, NJ, USA) is an acellular human dermal matrix derived from donated allograft skin that is processed by the Musculoskeletal Transplant Foundation. Using a rabbit model, the company demonstrated less degradation and better tissue integration of their AHDM compared to APDM at 4 and 20 weeks [26]. With regard to recurrence, FlexHD® has been compared to AlloDerm™ (LifeCell Corporation, Branchburg, NJ). The reported hernia recurrence was 31% in the FlexHD® group and 100% in the AlloDerm™ group. While this is a remarkable difference, it has not been reproduced, and other head-to-head studies have shown recurrence rates of 37% with FlexHD® and 35% with AlloDerm™ [18].

Permacol™

Permacol™ (Medtronic Corporation, Minneapolis, MN) is a cross-linked acellular porcine dermis. According to the manufacturer, the cross-linking process improves the stability of the dermal matrix and allows Permacol to be stored at room temperature. The implant also has greater longevity when compared non-cross-linked mesh [27]. Clinical experience is mixed; however, in a study of 270 patients undergoing ventral hernia repair with either Permacol™ or Strattice™ mesh, the Permacol™ group had a higher rate of postoperative wound infections compared to Strattice™ (21 vs. 5%, $p < 0.01$) and overall complications (28 vs. 13%, $p < 0.05$) including seroma/hematoma and dehiscence [28]. Patients were statistically similar between Strattice™ and Permacol™ groups; however more patients with Strattice™ had clean wound classification (45%) than in Permacol™ group (26%, $p < 0.01$). Within the Permacol™ group, there was a significant difference in overall complication rate between patients with infected and clean wound classifications (55 vs. 35%, $p < 0.05$). A similar hernia recurrence rate was noted between Permacol™ and

Strattice™ groups regardless of patient differences in prior mesh repair, obesity, or technique of mesh repair (reinforcement after primary closure versus fascial bridge).

Currently more than 200 meshes are on the market in the USA, but there have been few direct comparison studies of various biologic meshes [11, 19]. Furthermore, existing studies have been small or have compared meshes in a pairwise fashion, such as Strattice™ versus Permacol™ [19], AlloDerm™ versus Permacol™ [29], AlloDerm™, Permacol™, Surgisis [14], and SurgiMend versus FlexHD® [30]. While others have not demonstrated reproducible results, Huntington et al. examined 223 abdominal wall reconstructions in high-risk patients. Of the five most commonly utilized biologic meshes (AlloDerm™, AlloMax™, FlexHD®, Strattice™, and XenMatrix™), Strattice™ had the lowest hernia recurrence rate of 14.7% ($p < 0.001$) over an 18-month follow-up period [18]. A multivariate analysis controlling for confounding factors including patient comorbidities, hernia size, and intraoperative techniques (e.g., fascial bridge) demonstrated significantly higher odds of hernia recurrence with AlloMax™ (odds ratio [OR] 3.4), FlexHD® (OR 2.9), and XenMatrix™ (OR 7.8) compared to Strattice as a reference. After controlling for patient comorbidities and intraoperative factors, XenMatrix™ was the most expensive biologic mesh with adjusted cost of $59,122 after multivariate analysis compared to AlloMax™, the least expensive at $22,304 [18].

Absorbable Synthetic Mesh

Recently, there has been an increase in interest in absorbable synthetic meshes. These meshes are laminar from absorbable synthetic polymers and have been in clinical use for many years as suture and orthopedic fixation devices [2, 15]. One can change the composition and alter compliance, elasticity, fracture, strength, and rate of absorption and degradation. Compared to tissue-derived products, they have the added advantage of homogeneity, predictability, and limited size constraints. Furthermore, there are comparatively few mandatory storage, transport, or pretreatment requirements to preserve the integrity and function of these products. The most significant advantage of these meshes compared to tissue-derived meshes, however, may be a substantial reduction in cost, as much as 66% by one estimate [31].

Through modification of the micro- and macrostructure and composition of materials, the physical properties of the final implant can be manipulated according to the application, including tensile strength, stiffness, and rate of biodegradation. A summary of the most commonly used absorbable synthetic mesh grafts is included in Table 6.2.

The most common components of absorbable synthetic meshes are polyglycolic acid, polylactic acid, and trimethylene carbonate. Polyglycolic acid (PGA), or polyglycolide, is a semicrystalline hydrophilic polymer rapidly degraded in vivo primarily by hydrolysis into glycolic acid monomers, which are in turn oxidized by the citric acid cycle into CO_2 and water, followed by urinary excretion [15]. To improve its hydrolytic stability, it is frequently copolymerized with other polymers. Polylactic acid (PLA) is derived from lactic acid. It is absorbed significantly slower than PGA

Table 6.2 Market available absorbable synthetic mesh

	Vicryl	Gore Bio-A	PHASIX™	TIGR® Matrix
Manufacturer	Ethicon, Inc.	W.L. Gore & Assoc., Inc.	C.R. Bard, Inc./ Davol Inc.	Novus Scientific
Fiber	92% PGY 8% PLLA	67% PGA 33% TMC	P4HB	1. Primary matrix: PGA:PLA:TMC 2. Secondary matrix: PLLA:TMC
Mechanism of degradation	Hydrolysis	Hydrolysis	Hydrolysis	Hydrolysis
Maintains mechanical strength	14 days		12–26 weeks	6 months
Complete resorption	2–3 months	6 months	12–18 months	3 years
Approximate cost (20 ×30 cm^2) (USD)		$4400	$6775 (20 × 25 cm^2)	$4000

and adds mechanical strength when used in combination with less crystalline polymers such as PGA. PLA undergoes degradation to lactic acid through a process similar to PGA [15, 32]. Trimethylene carbonate (TMC, also polytrimethylene carbonate [PTMC]) is a comparatively elastic polymer that is degraded enzymatically through surface erosion and a macrophage-mediated mechanism. Its common use for biosynthetic hernia mesh is as a copolymer with other substances to increase elasticity of the final compound [15, 16, 33].

Phasix is composed of poly-4-hydryoxybutyrate (P4HB) which is produced by *Escherichia coli* K12 via transgenic fermentation techniques. Therefore, it is free from heavy metal residues from catalysts used during their synthesis. Degradation of P4HB in vivo occurs through surface erosion, and then hydrolysis into 4-hydroxybutyrate (4HB) like PGA and PLA is ultimately metabolized by the citric acid cycle into CO_2 and water. Its properties vary based on orientation of its fibers, but like TMC, P4HB is generally pliable and not prone to fracture [17, 34].

Recognition of the final degradation products of these implants is critical to their safety and overall biocompatibility and is therefore known in detail; end byproducts are typically eliminated through known pathways or are otherwise already present in the in vivo setting. However, the effect of pathogenic bacteria in the infected wound on the physical properties of these materials is less understood, including the effects of bacterial adherence, bacterial enzyme activity, and the altered wound pH.

Our knowledge of the inflammatory processes central to wound healing and mesh biocompatibility is growing. While some inflammation is necessary for wound healing and mesh integration, excessive or prolonged cytokine-mediated inflammation can lead to undesired pathologic effects such as mesh encapsulation or accelerated

degradation. Much investigation remains regarding the precise pathways that define successful mesh integration and fascial reinforcement. For absorbable synthetic products in particular, macrophage activity is central to mesh degradation both for hydrolysis and enzymatic activity; the net effect of the inflammatory response on the properties of the mesh with regard to rate of resorption in the presence of pathogenic bacteria and the associated immune response is a yet unanswered question. Both PGA and PLA are known to substantially increase the acidity of the wound bed upon degradation to their respective monomers, with unknown effects on wound healing [35]; changes in the local pH resulting from polymer degradation can in turn exponentially accelerate the rate of hydrolysis and absorption of mesh [15]. Additionally, PGA has been found to produce a nonspecific foreign body reaction in a small percentage of cases in orthopedic rod implants, resulting in chronic sinus formation [36]. Notwithstanding, although they bear mention, the ultimate clinical significance of these observations remains unclear, since materials derived from these polymers have been in widespread practical use since the 1960s.

Clinical studies are ongoing, and the volume of published data currently available on use in hernia repair for most of these is relatively small. However, we will review four most common types of absorbable synthetic meshes currently in use: Vicryl®, Gore Bio-A®, TIGR®, and P4HB meshes.

Vicryl®

The first absorbable synthetic meshes with widespread use for abdominal wall repair were predominantly polyglycolic acid based. Absorbable mesh used in temporary abdominal closure was first described by Levasseur et al. in 1979 [37]. It soon became an accepted method for fascial closure in contaminated fields where a hernia was already present or when the abdominal wall required gross debridement, such as in closure for necrotizing fasciitis, burns, and after infected mesh removal [38]. Vicryl® (polyglactin 910, PGA(92%):PLLA(8%)), Ethicon, Inc., Somerville, NJ, USA) is representative of this class of materials and is the absorbable synthetic mesh for which the greatest amount of data is available [39]. Vicryl® mesh has a tensile half-life of 2 weeks and is completely absorbed by 4 weeks. Its most commonly reported application in abdominal wall repair is as a damage control measure for temporary abdominal closure as a bridge to an eventual definitive repair, either by serial tightening with delayed primary closure of the fascia or by allowing the wound to granulate with subsequent skin grafting [40]. Recent data suggests it has the same adhesion-producing properties as non-coated synthetic meshes and may increase the inflammatory response while not resulting in any added wound strength [41–43]. A recent randomized control trial between polyglactin mesh placement and intra-abdominal wound vacuum-assisted closure found that both had similar rates of closure (26% vs. 31%, respectively) [44]. Vicryl mesh has been associated with high enterocutaneous fistula rates [45].

Gore Bio-A®

Gore® Bio-A® Tissue Reinforcement (Bio-A®, W. L. Gore & Associates, Inc., Flagstaff, AZ, USA) is a laminar absorbable synthetic mesh composed of a 67% PGA/ 33% TMC copolymer, constructed as a 1.3-mm-thick nonwoven three-dimensional web. Bio-A® is degraded by hydrolysis and enzymatic processes over 6 months. The composition is very similar to Maxon™ (Covidien Inc., Norwalk, CT, USA), and SureTac™ (Smith & Nephew Endoscopy, Andover, MA, USA) used for bone fixation, and is the same material used for Seamguard® (W. L. Gore & Associates, Inc., Flagstaff, AZ, USA). Other applications include treatment of perianal fistulas, [34, 46] paraesophageal hiatal hernia repair, [47, 48] and pelvic floor reconstruction [49]. In vitro evaluation indicates that Bio-A® stimulates significantly less chemotactic pro-inflammatory cytokine production (IL-1β, IL-6, IL-8, VEGF) than two out of three different human dermis-derived biologic meshes and the least absolute production overall [50]. Another study that evaluated neoperitoneum formation found that Bio-A® stimulated less in vitro mesothelial cover, greater macrophage production, and less neoperitoneum production than Tutomesh® or Strattice™, with greater biodegradation than Strattice™ at 90 days post-implantation [51]. Using a rabbit model, Bio-A® showed more type I collagen deposition at 30 days and at a time point significantly earlier than FlexHD®, Strattice®, or Permacol™, with significantly greater fibroblast and vascular ingrowth up to 180 days [52]. Other data indicate that mRNA expression of both type I and III collagen appears to peak significantly earlier in than Strattice® and Tutomesh® [53].

The COBRA (Complex Open Bioabsorbable Reconstruction of the Abdominal Wall) study is a prospective, multicenter trial to evaluate the use of Bio-A® for reinforcement of midline fascial closure in complex ventral hernias with contaminated or clean-contaminated surgical fields. One hundred four patients underwent hernia repair with a single sheet of absorbable synthetic mesh. They reported a wound infection rate of 20%, none of which required implant removal [54]. Hernia recurrence was 17% with 24 months of follow-up. Interestingly, with retrorectus mesh placement, the recurrence rate decreased to 13% [54].

TIGR®

TIGR® Matrix Surgical Mesh (Novus Scientific, Uppsala, Sweden), a dual-filament absorbable synthetic mesh system knitted from two fibers of different composition and rates of degradation, has been commercially available since 2010. The more rapidly absorbed fiber is a copolymer of PGA, PLA, and TMC and accounts for 40% of the composite product. This set of fibers loses tensile strength after 2 weeks, and complete resorption occurs by 4 months. The second polymer is a copolymer of PLA and TMC and makes up the remaining 60% of the mesh by weight, loses tensile strength at 9 months, and is resorbed by 3 years. TIGR® mesh is therefore designed to maintain its maximal tensile strength through 6 months post-implantation with complete degradation by 3 years [55, 56].

Clinical data on TIGR® mesh are available on the company website reveals. A study by Ramshaw et al. demonstrates early results on the use of TIGR® versus biologic mesh for abdominal wall reconstruction in 39 patients. They found equal or better mesh-related and overall outcomes (recurrence, 13% vs. 19%) and over 70% cost savings at a mean follow-up of 12 months [57]. Most recently, a Swedish group reported on a prospective pilot study of 40 primary inguinal hernias undergoing Lichtenstein repairs using TIGR® Matrix with long-term follow-up [58]. In their study, a 22.8% recurrence was noted at 36 months.

P4HB

P4HB was initially investigated experimentally in vitro and in vivo for use in engineered vascular conduits and heart valves [59–62]. It first became commercially available for clinical use in 2007 as surgical suture, with FDA clearance for P4HB absorbable synthetic mesh following shortly thereafter. PHASIX® is not recommended for use in patients with known allergies to tetracycline or kanamycin, and safety and effectiveness for use in children has yet to be established. Currently several P4HB mesh products are available for use in hernia repair, including PHASIX™ Mesh (C.R. Bard, Inc. [Davol], Warwick, RI, USA), PHASIX™ Plug and Patch for groin hernias, TephaFLEX® light mesh (Tepha, Inc., Lexington MA, USA), and Tornier® Surgical Mesh (Tornier, Inc., Edina, MN, USA). Deeken et al. used a porcine preperitoneal bridging hernia model to further investigate the pre- and post-implantation characteristics, of PHASIX mesh and P4HB plug over 52 weeks after removal of the peritoneum to assess the characteristics of the repair alone [63]. Both PHASIX® and P4HB plug had significantly greater burst strength compared to native abdominal wall, and between 6 and 52 weeks, neither showed a significant decline in burst strength, changes in stiffness, or evidence of hernia or diastasis, despite the bridging nature of the repair. The inflammatory response was judged to be mild with mild to moderate granulation and vascularization [63]. Wormer et al. compared 160 (50.2%) patients with prophylactic onlay mesh to 159 (49.8%) patients who did not receive mesh when undergoing DIEP reconstruction [62]. Wormer et al. were able to demonstrate a smaller bulge rate in bilateral DIEP patients with a mean follow-up of 16.4 months [64]. Currently, there is an ongoing prospective interventional trial with an accrual of 112 patients undergoing ventral hernia repair with PHASIX.

Hybrid Mesh

In attempts to join biologic and synthetic meshes, potentially capturing the most desirable characteristics of each, a new category of mesh has emerged. Hybrid meshes include Synecor™ (W. L. Gore & Associates, Inc., Flagstaff, AZ, USA) and Zenapro™ (Cook Medical Inc., Winston-Salem, NC, USA).

Synecor is designed for intraperitoneal use and marketed for use bridging fascial defects and as a replacement for biologic mesh in complex patients. It is comprised

of a combination of layered materials. These include Bio-A™ on the parietal surface, a macroporous knit monofilament PTFE in the middle, and an absorbable and a PGA/TMC nonporous film on the visceral surface.

Zenapro™ is comprised of acellular porcine small intestinal submucosa layered around a core of ultralightweight polypropylene mesh. It is FDA approved for hernia repair. However, like each mesh described previously, it is not approved for use in a contaminated field.

There are no clinical data on either product, but ongoing trials are in effect. Long-term data and definition of appropriate settings for use of hybrid meshes need to be further evaluated.

Conclusion

Abdominal wall reconstruction and hernia repair in high-risk patients remain an area of intense research. Mesh infections are costly complications, dramatically exceeding the up-front expense of any implant in the final calculation, with an unquestionably negative impact on patient quality of life. Understanding the value of mesh repair, impact of complications, and patient quality of life is fundamental. Guidelines should be based on comparative trials and long-term clinical data. As new meshes enter the market, large databases such as the AHSQC will be essential in obtaining long-term follow-up, defining techniques and minimizing complications.

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Prosthetic Fixation Options

7

Nathaniel Stoikes, David Webb, and Guy Voeller

There is a spectrum of mesh fixation options for all hernia repairs. The two main categories include mechanical fixation and adhesive fixation. Key differences between the two modalities include using point fixation of mesh by anchoring it to tissue (mechanical) versus the fixation of the entire surface area of mesh by covering it with a nonpenetrating fixative (adhesive). Selection of one form over the other (or combination use) is dependent on many factors that include operative approach, type of hernia, and the location of mesh placement. Aims of this review are to discuss the biomechanics of fixation and clinical outcomes of these various forms of fixation within the realm of hernia repair.

The Science of Fixation

Understanding the science behind prosthetic fixation relies upon the biomechanical study of the various forms of fixation being used. Whether it is mechanical fixation such as a suture or a tack or an adhesive like fibrin glue, the use of basic science models are necessary. The other key ingredient to understanding fixation is often ignored or forgotten and that is the understanding of how a prosthetic mesh responds and incorporates into surrounding tissues. Mesh behavior in terms of inflammatory response and timing of incorporation are important details that help us understand the true need for fixation. In other words, it helps us understand, "How strong is strong enough?" Throughout this chapter clinical data and supporting basic science data will be used to help clarify the advantages and disadvantages of each type of fixation. An example of a study that embodies the concepts of prosthetic fixation was published by Stoikes et al. [1]. The study goals were to evaluate the differences

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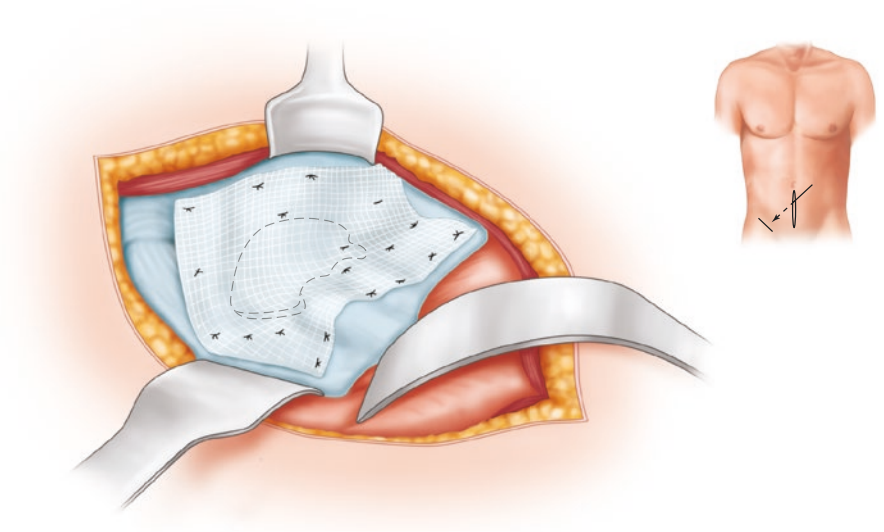

Fig. 7.1 Rives' preperitoneal inguinal hernia repair with mesh (note fixation points) (For the editor discretion picture comes from book *Hernia Healers* published by Arnette page 116, 1998)

in shear stresses of sutured and glued polypropylene mesh in a porcine model at 24 h, 7 days, and 14 days (Fig. 7.1). Histology with a scoring system was used to evaluate the mesh response at the three time points. Not surprisingly, sutured mesh had significantly stronger shear forces at 24 h (10 N vs 5 N), but equally interesting was that by 7 days the interfaces between the mesh and the fascia exceeded sheer stress testing in both groups because either the fascia or the mesh failed before the interface between the two was disrupted. Essentially this meant that by 7 days the form of fixation was irrelevant. Histology also confirmed complete ingrowth of the mesh by the 7-day time point in both groups. Other differences were also found in the early time points. Glued mesh tended to have better load-sharing properties likely secondary to complete fixation of the entire surface area of the mesh. Glued specimens also tended to fail in a reproducible manner due to more reproducible and even application, whereas sutured specimens tended to fail in a more unpredictable secondary to point fixation and inherent technical inconsistencies of placing sutures. An interesting observation during the study was that the glued specimens trended to have less mesh contraction at the three time points than the sutured specimens. All of these findings are thought to be due to the immediate and complete surface area fixation fibrin glue offers compared to point fixation with sutures. Scientific models like this only begin to describe the differences between mechanical and adhesive fixation, and new concepts like "load sharing" and the importance of "complete fixation vs point fixation" begin to take shape to permeate all categories of hernia repair. Hopefully, future biomechanical studies will continue to tease out the advantages of each type of fixation for a given hernia space so that hernia repair can be optimized. With this study alone, one can see how much there is to consider when it comes to prosthetic fixation and how little we really know.

Inguinal Hernia

Laparoscopic Preperitoneal

Preperitoneal inguinal hernia repair is essentially synonymous with laparoscopic inguinal hernia repair, and within this space there is clinical data on three fixation options: no fixation, tack fixation, and fibrin glue fixation. There is a common misconception that fixation of the prosthetic was not used when the open preperitoneal repair was first described. This is not the case. The origins for mesh fixation stem from Jean Rives' preperitoneal hernia repair, which was done through a lower midline incision. He fixated the mesh with interrupted sutures at multiple locations over the entire myopectineal orifice. Stoppa, who is classically known for giant prosthetic reinforcement of the visceral sac, did not use fixation for this approach, but this technique was for bilateral recurrent inguinal hernias where the mesh was massive and much, much larger than the defects it was covering. This repair is probably the reason that surgeons believe no fixation of the mesh was standard for unilateral repair where the mesh is much smaller relative to defect size. In his standard unilateral open preperitoneal hernia repair, Stoppa like Rives, also used suture fixation of the mesh (Figs. 7.2 and 7.3).

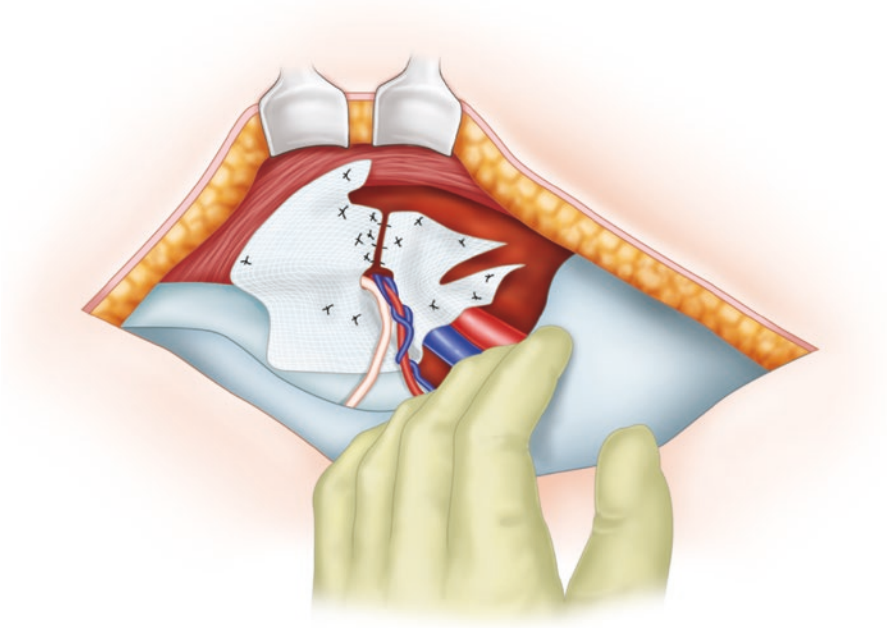

Fig. 7.2 Stoppa's unilateral inguinal hernia repair with mesh (note fixation points) (For editor picture comes from Third Edition *Hernia* by Nyhus and Condon page 208 by Lippincott 1989)

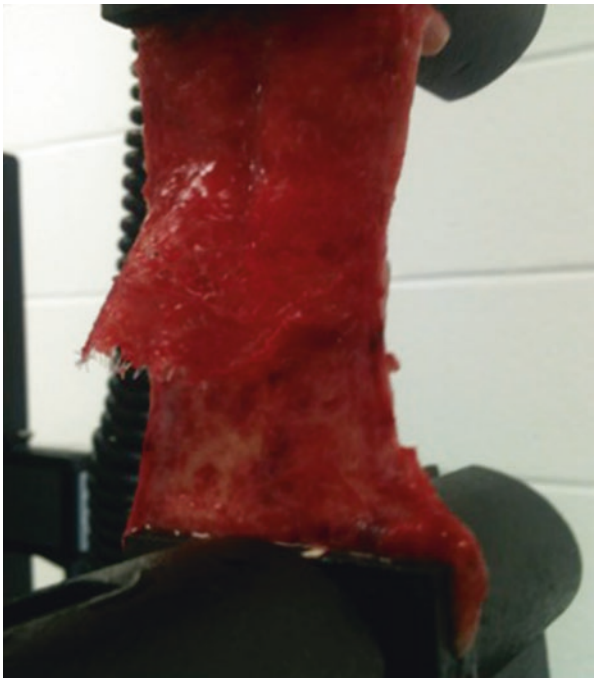

Fig. 7.3 Shear stress testing to evaluate biomechanics of mesh fixation

There is a fair amount of data evaluating no fixation for laparoscopic inguinal hernia repair, but it tends to be reviews of patients with smaller indirect defects. An example of this would be Taylor et al. who reviewed tack fixation vs. no fixation in TEP inguinal hernia repair. There was no difference in recurrence rates, but the average follow-up was very short at 8 months, and the defects were smaller in size. Golani et al. reviewed 538 TEP patients repaired over 6 years and found recurrence rates of 1.5% and chronic pain issues in 2.9%. Tacks were used in 11 patients that had larger direct defects [2].

Tack (mechanical) fixation is the original method of fixation for laparoscopic preperitoneal hernia repair. Tack fixation has evolved into two subtypes: permanent and absorbable. There is a paucity of data comparing these two types of fixation in inguinal hernia repair, but they have been biomechanically evaluated by Melman et al. [3]. In a porcine model evaluating acute fixation, permanent tacks were found to be significantly stronger than the absorbable counterpart. Despite the raw biomechanical data in this study, absorbable tacks are widely used with good results in laparoscopic hernia repair, which exemplifies the importance understanding the subtleties of all hernia types, mesh location, and operative technique options. When dealing with mesh fixation, "strong enough" is sometimes better than "strongest." This concept is especially important when evaluating adhesive fixation of mesh.

Adhesive fixation of mesh for laparoscopic inguinal hernia was first described by Jourdan [4]. The original case report described the use of a cyanoacrylate for mesh fixation in laparoscopic inguinal hernia. Cyanoacrylates historically lost favor for

fixation due to an intense inflammatory response and issues with oncogenesis; however, newer versions are now being used in Europe with good results. Kukleta et al. described their experience with n-butyl cyanoacrylate for mesh fixation in 1300 TAPP repairs. Their technique included using 6–8 drops of the cyanoacrylate for fixation of a 15 cm × 10 cm piece of mesh, which prevented any inflammatory or ingrowth issues. Over 9 years the recurrence rate was 0.37%. There were no infections or long-term complications [5]. In 2001, Katkhouda et al. described the use of fibrin glue for the fixation of mesh for laparoscopic inguinal hernia repair in an animal model. They compared fixation of mesh with fibrin glue vs. tacks as well as no fixation. They found significant movement without fixation, the tensile strength of the repair was stronger with fixation, and fibrin glue gave a stronger fibrous reaction. A critical advantage of fibrin glue included uniform fixation of the mesh decreasing the risk of mesh folding which occurred more frequently with no fixation or tack fixation [6]. Schwab et al. also evaluated fibrin glue in a similar way by looking at fixation with six different kinds of meshes. Similar results regarding fixation between tacks and glue were found. He found the meshes consistently dislocated without fixation and fixation prevented this dislocation. They concluded that stress resistance across the abdominal wall was significantly better with fibrin glue as well as better mesh incorporation [7]. In addition, Kes, looking at nine different meshes in TEP repair, showed protrusion and collapse of the mesh without fixation, and this increased as the size of the defect increased [8].

Clinical data has supported the conclusions of the animal and basic science studies regarding fibrin glue use. The first ever pilot study with fibrin glue was started in 2000 and published in 2006 by Novik et al. He did 9 consecutive TEP repairs with fibrin glue fixation and compared it to 96 patients with stapled mesh fixation. They concluded there was no difference in types of fixation in terms of outcomes at 1, 16, and 40 months postoperatively [9]. A recent meta-analysis by Kaul et al. reviewed a large population of patients and found recurrence rates between tack fixation and glue fixation to be equivalent. They also found that the chronic groin pain at 3 months postoperatively was higher in the tack groups [10]. One of the main advantages of adhesive use for mesh fixation is that fixation can be done where mechanical fixation is not safe due to risk of injury to vital structures. Looking back at the original descriptions of both Rives' and Stoppa's inguinal hernia repair techniques, we see that they fixated the mesh in multiple locations with sutures. The use of fibrin glue to fixate mesh in the preperitoneal space allows for the breadth of fixation consistent with the techniques of both Rives and Stoppa based on their operated schematics.

An alternative adhesive type of fixation for laparoscopic inguinal hernia is self-gripping mesh. This mesh is made with absorbable barbs that provide the means of fixation to the tissues. From a basic science standpoint, there is only one study to evaluate fixation properties of self-gripping mesh vs. fibrin glue. Shahan et al. reviewed an experimental mesh but also looked at fibrin glue fixation and self-gripping mesh in an acute fixation trial. They found no statistical difference in fixation properties of fibrin glue compared to self-gripping mesh though fibrin glue consistently trended to be stronger [11].

Clinically, Fumagalli et al. evaluated 96 patients in TAPP inguinal hernia repair and found no differences between the tack group and the self-gripping mesh group. Follow-up was 13.8 months, and there was one recurrence in the tack group. They also concluded there trended to be less chronic pain in the self-gripping mesh group [12].

Open Anterior Approach

Classic fixation in open inguinal hernia repair has been suture fixation of all various types. Data supports the use of a slowly absorbable suture for best results from a recurrence and chronic pain standpoint. More recently, fibrin glue has been proven effective in the open inguinal hernia space. Campanelli et al. produced the TIMELI trial which compared fibrin glue to suture fixation in Lichtenstein hernia repair. It was found that at 12 months, there were only 3 total recurrences out of 319 patients. The fibrin glue group had less disabling complications. At 1 and 6 months, the fibrin glue group had less pain, and it was concluded that the use of fibrin glue decreases the risks of pain, numbness, or discomfort by 45% [13].

Self-gripping mesh is also used in the open inguinal hernia space and has been found to have similar outcomes to both suture fixation and fibrin glue. Ronka et al. did a randomized trial comparing suture, fibrin glue, and self-gripping mesh for Lichtenstein hernia repair. An even distribution of the fixation forms was evaluated in 625 patients. There were four total recurrences at 12 months follow-up, and there were no differences between the groups regarding chronic groin pain [14].

Ventral Hernia

Fixation for the ventral hernia space is complicated because there are so many types of repairs that can be done. Mesh fixation is dependent upon the space where the prosthetic is being placed: intraperitoneal, retrorectus/preperitoneal, and onlay.

Intraperitoneal Mesh Placement

Historically, intraperitoneal mesh placement for ventral hernia repair stems from the Rives retrorectus repair, which was developed in the 1970s. The idea was that placing the mesh behind the defect was better than on top of the defect. Prior to the popularity of the Rives repair, in the United States, it was standard to bridge a hernia defect with a prosthetic by suturing it to the fascial edges of the defect. Recurrence rates were significant since the tissue the mesh was fixated to was not strong enough to resist high intra-abdominal pressures. With the introduction of the laparoscopic repair of ventral/incisional hernias, the technique required, at that time, that the mesh be placed intraperitoneally. Initially point fixation with staples was used, and this was then soon replaced by the "tack," which gave better fixation than the classic staple. We used our early experience with the Rives open repair, where suture

fixation of the mesh is done, to add suture fixation to the laparoscopic intraperitoneal repair, and this became the standard approach for long-term success.

Basic science data comparing suture fixation and tack fixation for intraperitoneal mesh fixation has shown that transfascial suture fixation is biomechanically stronger. Van't Riet et al. conducted a porcine model evaluating the differences in fixation strength between suture and tack in 1–5 different locations on a 7 cm piece of mesh. For one point of fixation, suture was significantly stronger (67 N vs 28 N). For two points of fixation, suture was again statistically stronger (115 N vs 42 N). For five points of fixation, there were no statistical differences though suture trended to be stronger (150 N vs 82 N) [15].

The standard of transfascial fixation combined with tack fixation of mesh has produced excellent clinical results. Heniford et al. reviewed 850 laparoscopic repairs with this technique and found a recurrence rate of 4.7% with mean of 20.2 months follow-up [16]. For those surgeons not wanting to add suture fixation to their repair, Morales-Conde described the "double-crown" method of intraperitoneal mesh fixation wherein an inner and outer ring of tacks are used for mesh fixation. They reviewed 140 patients with 40 months follow-up and found a recurrence rate of 2.1% [17]. Baccari et al. reviewed 200 patients with a double-crown tack technique with mean defects of 107 cm^2 and found a recurrence rate of 3.5% at 22 months [18]. Wassenaar randomized three groups: tacks and permanent suture, double-crown tacks, and tacks and absorbable sutures. A total of 199 patients were studied, and there were only 2 recurrences (1 double-crown and 1 absorbable suture with tacks) [19]. Brill et al. conducted a meta-analysis reviewing 6015 patients with tacks and sutures and 2045 with tacks only and found no significant differences in recurrence or chronic pain [20]. Alternatively, Leblanc et al. reviewed his first 100 patients in 2001 and found that the recurrence rate was 9.3%. All patients with recurrence had been identified to have tack or staple fixation without transfascial suture fixation [21]. He followed up that study in 2007 with a meta-analysis reviewing whether transfacial sutures were necessary, but no firm conclusions could be made as the variations in suture placement could not be accounted for. By the numbers recurrence rates with suture fixation were 4% and without were 1.8%. He did conclude that if no sutures were used, a larger overlap of the defect [3–5] was needed [22].

Adhesive fixation in the intraperitoneal space has not proven to be effective as a primary form of fixation. Shug Pass et al. evaluated the strength of fibrin glue fixation of mesh to peritoneum and to muscle in a basic science model and a pig model. There was a significant difference in fixation strength between muscle and peritoneum (47 N vs 11 N) suggesting that fibrin glue should not be used to fixate mesh to the peritoneum [23]. As previously mentioned, Melman et al. did an acute fixation study comparing permanent tacks, absorbable tacks, suture, and fibrin glue. Suture was significantly stronger than all other methods of fixation. Glue was the weakest fixative, and permanent tacks were stronger than absorbable tacks [3]. Multiple reasons can be theorized as to why fibrin glue does not fixate mesh well to the peritoneum. One reason is that coated meshes inherently do not fixate well with fibrin glue due to the inability of the glue to permeate the entire surface of the mesh. Secondly, the peritoneum is a fluid structure that classically has slower ingrowth of mesh compared to muscle and fascia.

Retrorectus Mesh Placement

The retrorectus space refers to the Rives retrorectus repair and the newer transversus abdominis release (TAR). Options for fixation in this space are classically transfascial suture fixation though fibrin glue is gaining some popularity in the space. Biomechanically, the principles and findings of intraperitoneal mechanical fixation apply, but it is likely that fibrin glue fixation is stronger than it is in the intraperitoneal space because uncoated and wider pore mesh is being fixated to fascia and muscle instead of coated mesh being fixated to peritoneum. A recent study by Moazzez et al. described their technique for fibrin glue use in the retrorectus space for ventral hernia repair. In their description a few sutures are used to fixate the mesh to the posterior sheath, and then after closing the posterior sheath and securing the mesh to it, fibrin glue is used to fixate the mesh to the entire surface area of the posterior sheath [24]. Currently there is a paucity of basic science data evaluating fibrin glue use in the retrorectus space. Historically, the Rives repair is a tension-based repair, which inherently required the use of sutures to accomplish the retrorectus fixation of the mesh thereby decreasing forces on the anterior fascial closure (Fig. 7.4). This foundational principle of the repair calls

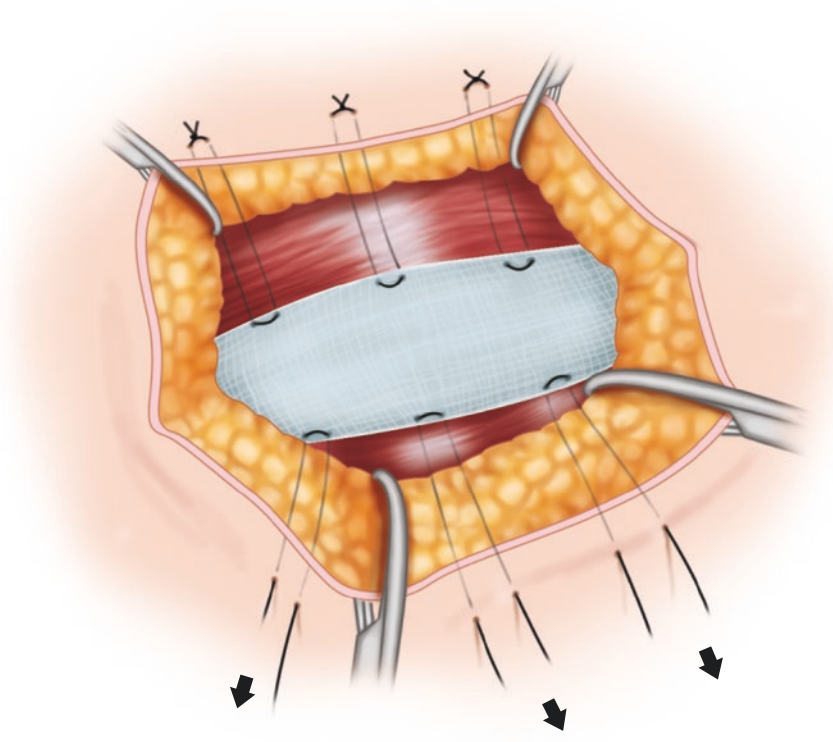

Fig. 7.4 Rives' retrorectus repair with tension-based mesh fixation (Picture comes from *Atlas of Hernia* by Wantz 1991 Lippincott)

into question the potential utility of fibrin glue fixation. As newer preperitoneal and retrorectus techniques like laparoscopic and robotic preperitoneal ventral hernia repairs mature clinically, there will be a greater need for understanding the behavior of fibrin glue in this space.

Onlay

At the same time that Rives was describing his retrorectus repair, Chevrel, also in France, described his onlay method for incisional hernia repair. Chevrel's goals of repair were to recreate the linea alba with the anterior rectus sheath. This concept was based on cadaver studies he conducted that revealed the anterior rectus sheath was the next strongest part of the abdominal wall secondary to the linea alba. In his repair, he reconstructed the abdominal wall in three layers, which included a double-layer midline closure using the anterior rectus sheath and then placement of an onlay prosthetic. Chevrel's approach to fixation was revolutionary for the time. He sutured his onlay mesh but also described how to make and place fibrin glue on the midline closure. His outcomes were excellent with up to 20-year follow-up and a recurrence rate of 4.9% [25].

Over the past few years, the onlay repair with fibrin glue fixation has slowly increased in popularity in the United States and has been supported by basic science research (see section "The Science of Fixation"). A large series of 97 patients by Shahan et al. reviewed the onlay technique on large ventral hernias that were complex and required myofascial advancement flaps. In this technique the primary form of fixation is with fibrin glue with some skin staples used as place holders to orient the mesh onto the abdominal wall for application of the fibrin glue. Mean BMI was 32 kg in this study with a mean hernia defect size of 150 cm^2. Follow-up was 1 year, and there were no recurrences reported in the series. As with all ventral hernia repairs, the main issue was persistent seroma, which was found in 21% of patients. Due to other various wound complications (seroma included), 9% of patients required operative wound management. However, 100% of mesh was salvaged in the series, and it was found that contamination status at initial operation did not affect the need for reoperation [26].

Hiatal Hernia

The routine use of mesh (as well as type) remains a controversial topic that continues to be debated. Hundreds of clinical articles have looked at mesh placement in this location, but few have looked at types of fixation for the mesh. Due to the movement of the diaphragm and esophagus thousands of times a day, strong fixation in this area is key since migration can lead to esophageal erosion due to the movement of the diaphragm and esophagus thousands of times a day. Generally speaking, biologic mesh or absorbable biosynthetic mesh approved for intra-abdominal use is recommended if mesh is to be placed. Krpata et al. have reviewed sutures vs. fibrin glue fixation of mesh at the hiatus. He used a porcine model and a biologic mesh to

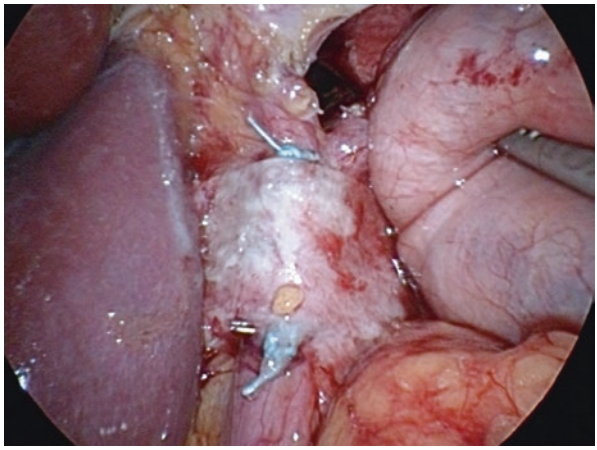

Fig. 7.5 Fixation of biosynthetic mesh at the hiatus with fibrin glue

evaluate the two forms of fixation. A 30-day survival study was done, and the biomechanics revealed no migrations in either group and similar ingrowth implying similar fixation strengths [27]. Fortelny et al. did a similar study in a porcine model using fibrin glue to fixate titanized polypropylene mesh at the hiatus. At 4 weeks they found excellent integration and no mesh migrations [28].

Clinically, Powell et al. reviewed 70 patients with cruroplasty reinforcement with bio-absorbable mesh and fibrin glue as the sole fixation method for hiatal hernia repair. The short-term study revealed no immediate complications [29]. We have used this method of mesh fixation in over 200 hiatal hernia repairs with no known case of mesh erosion into the esophagus (Fig. 7.5).

Good-quality fixation data in the hiatal hernia space is sparse. This is partially due to the inherent controversy surrounding mesh use, but also repair outcomes can be hard to follow as imaging and clinical suspicion are necessary to evaluate for recurrence. Regardless, continued study is necessary to optimize fixation.

Conclusions

The need for optimal mesh fixation spans all types of hernia repairs. The type of hernia, the technique selected, and the type of mesh determine fixation options. Understanding the basic science helps to provide an underlying logic that can help formulate an approach to each hernia situation. Realizing that "strongest" fixation is not always "best" fixation leads to the real question that must be answered: "how strong is strong enough?" Fixation continues to evolve, and further study using "out of the box" thinking will be needed to tailor optimal fixation of mesh for a given hernia presentation.

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How to Choose a Mesh in Hernia Repair

8

David Earle

Since the introduction of polypropylene (PP) mesh for hernia repair [1], surgeons continue to discuss the use of mesh in a variety of settings for one of the most common operations performed by general surgeons—hernia repair. This discussion has involved raw materials, cost, and outcomes and for many years referred to only a few products, as manufacturing was limited. Nowadays, with multiple permanent, absorbable, biologic, and hybrid products on the market, the choice of mesh for a hernia repair can be daunting. Increasing clinical complexity further emphasizes the need for individualizing care, but more frequently, hospital supply chain personnel institute product procurement procedures for cost control, limiting mesh choice for surgeons. This can force surgeons into a "one-size-fits-all" practice regarding mesh choice, which may not be ideal for some patients. Conversely, current literature lacks definitive evidence supporting the use of one mesh over another, a fact that has not escaped the radar screen of the hospital supply chain and mesh industry, both of which attempt to limit vendor and mesh choice for financial gain. It is unlikely that this type of "proof" will ever come to fruition. This leaves us with choosing a mesh based on an algorithm that is centered on the patient and the patient's unique clinical scenario [2]. This algorithm (Fig. 8.1) will culminate in mesh choice, but could also apply to non-mesh techniques as well.

Below are generic two examples, based on real cases, which will serve as background information. I will refer to these examples throughout the chapter to highlight how an algorithmic approach to mesh choice can be utilized.

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1. Identify goals of hernia repair
    a. Explicitly ask patient about their goals – symptom relief, prevention, or both.
    b. Align those goals, and discuss the likelihood of their realization with hernia repair.
2. Evaluate the clinical scenario
    a. Is the case elective, urgent, or emergent?
    b. Is the case clean, contaminated, or potentially contaminated?
    c. Is the patient a better candidate for local or general anesthesia?
    d. Does the patient's history suggest higher likelihood of future operation? (e.g. pregnancy, Crohn's disease, ostomy closure)
    e. Evaluate the hernia details –previous repairs, location, size of defect, size of sac, associated skin issues.
3. Choose a technique
    a. A technique that is most likely to meet the goals in the given clinical scenario should be chosen. In the event this technique is not the one the surgeon is the most comfortable with or has the adequate resources, referral or a different technique and rationale should be discussed with the patient, and a joint decision can be made about how to proceed. This is obviously limited in emergency situations.
4. Choose a mesh designed for use with the chosen technique
    a. Consider the raw material –permanent, absorbable, synthetic, biological, hybrid
    b. Consider the design –A high priority should be placed on the relative strength of the mesh, data that can be difficult to obtain. Porosity, fiber size, and barrier coating are also important to evaluate, as each mesh performs differently in different locations (e.g., intra-vs extra-peritoneal, bridging vs support).
5. Preoperative planning
    a. Plan enhanced recovery strategies with anesthesia, and coordinate regional anesthetic blocks as necessary.
    b. Define need for multidisciplinary coordination before you start, such as plastics, colorectal, gynecology, and urology.
    c. Make sure the mesh you have chosen is available, and in a variety of sizes.
    d. Have an alternate plan and/or mesh available in the event intraoperative findings dictate a change.

Fig. 8.1 Algorithm for mesh choice for hernia repair

Example 1: A 70 year old patient who works as a physician presents with a small, asymptomatic incisional hernia after a laparotomy. The patient has a BMI of 26. The patient is concerned it will grow, as it seems to have grown from the size of a marble to that of a golf ball in a short period of time. There is no pain. The surgeon may tell the patient not to worry about the hernia unless it starts causing problems. As the hernia sac grows, the patient returns with an enormous hernia sac, associated with overlying skin excoriation.

Example 2: A 60 year old obese patient (BMI 52) with multiple medical problems and actively smoking is concerned about progressively worsening pain from an intermittently incarcerating primary ventral hernia, requiring two visits to the emergency room within the past month. The patient noticed the symptoms for several months before the ER visits, but the pain was never that severe. The intermittent pain seems to be increasing in frequency and severity. The patient would like to relieve the symptoms and avoid a life-threatening emergency. The bulge is barely noticeable and located in the midline epigastrium. CT scan reveals the defect is 6 × 6 cm and contains omentum and a portion of the transverse colon.

Step 1: Goals of the Hernia Repair

It is important to identify the patient goals for the operation. Regarding hernia repair, this is usually associated with symptom relief, prevention of developing symptoms (including acute incarceration), or both. Symptoms include discomfort, pain, abnormal abdominal wall contour, skin changes, intermittent bowel obstruction, and limitations of important activities. Prevention is typically the goal associated with asymptomatic hernias found during a routine physical exam or during an imaging study performed for another problem. Often, a patient with mild, but slowly progressive symptoms, desires both to alleviate the current symptoms and avoid waiting until they become so severe it will compromise their care.

Once the goals of the repair are identified, the surgeon must align those goals with the healthcare team. This will allow the surgeon to identify and address unrealistic goals, and formulate a strategy of repair, including mesh choice, which will most likely meet the goals. It is also important to explicitly discuss the likelihood of meeting the patient's expectations, as patients and surgeons may have different perceptions of what is important [3, 4].

In example 1 (asymptomatic, marble-sized incisional hernia; goal is to prevent it from getting worse), there are a variety of techniques and mesh options available. As the hernia defect and/or sac enlarges, or if the hernia becomes acutely incarcerated with compromised bowel, the number of acceptable options dwindles, which affects the choice of mesh.

In example 2 (obese patient, escalating symptoms, 6 cm primary defect; goals are pain relief and avoidance of an emergency operation), one option for the surgeon is to recommend weight loss before an elective hernia repair is considered, as

the risk of repair is perceived to be too high for this BMI. The patient may be told to call back when 50 lb of weight have been lost. While this may be effective, patients may feel their problem is being dismissed due to their obesity. A possible outcome in this scenario is that the patient returns to the ER 6 weeks later with an acutely incarcerated hernia containing ischemic transverse colon, requiring laparotomy, partial colectomy, and colostomy. This series of events may then lead to a clinical situation where options are extremely limited and include only major abdominal wall reconstruction techniques, with or without concomitant colorectal procedure. While it's true there is an increased risk of complications with open ventral hernia repair in this population, 85% of patients with a BMI >50 will not have any complications according to a recent review of more than 100,000 open ventral hernia repairs in the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) database [5]. And this risk is even lower with a laparoscopic approach [6].

Even though the patient did not present with an emergency, the progressive nature of the symptoms usually warrants an approach on an urgent basis, without enough time for proper preparation, such as weight loss. In this case, even without weight loss, both open and laparoscopic options could have been pursued in the face of a high BMI with a reasonable expectation of success.

Step 2: Clinical Details

Important clinical details regarding mesh selection include (1) operative urgency, (2) past history (medical problems, prior hernia repairs), (3) outlook for the future (Crohn's disease, pregnancy), and (4) hernia details (location, size, etc.). While we all perform a complete history and physical, we tend to focus our evaluation on the hernia details, which should only be done in the context of the primary goal(s) of the hernia repair.

Operations are performed in one of three scenarios—elective, urgent, and emergent. The following definitions will be used for the purposes of this manuscript. Elective cases will refer to those operations that can be booked at any time, even up to a year in advance, or observed without operation. These cases allow ample time to identify and discuss the goals, review old records, prepare for operation with weight loss and smoking cessation, participate in multidisciplinary collaboration, obtain a variety of imaging studies as necessary, utilize preoperative botulinum toxin A, participate in enhanced recovery programs, travel as necessary, and arrange for postoperative care. Urgent operations will refer to those that need to be accomplished within 1–4 weeks of the initial evaluation due to symptom escalation and/or impending complications such as skin necrosis or progressively more frequent and/or severe symptoms, such as bouts of incarceration or bowel obstruction. Emergent operations will refer to those that must be performed within hours to less than 1 week and include patients with acute incarceration with significant pain, unrelenting bowel obstruction, impending bowel ischemia, cellulitis, and/or perforation of the GI tract.

Prior surgical history is always important to obtain, and impacts mesh choice for hernia repair. Efforts should be made to review the details of the prior hernia repairs. This may yield information regarding the difficulty level of the operation, including the amount and density of adhesions. Information about the postoperative course may also lend clues to an otherwise unpredictable course. Finally, the history may allow identification of how a particular mesh performed after implantation. For example, if a patient had an exaggerated inflammatory response to a particular mesh used for a previous repair, avoiding this mesh for the current repair would be logical. Conversely, if a patient had a prior repair with a mesh that performed very well (no shrinkage, seroma, or exaggerated inflammatory response) in another location, the use of the same mesh would also be expected to be associated with a good outcome with regard to the host response to the mesh.

Potential need for future operation is also an important clinical detail and includes C-section, ostomy closure, or operation for Crohn's disease [7, 8]. Higher-risk or known planned future operations should factor into the decision for technique and mesh choice. For example, techniques using intraperitoneal mesh should generally be avoided if possible, as they would be expected to increase the risk and difficulty of subsequent operations [9–11].

Laparoscopic inguinal hernia repair, however, should not be considered a contraindication for men due to the low risk of developing prostate cancer, and the fact it does not unreasonably complicate future prostatectomy [12].

Consider hernia repair in women of childbearing age before, during, and after pregnancy. There is no consensus whatsoever regarding hernia repair timing or technique. Using an algorithmic approach, addressing the patient's goals and discussing the pros and cons of repair type, timing, and mesh use should lead to the best decision and plan for that patient. The surgeon should not prevent access to hernia care for women of childbearing age, nor proceed with hernia repair without a proper informed consent that includes pregnancy-related issues [13, 14].

Finally, the hernia details are clearly important. Hernia *location* is important, as it will dictate the type of fixation points and amount of overlap available. Consider a midline hernia near the umbilicus. There is plenty of room for wide overlap, as well as available abdominal wall muscle/fascia for fixation. If the midline defect is near the pubic bone, the amount of inferior overlap will be limited, but the available structures for fixation (pubic symphysis and Cooper's ligaments) are much stronger than muscle and fascia, mitigating the need for larger amounts of overlap. If the midline defect was near the xiphoid, bony fixation is more limited, but surface area for more overlap is available, with the ability to drape the mesh high on the diaphragm, taking care to avoid fixation to the pericardium. Hernia defect *size* is a very important detail, as it relates directly to technical difficulty of the operation and risk of recurrence [15, 16].

Through clinical experience, I have found that midline hernias can generally be categorized into small, medium, and large, depending on their transverse dimension. Small defects (<5 cm in width) have many viable options. They can usually be closed primarily without adjunct techniques such as component separation or BTA

Table 8.1 Clinical concerns with small, medium, and large hernia defects

Small	<5 cm	• Many options for repair available • Can usually close primarily without adjunctive techniques • Mesh choice less critical
Medium	5–10 cm	• Many options for repair available • Ability to close defect is more variable, and highly dependent clinical scenario, patient history, defect location, and body habitus • Mesh choice highly dependent clinical scenario, patient history, defect location, and body habitus
Large	>10 cm	• Fewer options available for repair • Defect closure usually requires adjunctive techniques • Mesh choice more critical

injection. They are also easily bridged if necessary and have lower recurrence rates compared to larger defects [15, 16]. Medium defects (5–10 cm in width) are more dependent on the clinical scenario, patient's medical history, and body habitus. While they may be bridged, larger mesh is required, and adjunct techniques such as component separation or BTA injection may be necessary. Large defects (>10 cm in width) are typically very difficult to bridge given the limitation of the size of the abdominal wall (Table 8.1). Additionally, large defects usually require adjunct techniques to close them, such as component separation, preop BTA injection, or both. Lastly, hernia details should include *associated problems* such as skin excoriation, prior skin grafts, large hernia sacs, and disfiguring scars, all of which will help guide technique and subsequently mesh choice.

Step 3: Choose a Technique

With knowledge of the patient's goals, the clinical scenario, the medical history, and the details of the hernia, a technique can be chosen that will be most likely to be successful at realizing the goals of repair. For ventral hernias, if restoration to normal abdominal wall contour is one of the main goals of repair, techniques that involve defect closure will be more likely to achieve success compared to bridging techniques. If the primary goal is pain relief, bridging techniques can be as effective as techniques that utilize defect closure, and this will drive prosthetic choice. If part of the goal is revision of a disfiguring laparotomy scar/skin graft, or removal of excess skin and subcutaneous tissue (e.g., panniculectomy), an open approach will likely be more appropriate than a laparoscopic approach, and the prosthetic choice will be dependent on the specific open technique and placement location of the mesh.

In example 1, (asymptomatic, marble-sized incisional hernia; goal is to prevent it from getting worse), many options are available with open and laparoscopic techniques. In this case, clinical details related to the medical history and physical examination will be important guides to choosing the best technique. The technique with the lowest chance of recurrence would be most appropriate for the goal of prophylactic hernia repair, and the technique chosen will drive mesh choice.

In example 2 (obese patient, escalating symptoms, 6 cm primary defect; goals are pain relief and avoidance of an emergency operation), a laparoscopic bridging technique is a good option, as it lowers the risk of wound complications and doesn't require defect closure, simplifying the operation and having a high probability of success. This choice of technique would then guide mesh choice.

Step 4: Choose a Mesh

Once the goals have been established, clinical details sorted out, and a technique chosen that will most likely realize the goals while minimizing risk, it is time to choose a mesh. While there is no agreement as to which mesh is the "best," there are some details that bear emphasis and require a knowledge of mesh devices that many surgeons dismiss as unimportant, unproven, and/or unknown. Further, since there is no consensus regarding which mesh feature is most important to evaluate, consider what we are doing—implanting a mesh device to support soft tissue where weakness or defects occur. Therefore, biocompatibility and strength should be at the top of the list informing surgeons about mesh choice, with mesh strength being most important.

While biocompatibility is important to consider, all mesh devices have already been determined to be biocompatible through the approval process by the US Food and Drug Administration. Furthermore, the individual biocompatibility for a particular mesh in a unique host is unpredictable, unless there is previous exposure to the product, with a known response.

Therefore, strength becomes the number one metric surgeons should be concerned with when choosing a mesh. Given this logic, it is surprising that strength data is rarely reported in a manner that surgeons can access and use clinically, or to accurately compare mesh devices. A shining example of the misunderstanding of mesh strength data is the recent manufacturer recall of Physiomesh™ (Ethicon, Inc., Cincinnati, OH, USA) [17]. The ultralightweight [2], coated PP mesh was designed for intraperitoneal use and was marketed for use for all types of ventral hernias, including bridging techniques in all types of defects and patients, large and small. The PP component of Physiomesh™ has a weight of <30 g/m^2 and can be manually torn in half with ease. This means that the choice of an ultralightweight mesh for bridging techniques will have a higher risk of recurrence compared to a stroinger mesh. For context, Marlex™ (CR Bard, Warwick, RI, USA) uncoated PP mesh, considered by most classification systems to be "heavyweight," is 95 gm/m^2.

It is important to point out, however, that weight (typically reported in g/m^2) is only a surrogate for mesh strength and is only useful for mesh comparison when considering the same polymer or different polymers with the same density. The units of measurement are also important to consider making accurate comparisons among products. The different densities among polymers may have significant implications for mesh strength [18]. For example, a denser polymer will weigh more per area, and thus could have thinner, weaker fibers, yet still have the same weight/area as a less dense mesh which may be stronger. The weight of a knitted mesh can be altered by increasing the number of fibers (which reduces pore size)

and/or increasing the fiber diameter (which may decrease pore size to a lesser extent, but can increase strength). Recently, Deeken and Lake have published a manuscript detailing these issues, which can serve as an excellent, independent resource for clinical decision-making [19]. These authors have also contributed a chapter dedicated to this topic later in this book.

Mesh strength can be measured with a variety of methods. However, none of the methods take into account the host reaction for an individual patient, and none of the methods can precisely extrapolate their data into real-life clinical situations. The missing clinical data include patient activity and body habitus, variable tissue quality, and the heterogeneous group of hernia defects that present with many sizes and variable locations. In vitro, or bench testing, maneuvers such as tear strength, suture pull through, and ball burst are common, but not standardized. When comparing studies however, details of how this data were obtained are critical. Strength data are dependent on equivalent methods of mesh fixation to the tensiometer, speed and direction of load application, and reporting in the same units of measurement [19].

Recognizing that this data is not practical for surgeons to review, and that there is no ideal mesh for all cases, it is helpful to avoid extremes. This is particularly important when relying heavily on the mesh for repair, such as with bridging techniques for larger ventral hernia defects. Even knowing the relative weights, and by inference strength, it becomes obvious that an ultralightweight mesh should be avoided in patients with large defects when used with a bridging technique. Strength is probably less important for bridging techniques with inguinal hernias, as the defects are all relatively small and proximate to rigid tissues surrounding the myopectineal orifice such as the pelvis, inguinal ligamnent, and psoas muscle. Making strength comparisons more difficult are mesh products designed to remodel (biologic) or absorb (synthetic) completely. The ultimate strength of repair for a given individual with these types of mesh is totally unpredictable. For inguinal hernia however, the defects are generally not closed, making use of absorbable or remodeling mesh more prone to recurrence, particularly for direct defects using an open technique [20, 21]. Laparoscopic techniques utilizing biologic mesh intended to remodel have been reported, and initial results in one small series of ten patients revealed a 9% recurrence rate at 14 months [22], and one small series of ten patients operated on for non-palpable tears in the transversalis associated with groin pain in athletes (“sports hernia”) revealed an 80% chance of pain relief and no evidence of hernia at 12 months telephone follow-up [23].

In example 2 (obese patient, escalating symptoms, 6 cm primary defect; goals are pain relief and avoidance of an emergency operation), if a laparoscopic bridging technique is chosen, using a permanent mesh with the lowest available weight/strength or synthetic absorbable/biologic mesh would be associated with the highest risk of recurrence and should be avoided. Additionally, if an intraperitoneal placement was planned, a mesh of sufficient strength that is also designed for intraperitoneal placement would be most appropriate.

In addition to strength data, each prosthetic has a list of features designed to address a specific clinical issue. Examples include designs for use specifically

within the peritoneal cavity, or for use as an adjunct to repair instead of bridging a defect. Again, using example 2 (obese patient, 6 × 6 cm defect, progressive bouts of acute incarceration and pain; goal is to treat episodes of incarceration, i.e., avoid recurrence), if the surgeon chose a laparoscopic technique without defect closure, placing the mesh intraperitoneally, a mesh should be chosen that is designed specifically for the intraperitoneal location, and is not the weakest mesh on the market. This approach would meet the primary goals of the patient, with the least overall risk, provided the surgeon has the appropriate training and experience in this technique. An alternative strategy would be an open repair with defect closure and mesh. If the retrorectus space was to be used for mesh placement, and the defect could be closed, a bare polypropylene mesh of any weight should suffice, as the anticipated stress on the mesh would be low. The open approach would however increase the risk of wound complications.

Finally, there are two major categories of mesh available—permanent and nonpermanent. Of those that are not permanent, some are absorbable (synthetic), and some are designed to remodel into host tissue (biologic). If the technique chosen is a bridging technique, an absorbable or remodeling type of mesh is probably not the most appropriate choice if hernia recurrence is to be minimized. This includes both inguinal and ventral hernias [20, 21, 24]. For bridging techniques, permanent mesh would be expected to have the lowest risk of failure, and mesh designed to remodel (typically biologic mesh) would be somewhere in between, depending on the size and location of the defect being bridged. In example 1 (thin patient, asymptomatic, small, midline incisional hernia), mesh choice for bridging would include permanent and remodeling type mesh or absorbable mesh used as an adjunct to primary repair. In example 2 (obese patient, 6 × 6 cm defect), bridging with an absorbable or remodeling type mesh would have a much higher risk of failure compared to a permanent mesh of sufficient strength.

Step 5: Preoperative Planning

Once the patient has been fully evaluated, and an operative plan crafted, the reaminder of the preoperative process begins. There are many aspects of the preoperative planning process, but one important and sometimes overlooked aspect is mesh availability. This not only concerns the mesh type that has been chosen for repair, but also must include a variety of sizes, as intraoperative findings may change the plan. Additionally, a backup mesh should be available in the event the wound classification of the case changes unexpectedly, or the mesh needs to be placed in an area it was not designed for. In example 1 (thin patient, asymptomatic, small, midline incisional hernia), the surgeon may be planning a laparoscopic approach (with or without robotic assistance) with defect closure and *extra*peritoneal mesh placement. The mesh chosen was a lightweight, macroporous, bare PP mesh. Intraoperatively however, it may become apparent that the mesh cannot be placed in the extraperitoneal location and/or the defect cannot be closed. In these cases, a mesh appropriate for intraperitoneal use and/or bridging mesh should be available.

Summary

In summary, there are many hernia repair mesh products available on the market, and there is no proof that one device is better than another. It is clear, however, that certain types of mesh are more appropriate in certain circumstances, which is why an algorithmic approach is so important. While the algorithm does require some knowledge of the features and strength specifications of mesh devices, the knowledge does not have to be encyclopedic. The surgeon should at least know the basics regarding strength, design features with respect to mesh position, and how these features fit with the technique being used for repair, in the specific clinical circumstance of their individual patient.

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9 Patient Comorbidities Complicating a Hernia Repair: The Preoperative Workup and Postoperative Planning

Desmond T. K. Huynh and Omar M. Ghanem

Introduction

Abdominal wall hernia is one of the most common surgical pathologies worldwide, and general surgeons must be able to address hernias on a daily basis. Despite the ubiquity, or perhaps because of it, approaches to hernia management vary widely. One facet of this management is the preoperative optimization of patients prior to surgery. New evidence has repeatedly highlighted the critical importance of preoperative optimization in obtaining the finest outcomes. This chapter reviews the available literature as it pertains to the management of patients prior to hernia repair and makes recommendations based on this evidence. We will address the specifics of hernia evaluation as well as describe how to safely address various comorbid conditions. Within each topic, we will review and recommend practices that have been shown in the literature to produce the best possible outcomes.

Preoperative Considerations

Surgical History

As with all surgical undertakings, a thorough surgical history should be obtained during preoperative planning for hernia repairs. This history should begin with a comprehensive description of any and all previous abdominal or groin operations. In interrogating a patient's history, the surgeon should obtain previous operative

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reports and pay close attention to information regarding surgical incisions, operative times, and the density of intraabdominal adhesions. Additionally, details on previous operative complications, such as enterotomies, anastomotic leaks, abscesses, and wound infections, should be obtained prior to the planned herniorrhaphy because these elements may provide insight into the accessibility of a patient's abdomen.

Perhaps the most critical element of the surgical history comes from details of prior hernia repairs. Specifics regarding recurrences, the history of component separation, and the history of mesh repair are mandatory. Similar to the general surgical history, all complications and surgical site occurrences, such as fistula, hematoma, seroma, and wound infection, should be evaluated in the preoperative period.

The aforementioned data are relevant and essential to proper operative planning. These details may guide the selection of the optimal repair approach (tissue or mesh repair as well as mesh selection). A history of previous surgeries may dictate the most amenable planes for mesh placement, as well as the approach and the need for component separation.

Smoking

Tobacco smoke is a known risk factor for perioperative hernia complications. Smoking comprises a unique risk factor in its ability to be modified prior to surgical intervention through both counseling and chemically mediated cessation strategies.

Smoking constitutes a multifactorial insult to wound healing capacity through several physiologic mechanisms. Nicotine was the presumptive causal agent for many years; however, tobacco smoke consists of several additional physiologically active compounds such as tar, carbon monoxide, hydrogen cyanide, nitrogen oxides, *N*-nitrosamines, formaldehyde, and benzene [1]. These agents are responsible for a reduction in both blood and tissue oxygen tension, a reduction in the capacity for collagen deposition, a blunting of the inflammatory process, and an impairment of growth factors [2]. This constellation of effects is responsible for a predisposition toward wound ischemia and infection leading to increased morbidity and mortality in hernia management.

Smoking has been identified as a significant risk factor for the development of incisional wound infection following abdominal surgery [3]. Smoking thus contributes to surgical site occurrences and thereby an increased risk for the development of an incisional hernia.

Smoking has been well established as a risk factor for perioperative morbidity and mortality. A review of the American College of Surgeons' National Surgical Quality Improvement Program from 2005 to 2010 recorded 1706 patients undergoing abdominal wall reconstruction and found smoking to be a significant preoperative predictor of major operative complications, which were defined as deep wound infection, graft or prosthetic loss, or unplanned return to the operating room within 30 days [4]. These findings have been corroborated in prospective randomized controlled trials in the setting of ventral hernia [3], with investigators

showing a significant increase in postoperative wound infection in smokers compared to nonsmokers. In addition to the above operative complications, multiple studies have demonstrated smoking to be a significant predictor of perioperative respiratory complications in the setting of all surgery [5] as well as hernia repair surgery specifically [6]. Smoking has also been shown to increase the risk for readmission following hernia repair in numerous studies [7, 8]. Finally, in addition to the increased risk of surgical site occurrence and perioperative complications, smoking has been shown to be a direct predictor of recurrence following hernia repair [9, 10].

As previously noted, smoking presents as a unique preoperative risk factor that is readily intervened upon before surgery. These interventions may include both counseling and nicotine replacement therapy, which has been shown to be effective in patients undergoing hernia repair. While some of the detrimental physiologic activity of smoking may be attributable to nicotine, smoking cessation strategies that utilize nicotine patches have been shown in prospective randomized controlled trials to have an overall benefit in the reduction of postoperative complications including wound infection, dehiscence, and readmission [11].

With this evidence in mind, our recommendation in elective hernia repair is for the mandatory cessation of smoking preoperatively for at least 4 weeks [10]. Compliance toward smoking cessation can be evaluated using the cotinine assay, which has a high diagnostic performance in determining whether patients are currently smoking and are expected to have a high risk of perioperative complications. While we recommend both counseling and nicotine replacement therapy as strategies to achieve smoking cessation, it should be noted that nicotine replacement will yield a positive cotinine test; thus, this test should be ruled out in determining compliance. Thus, if the surgeon suspects noncompliance, obtaining anabasine or nornicotine levels (indicates tobacco use irrespective of nicotine replacement therapy) may be warranted. To decrease morbidity, we recommend that any patient found to be non-compliant should be rescheduled for surgery particularly in the setting of complex hernia repair and abdominal wall reconstruction. When dealing with smaller noncomplex hernias, smoking might not necessarily result in significant wound morbidity; however, uniform smoking cessation is our rule.

Obesity

Obesity represents a significant risk factor in hernia repair during both the perioperative and longitudinal periods. The relationship between obesity, metabolic syndrome, and cardiopulmonary comorbidities predisposes patients to complications during the physiologic demands of surgery. This relationship was demonstrated in a retrospective analysis of 78,348 patients who underwent ventral hernia repair in the United States between 2004 and 2008.This analysis showed an increased risk of serious pulmonary complications, including pneumonia, respiratory distress, and pulmonary embolism, as well as significantly longer hospital admissions in

patients with obesity [12]. This evidence has been correlated in multiple studies that also identify the relationship between obesity and complications in the immediate postoperative period as well as the role of obesity as a risk factor for recurrence [13, 14].

In the setting of open ventral hernia repair, patients with a BMI ≥ 40 have been shown to be significantly more likely to undergo a subsequent operation to repair a recurrence [15]. One of the primary reasons for this increased risk for recurrence lies in the predisposition of obese patients toward surgical site occurrences [16]. As such, minimally invasive approaches have been postulated to decrease this risk of surgical site occurrence and thereby decrease the chance of recurrence. However, obesity presents a unique challenge in minimally invasive approaches as thick abdominal walls and large amounts of visceral fat increase the technical difficulty of these repairs. Ultimately, the evidence shows similar findings between laparoscopic approaches and open ventral hernia repair. A retrospective study of 901 patients who underwent laparoscopic ventral hernia repair also showed that patients with a BMI ≥ 40 are at an increased risk for recurrence following hernia repair [17]. Following this evidence, we currently recommend that patients whose BMI falls into this range should not undergo open or laparoscopic elective hernia repair until their weight has been optimized.

Rapid developments in the field of hernia repair and bariatrics create an ever-changing landscape in managing these patients. Guidelines for optimal management will change as more ventral hernia repairs and abdominal wall reconstructions employ minimally invasive approaches with mesh in the retrorectus and preperitoneal positions. Guidelines will also change with new bariatric solutions, such as balloon occlusion and endoscopic gastric sleeve. In light of this, our current recommendations for managing hernia in obese patients are as follows.

Preoperative weight loss begins with medical weight loss. A well-established protocol for patients with ventral hernias and associated obesity was described by Rosen et al. [18] The protocol utilizes a protein-sparing modified fast in collaboration with a medical weight loss specialist. Using this technique, the authors were able to reduce the BMI of a group of 25 patients from an average of 49 to 40 kg/m^2 over an average period of 17 months prior to undergoing complex abdominal wall reconstruction. In addition, 88% of the patients were able to maintain this reduction in weight for up to 18 months postoperatively. If this initial medical and behavioral therapy fails, we recommend bariatric surgical intervention. In patients with concomitant morbid obesity and ventral hernia who have failed medical management, we recommend a minimally invasive weight loss operation followed by repair of the hernia. Repair of the hernia should be timed to occur during the plateau in the weight loss curve after bariatric surgery, typically at approximately 12–18 months postoperatively. Patients for whom a minimally invasive bariatric procedure is not an option present a more complicated clinical decision. In cases that necessitate an open weight loss operation, the surgeon must evaluate the risks and benefits of simultaneously repairing the hernia in order to close the abdominal fascia without tension.

Diabetes

Hyperglycemia has profound effects on wound healing through both immunomodulatory and vasculopathic mechanisms. Due to a blunted inflammatory response, patients with diabetes are at risk for delayed wound healing. Additionally, damage to the microvasculature can lead to relative ischemia, further decreasing the patient's capacity to recover following surgery. For patients undergoing inguinal hernia repair, diabetes has been shown to increase the risk of complications in the intraoperative and immediate postoperative period (<30 days). This increased risk of complications included infections, bleeding complications, and superficial wound dehiscence [19]. Regarding complex hernia repairs, insulin-dependent patients and patients with a blood glucose of >140 mg/dL were found to have a lengthened time to their first meal following surgery as well as an increased length of stay and increased cost of hospitalization [20].

As described in the studies above, a patient's current glycemic status plays a critical role in their ability to heal and fight infection. A study conducted between 2000 and 2003 showed a significant reduction in surgical site infection in patients with a hemoglobin A1c of less than 7% in the setting of all non-cardiac surgery. This generalized finding has been corroborated in hernia repair as well; Petro et al. showed that a diagnosis of diabetes is a significant predictor of surgical site occurrence including surgical site infection [21]. Following from this association in regard to surgical site occurrence, diabetes has also been linked to an increased risk of recurrence in umbilical hernia repair [22].

Considering this evidence, our recommendations align with the expert consensus on ventral hernia management [23]. Patients with a hemoglobin A1c of greater than 8% should not undergo elective hernia repair. Patients with a hemoglobin A1c between 6.5 and 8% must first be optimized through either medical or surgical means. Once long-term glycemic control has been achieved, we recommend a perioperative blood glucose level of approximately 140 mg/dL, which prevents the aforementioned consequences of hyperglycemia while also preventing the risks associated with hypoglycemia in the operative setting.

Nutritional Assessment and Supplements

Nutritional status is of critical importance when considering a patient for surgery. Failing to optimize a patient's nutritional status preoperatively increases the risks of morbidity, mortality, and poor outcomes [24, 25]. A well-studied method of assessing nutritional status in the surgical literature uses serum chemistries, such as albumin, with low levels of albumin predicting poor postoperative outcomes [26, 27]. However, recent evidence offers imaging techniques as an alternate modality for assessing a patient's preoperative nutritional status. Using cross-sectional imaging, a patient's sarcopenia, and thereby their nutritional status, can be evaluated by comparing the ratio of lean body mass to lipid content [28].

Several nutrients have been evaluated in the literature and have been demonstrated to have a significant clinical impact when given prior to surgery. Arginine is one such nutrient and has been shown to improve wound healing, augment the tissue inflammatory response, and prevent ischemia by promoting vasodilation through local increases in NO [29–31]. While the specific benefits of preoperative arginine administration have not been shown in hernia surgery specifically, they have been described in the colorectal literature and showed a decrease in the number of readmissions and hospital days [32].

In addition to individual agents, the repletion of certain combinations of nutrients has been shown to decrease the rate of perioperative complications. One well-studied regimen is the "metabolic modulating formula" described by Braga et al. [33], which included omega-3 fatty acids, docosahexaenoic acid, and eicosapentaenoic acid. When preoperatively optimized using these nutrients, patients were demonstrated to have reductions in infection, length of stay, and hospital cost [34]. In addition to optimizing patients with these nutrients, the patients can also be preoperatively loaded with carbohydrates to maximize glycogen stores during surgery [35].

We find that while nutrition is of critical importance, it is often overlooked during the preoperative planning period. There remains a significant lack of evidence-based recommendations on the subject, especially as it pertains to specific areas of surgery such as hernia. To date, there is a marked absence of evidence guiding nutritional management in abdominal wall reconstruction. In this setting, we apply the generalized data discussed above and administer the Impact© Nutritional Supplement three times daily for the 5 days leading up to surgery to replete the validated nutrients in the metabolic modulating formula.

Other Comorbid Conditions

The NSQIP surgical risk calculator is the premier resource for a comprehensive assessment of perioperative risk [36]. The calculator represents a global assessment of a patient's risk for all complications in the perioperative period and sub-stratifies by risk for specific complications.

Due to the stress of surgery, patients with outstanding medical conditions should be evaluated before planning surgery and optimized prior to operating. Conditions of the heart, lungs, and liver as well as all concurrent medical issues should be investigated and considered when weighing the risks and benefits of proceeding with a repair.

When assessing a patient's cardiac readiness for surgery, we recommend assessment using the American College of Cardiology/American Heart Association guidelines on perioperative cardiovascular evaluation [37] as well as the multifactorial index of cardiac risk [38]. Patients with pulmonary comorbidities who require small abdominal wall or groin hernia repair should be managed using monitored anesthetic care if possible to avoid the respiratory strain of general anesthesia and ventilation. Larger hernias in this population also warrant attention to the effects of

restoration following the loss of domain because the reduction of hernia content into the abdominal cavity will create significant pulmonary changes in peak airway pressures and oxygenation. To successfully manage these patients, new studies have described and demonstrated the efficacy of a volume transposition technique [39] in which hernia repair is achieved with mesh that has been sized according to the calculated hernia volume. This avoids any increases in the intraabdominal pressure and may reduce the risk of recurrence.

Finally, all pathologies that predispose patients to increased intraabdominal pressure should be optimized preoperatively because these pathologies put patients at risk for increased herniagenicity as well as postoperative recurrence. Such conditions include chronic constipation, chronic cough, and obstructive uropathies.

Preoperative Workup

Laboratory Studies

The laboratory studies that will be useful when planning for a hernia repair are defined by the specifics of the patient in question. Based on comorbidities, the type of anesthesia, and the type of repair, different studies must be obtained to optimize and clear the patient for surgery. To this end, the studies we recommend have been discussed alongside the condition that they are aimed to assess. In general, we recommend obtaining a complete blood count, basic metabolic panel, coagulation panel, serum albumin, hemoglobin A1c, and cotinine if the patient is a smoker. In addition to laboratory studies, we wish to emphasize evaluation through imaging studies.

Imaging

While simple hernia may be diagnosed and managed based on physical examination alone, imaging can be an invaluable if not mandatory part of preoperative planning in complex hernias.

Ultrasound can be a helpful adjunct in the detection and management of hernias, particularly those in the groin [40]. Ultrasound had the benefit of being inexpensive, noninvasive, and easily performed in the clinic. Ultrasound has achieved particular utility in the detection of occult inguinal hernia as a cause of groin pain. Due to the real-time nature of ultrasound, physicians can image as part of the physical exam and are able to correlate exam findings and maneuvers, such as Valsalva, with ultrasound imaging [41].

With more complicated hernias, both inguinal and otherwise, CT is an invaluable imaging modality for herniography [42], being both relatively inexpensive and nonoperator dependent. CT not only yields information regarding the abdominal wall but also provides insight into a patient's intraabdominal condition. CT scan can be used to assess hernia contents, for example, in the acute setting of

small bowel obstruction when attempting to determine if the nidus of obstruction is within the hernia sac or due to intraabdominal adhesions. Certain considerations should be made when interpreting a CT before hernia repair. First and foremost, the imaging should be assessed in its entirety to identify all defects and their locations so that the most efficient operation can be planned with regard to approach and technique. This identification is best guided by comparison with the physical exam, which should always guide the assessment of hernia. Once the defects have been identified, they should be characterized by answering the following questions: What is the size of the defect? Can the defect be primarily closed? What planes have been violated and does this corroborate with data from previous operations? What is the optimal location for mesh placement? How robust is the abdominal wall, and is component separation necessary or even possible? When considering recurrent hernias, one must also assess the position of any old mesh and formulate a strategy for safe explant if needed. Old mesh should be assessed for long-term mesh-related complications, such as shrinkage and adhesions, and these imaging findings should be compared with the history and physical exam [43].

Perioperative Considerations

Anticoagulation

Anticoagulants are a powerful class of medication that when used appropriately in the surgical setting provide significant benefits to morbidity and mortality but which by definition increase the risk of uncontrolled bleeding: the classic surgical complication. When deciding on whether and when to continue anticoagulation, it is vital to understand what the medication is treating. Ultimately, there is no hard and fast rule to dictate when to maintain and when to discontinue anticoagulation. When in the elective setting, these decisions should be discussed with the cardiology, medicine, and vascular specialists who are responsible for prescribing these medications, and there should be consensus on whether to stop or bridge these medications. In the emergent setting, we recommend reversal of the agent if possible while ensuring that considerations are made to restart the medication at the appropriate time postoperatively.

Venous Thromboembolism Prophylaxis

Venous thromboembolism is a common perioperative complication in hernia repair. As the complexity and size of the hernia repair increase, so does the period of intra- and postoperative immobility and thus the risk of a venous thromboembolic event. Thus, we recommend adherence to the CHEST guidelines [44] for antithrombotic therapy. These include either low-molecular-weight heparin or low-dose unfractionated heparin in addition to mechanical prophylaxis.

Infection Prophylaxis and Control

A significant part of hernia repair optimization does involve infection prophylaxis and control. This segment will discuss the different aspects in this regard including antiseptic rinsing, hair removal, skin preparation, antibiotic prophylaxis, as well as MRSA testing.

Preoperative rinses or showering is a controversial subject that has shown varying benefit in previous studies. A Cochrane review evaluated the effectiveness of preoperative rinses with antiseptic agents such as chlorhexidine or betadine versus the use of normal soap and found no benefit in reducing surgical site infection [45]. However, many of the existing studies available for review have been underpowered and retrospective in a heterogeneous population. Additionally, this evaluation places all antiseptic use in one arm with no consistent protocol with which to compare. With this in mind, we recommend the protocol described in a 2015 study by Edmiston et al. This protocol involves a preoperative minimum of at least two sequential showers using 118 mL of aqueous chlorhexidine gluconate 4% per shower with a 1-min pause after application and before rinsing [46]. This optimizes the antiseptic concentration to best eliminate gram-positive and gram-negative flora prior to surgical intervention.

Hair removal is another intervention in which the evidence has shifted over time. In 1999, the CDC strongly recommended against the removal of hair prior to surgery [47]. However, a 2011 Cochrane review involving 14 randomized trials found no difference in the rate of surgical site infection in patients who had hair preoperatively removed versus those who did not. Moreover, the review concluded that electric clippers used to remove hair were associated with a lower rate of surgical site infection than razors [48], a finding that has been recapitulated in other meta-analyses [49]. On the other hand, the National Institute for Health and Clinical Excellence recommendations suggested that hair may serve as a nidus for infection and thus recommend that the mode of hair removal should minimize skin trauma [50]. In keeping with these findings, we recommend the use of either clippers or depilatory cream prior to surgery when it is necessary to gain adequate vision or access to the operative site.

When selecting surgical prep solutions, we recommend chlorhexidine versus povidone-iodine in the clean and clean-contaminated setting of hernia repair surgery [51]. Further, and because alcohol appears to be the operative agent in these solutions, alcohol-based preps such as DuraPrep® and ChloraPrep® can be used with comparable outcomes [52].

The discussion on preoperative antibiotics can first be divided into the settings of inguinal versus ventral hernias. In inguinal hernias, the discussion can be further delineated by approach. In a double-blinded comparison of antibiotics versus placebo in open inguinal hernias repaired with a mesh plug, antibiotics significantly reduced the rate of surgical site infection [53] with β-lactam/β-lactamase antibiotics as the most effective agent followed by first-generation cephalosporins [54]. Conversely, in open groin hernia not restricted to the mesh plug technique, a recent meta-analysis showed no difference in outcomes when preoperative antibiotics were utilized [55]. When considering a laparoscopic approach, studies have similarly

shown no benefit for antibiotics preoperatively [56]. Nevertheless, our practice still uses prophylactic antibiotics prior to both open and laparoscopic inguinal hernia repair.

The evidence for antibiotics in ventral hernia repair paints a different picture, particularly in incisional hernia. The evidence currently suggests that the rate of wound infection is higher in incisional hernia repair than in other cases similarly classified as clean. As such, the evidence shows a clear benefit for the use of systemic antibiotics when performing incisional hernia repair [57]. In keeping with the evidence, we recommend following Surgical Care Improvement Project measures, with the administration of preoperative antibiotics within 60 min of the surgical start time.

The prophylaxis of methicillin-resistant *Staphylococcus aureus* (*MRSA*) is a controversial topic. A 2015 study in the *Journal of the American College of Surgeons* showed that a history of MRSA infection, even those isolated away from the abdominal wall, increases the risk of MRSA surgical site infection in ventral hernia repair within the first 30 days postoperatively [58]. However, a similar study published in *Hernia Journal* in 2016 contradicted these findings, showing that a history of MRSA infection had no impact on surgical site infection [59]. Both studies were limited as they were retrospective single institution studies; however, when taken together, they appeared to suggest that it was more effective to identify and treat higher risk patients and move away from long-term suppressive antibiotics.

A 2017 discussion post on the International Hernia Collaboration© Facebook group page showed three main strategies for managing MRSA among hernia surgeons. The first, in accordance with the 2015 *Journal of the American College of Surgeons* study, does not test for MRSA at all. The second selectively tests high-risk patients preoperatively using nasal swabs to determine if treatment is necessary, with a high risk being defined as having a personal history of MRSA infection, health care workers, or a history of SSI. The third protocol tested for MRSA with nasal swabs in all patients and treated them accordingly, a strategy that we recommend.

If MRSA testing is positive, we recommend the treatment protocol described by Bode et al., which is comprised of nasal mupirocin twice per day for 5 days preoperatively and daily chlorhexidine showers for 5 days [60]. This protocol was shown to significantly decrease the rate of surgical site infection. In addition to this protocol, we administer cefazolin and vancomycin in the immediate preoperative period to treat both methicillin-sensitive *Staphylococcus aureus* and MRSA. However, a positive MRSA culture from the wound in proximity or overlying a hernia (fistula, infected mesh, etc.) mandates, in addition to the above measures, prolonged (up to a year) suppressive postoperative doxycycline therapy.

Postoperative Considerations

The postoperative optimization is achieved through the enhanced recovery after surgery pathway protocol aims to reduce the metabolic, neuroendocrine, and inflammatory impact of surgery to minimize morbidity and length of stay postoperatively

[61]. This pathway relies on several key principles to accomplish this goal: the maintenance of physiologic function, the reduction of intraoperative stress, the minimization of postoperative pain, the optimization of mobilization after surgery, and early postoperative enteral nutrition. In application, this involves a preoperative discussion of the hospital course and planned interventions for recovery with the patient to maintain expectations and maximize their participation in their care. In the immediate preoperative period, pain medication and alvimopan should be started to reduce surgical stress and promote postoperative motility, respectively. This leads into the postoperative protocol, which emphasizes an early transition to enteral feeding, early ambulation, incentive spirometry, and the minimal use of narcotics.

Compared to other areas of gastrointestinal surgery, such as colorectal surgery, hernia surgery has lagged behind in implementing enhanced recovery pathways. The first group to report a protocolized pathway was Novitsky et al. [62], who described an enhanced recovery pathway that we currently follow. These pathways have been validated through numerous metrics and have demonstrated a more rapid advancement of diet and decreased time to return of gastrointestinal function with a significant cumulative reduction in the length of stay and decreased rate of readmission [63]. These findings have been recapitulated by many labs, all demonstrating similar benefits as well as reductions in reported pain [64] and opiate usage [65].

Conclusion

To best prepare for a hernia, the surgeon must orchestrate a host of interventions that come together to give the patient the best chance of a good outcome. This begins with a proper history and physical and the proper use of laboratory studies and imaging. These tools enable the surgeon to determine the specific preoperative interventions that will benefit these patients. Interventions such as optimizing nutritional status, encouraging smoking cessation, and promoting good glycemic control provide the patient with a benefit that is greater than the sum of each individual intervention. When combined, this preoperative optimization enables the surgeon to perform a superior operation and allows the patient to achieve a superior recovery, thereby decreasing the risks of complications, morbidity, and mortality following hernia repair. The literature guiding these interventions is constantly in flux; however, we have offered recommendations that we employ in our own practices and that we believe best embody currently available evidence.

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Enhanced Recovery in Abdominal Hernia Repair

10

Andrew S. Wright and Rebecca P. Petersen

"A surgeon can do more for the community by operating on hernia cases and seeing that [their] recurrence rate is low than [they] can by operating on cases of malignant disease."

—Sir Cecil Wakely, 1948

While there is no question that operative technique is important in achieving good patient outcomes, increasing evidence suggests that a coordinated and systematic approach to pre-operative patient preparation, intra-operative management, and post-operative care may be an even more critical contributor. Collectively, this approach has come to be known as "Enhanced Recovery After Surgery," or ERAS, and represents a multidisciplinary approach to patient selection, pre-operative nutrition and optimization, intra-operative fluid management, advanced pain control, and early diet and mobilization. Originated and best studied in colorectal surgery, ERAS protocols have been shown to reduce length of stay [1], reduce the rates of post-operative complications by up to 40% [2], and significantly reduce costs [3]. In fact, by one estimate, every dollar spent in implementation of ERAS protocols results in a $3.8 savings [4]. ERAS protocols are now being adapted and extended to other types of surgery including bariatric [5], hepatobiliary [6], gynecologic [7], and recently to hernia surgery [8–10].

Although many of the principles of enhanced recovery come from the colorectal literature, early results in extending these principles to hernia have been very encouraging. Novitsky's group at Case Comprehensive Hernia Center have recently published their early results after implementation of an ERAS protocol in abdominal wall reconstruction [9] with a 1.8-day reduction in time to regular diet, a

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reduction in length of stay from 6.1 to 4.0 days, and significantly reduced 90-day readmission rate, from 16 to 4%.

At the UW Medicine Hernia Center, we have implemented a similar protocol, but for all patients requiring inpatient admission following hernia repair—including laparoscopic and open hernia repair as well as in more complex abdominal wall reconstruction. Our current ERAS protocol is shown in Appendix 1, with key components as shown in Table 10.1. In our more heterogeneous population, we have seen significant improvements in length of stay and readmission (Table 10.2). Importantly, this applies to both our laparoscopic and our open hernia population,

Table 10.1 Elements of a typical hernia ERAS Pathway

Pre-operative
Assessment of modifiable risk factors
Patient optimization
Smoking cessation
Immunonutrition
Weight loss
Patient education
Peri-operative
Minimized pre-op fasting
Pre-op carbohydrate load
Restricted IV fluid
Advanced pain control (epidural or TAP block)
Glycemic control
Antiemetic prophylaxis
Multimodal, opioid-sparing analgesia
Post-operative
Early nutrition
Early mobilization
Daily care maps
Defined discharge criteria

Table 10.2 Results of ERAS implementation at the UW Hernia Center

		# cases	LOS	ICU LOS	Direct cost	30-day readmission (%)
All Cases	Pre-ERAS	138	5.21	0.52	$13,875	7.25
	Post-ERAS	264	4.22	0.16	$11,917	5.30
	% Improvement		19.22%	14.11%	14.10%	26.90
Open Cases	Pre-ERAS	116	5.31	0.57	$14,387	6.89
	Post-ERAS	204	4.60	0.17	$12,372	6.86
	% Improvement		13.20%	69.40%	14.00%	3.00
Lap Cases	Pre-ERAS	22	4.75	0.22	$12,358	9.00
	Post-ERAS	60	2.90	0.13	$10,729	0.00
	% Improvement		39.00%	41.30%	13.10%	100.00

and was effective across two hospitals in our system with different cultures, administration, and IT infrastructure. Although the ERAS pathway was implemented with a goal of improving patient outcomes, a beneficial side effect has been significant cost savings, with over $500,000 saved annually after implementation.

This chapter is designed as a brief introduction to the concepts and principles of ERAS programs, as well as an overview of implementation and application in the realm of hernia surgery. SAGES and the ERAS Society have recently published a Manual of Enhanced Recovery Programs in Gastrointestinal Surgery which explores many of these topics in depth, and which is an excellent resource for surgeons or others interested in starting or refining an ERAS program. Additionally, SAGES has developed the SAGES SMART™ program to help disseminate information about enhanced recovery programs, with further information available at https://www.sages.org/smart-enhanced-recovery-program/ [11].

Pre-operative Phase

Success in hernia surgery starts at the first clinic visit, with proper patient selection and pre-operative optimization. Some risk factors (size and location of hernia, prior operations, etc.) are not modifiable but may affect decision-making about whether to offer repair or may affect operative planning (surgical approach, use or type of mesh). These considerations are out of the scope of this chapter, but are addressed elsewhere in this textbook. ERAS pathways concentrate on identification of modifiable risk factors that have been shown to affect patient outcomes.

Smoking has been demonstrated to affect post-operative complication rates across almost all types of operations. In a recent analysis of the American College of Surgeons National Surgical Quality Improvement Program (NSQIP), Schmid et al. showed smokers have a higher risk of overall pulmonary, wound, and septic/shock complications [12]. Although this paper did not specifically look at hernia operations, the effect of smoking on wound dehiscence and other wound complications is well described. Smoking increases the risk of hernia formation after abdominal surgery by 2×, the risk of wound dehiscence by almost 80%, and the risk of all wound complications by 227% [13].

In the past, the impact of pre-operative smoking cessation has been controversial, with some arguing that short-term cessation may not be sufficient to affect patient outcomes [14]. A meta-analysis of 25 studies has shown that smoking cessation significantly reduces risks of both respiratory and wound complications although the timing of cessation is important [15]. With respiratory complications, cessation less than 4 weeks prior to surgery had no benefit while cessation >4 weeks reduced the relative risk (RR) of all complications to 0.77 and with even greater benefit with >8 weeks smoking cessation (RR 0.53). Based on this data, we recommend that no elective hernia operations be performed in active smokers, and in our program we require 8 weeks of abstinence prior to surgery. Compliance is checked with a urine cotinine screening test the week prior to surgery.

Obesity is a risk factor for both wound complications [16] and recurrence [17, 18] after hernia repair. This is addressed more fully in the previous chapter. In the context of ERAS protocols, the importance is recognition of patients with obesity as a modifiable risk factor. Rosen et al. have published their results with a medically supervised program for pre-operative weight loss prior to surgery [19]. Out of 25 patients, 24 successfully lost weight with a mean weight loss of 24 kg and a 9-point reduction in BMI. Of these, 22 maintained weight loss for a median follow-up of 18 months. In our program, patients with a BMI >40 are referred to our weight loss center, which offers both medical and surgical weight loss.

Poor pre-operative nutrition is clearly associated with poor surgical outcomes [20]. There have been many proposed methods for assessing pre-operative nutrition [21], many of which are impractical to use in clinical practice. In our center, we use the Strong for Surgery checklist, available from the American College of Surgeons (https://www.facs.org/quality-programs/strong-for-surgery) [22]. This consists of four questions, with a "yes" answer to any questions resulting in referral to a nutritionist: Is BMI less than 19? Has the patient had unintentional weight loss of over eight pounds in the last 3 months? Has the patient had a poor appetite—eating less than half of meals or fewer than two meals per day? Is the patient unable to take food orally (e.g., dysphagia, vomiting)? Although albumin is an imperfect marker of nutritional status, all patients have a screening albumin checked, which is important in risk stratification (albumin is a major contributor to the NSQIP algorithm) and in identifying additional at-risk patients.

Pre-operative immunonutrition is a controversial topic, but is part of many ERAS pathways. This consists of pre-operative nutritional supplementation using a special formula including arginine and omega-3 fatty acids, theorized to support wound healing and reduce infections complications [23]. A recent meta-analysis of 83 RCTs of immunonutrition in abdominal surgery showed a significant benefit with reduced overall complications (odds ratio (OR) 0.79), infectious complications (OR 0.58), and 1.79 day reduced LOS [24]. Interestingly, the authors of this meta-analysis found a strong likelihood of publication bias; when industry-funded studies were removed from the analysis, the benefits of immunonutrition disappeared. We currently use these supplements in our ERAS pathway although we continue to have some concerns about compliance due to poor taste and expense (average cost ~$55).

Glycemic control is very important prior to surgery, with uncontrolled blood sugars being associated with significant risk of post-operative complications [25]. It is not uncommon for patients without the diagnosis of diabetes to have an elevated hemoglobin A1C, essentially meaning that they were undiagnosed diabetics prior to surgery. This elevated hemoglobin A1C in previously undiagnosed patients is associated with worse outcomes after surgery [26]. We therefore recommend testing hemoglobin A1C in patients scheduled for hernia repair. Although there is no level 1 evidence that interventions to improve glycemic control in the pre-operative period affect outcomes of surgery, we prefer to have patients attain a hemoglobin A1C level below 8% prior to elective hernia repair.

Other cardiopulmonary comorbidities should be assessed and optimized prior to surgery. There are numerous clinical guidelines for whom should have pre-op testing for cardiac or other issues [27, 28]. In our practice, we have found assistance from a dedicated medicine consultation hospitalist service to be invaluable. We liberally consult our medicine colleagues for assistance with pre-operative risk stratification and modification, as well as peri-operative management. Such services have been shown to improve outcomes after vascular [29], orthopedic, and neurosurgical procedures [30] although to our knowledge have not been studied in abdominal or hernia surgery.

There is increasing interest in prehabilitation of patients prior to major elective surgery. The group at McGill have initiated a 4-week program or pre-operative moderate aerobic and resistance exercise, nutrition, and relaxation exercises [31]. They have shown this program to result in improved post-operative exercise capability 8 weeks following surgery, as measured with a 6-min walk test. It is unclear which patients might most benefit from such prehabilitation although it does appear that patients with worse initial exercise tolerance may have a greater degree in improvement than those with initially good exercise tolerance [32]. It is also unclear if prehabilitation will affect other outcomes such as length of stay, complication rates, or long-term physical function. While we have not incorporated prehabilitation into our formal hernia ERAS protocol, this is an interesting area for future study and possible addition.

Peri-operative Phase

Long-standing tradition calls for nothing by mouth after midnight prior to surgery. In fact, this tradition is contradicted by the evidence, which suggests that solid food can be safely eaten up to 6 h and clear liquids can be taken up to 2 h prior to surgery [33]. A pre-operative carbohydrate-rich drink appears to actually improve post-operative glycemic control, reduce insulin resistance, and decrease protein loss following surgery [34]. Most studies in this arena have used complex carbohydrate formulas, whereas many hospitals that have adopted carbohydrate loading use sports drinks or apple juice, which primarily contain simple sugars. It is unclear if such drinks will have the same effect on post-operative glycemic control, or if they may in fact worsen hyperglycemia due to differences in rapidity of absorption and metabolism.

There is great debate in the colorectal surgery literature regarding the utility of bowel preparation, and bowel preparations of various sorts are typically included in colorectal ERAS pathways [35]. Given that most hernia repairs do not require colon resection, we have not included bowel preparations in our hernia ERAS protocol. On the occasional setting of an enterocutaneous fistula or expected concomitant bowel resection, we often will move patients over to our colorectal, rather than hernia, ERAS pathway. For patients with a planned or likely bowel resection the pathway also includes alvimopan, a peripheral mu opioid-receptor blocker, which may reduce ileus [36].

There are many anesthetic considerations which affect recovery following surgery [37]. Over or under resuscitation is common during surgery, and patients kept close to fluid balance (<2.5 kg weight change) have significantly less complications and shorter LOS [38]. Prevention of post-operative nausea and vomiting improves post-operative recovery [39], and there are numerous pharmacologic strategies to deal with this. Normothermia reduces risk of surgical site infection (SSI) [40], and this starts in the pre-operative holding area [41].

Hyperglycemia in the peri-operative period doubles the risk of SSI after major abdominal surgery, and also increases the risk of both reintervention and death, as seen in an analysis of a Washington state Surgical Care and Outcomes Assessment Program database of more than 18,000 patients [42]. Interestingly, hyperglycemic patients who received intra-operative insulin had no increased risk of complication, reintervention, or death. This highlights the importance of early recognition and management of hyperglycemia in the operating room. Despite this, more than 25% of patients who were found to be hyperglycemic were never started on insulin.

Glucose monitoring should not be limited to diabetic patients, as hyperglycemia is common in non-diabetic patients and outcomes of hyperglycemic non-diabetic patients may actually be worse than outcomes of hyperglycemic diabetics, perhaps due to underuse of insulin in this group [43]. In our practice all patients get pre-, intra-, and post-operative glucose checks. Insulin drips are started for any glucose >140.

Avoidance of narcotics post-operatively has been a major goal of most ERAS programs. Excellent pain control with minimal narcotics reduces post-operative ileus, enhances post-operative mobility, and facilitates earlier recovery with reduced LOS. Two main strategies exist for this: (1) use of blocks such as epidurals and (2) multimodal analgesia. Together we call this "Advanced Pain Management," which crosses from the peri-operative to the post-operative period.

Epidurals have been frequently used in this effort [44]. As ERAS pathways and use of laparoscopic surgery have driven LOS ever shorter, epidurals have become a barrier to early discharge in some patients who may only need to be in the hospital for 2–3 days but who are held up due to the logistics of the transition from epidural to oral analgesia [45]. There is increasing experience with alternatives to epidurals such as the Transversus Abdominus Plane (TAP) block [46].

The TAP block can be performed with standard local anesthetics injected into the plane [47], with catheters threaded into the plane for continuous delivery of local anesthetics [48], or more recently with slow-release liposomal bupivacaine [49]. Although literature is limited, use of liposomal bupivacaine may be more effective than standard local anesthetics [50]; however, the costs of this new pharmacologic agent are high and cost-effectiveness is still unclear. The relative efficacy of TAP block in comparison to epidurals is also unknown, with limited evidence suggesting that epidurals may be superior in some settings [48] and inferior in others [51]. Because of this uncertainty, our current ERAS pathway calls for epidural analgesia in open cases but not in laparoscopic surgery. We have increasing experience with TAP blocks using liposomal bupivacaine off pathway, and are in the midst of looking at our own outcomes to determine if our ERAS pathway should be modified to include TAP blocks.

By its nature, "multimodal analgesia" comprises many different adjunctive treatments, and also spans the peri-operative and post-operative periods. A complete review of the entirety of options for multimodal analgesia is out of the scope of this chapter, but there are a number of excellent reviews and guidelines available [52, 53]. Very briefly, intravenous acetaminophen, nonsteroidal anti-inflammatories, gabapentinoids (gabapentin or pregabalin), tramadol, intravenous lidocaine, and glutamate receptor antagonists are all options that have been shown to reduce post-operative narcotic use [52]. The relative efficacy of each of these potential adjuncts is not clear, nor is cost-effectiveness. In our own pathway, we have chosen to include pre- and post-operative gabapentin and oral acetaminophen and oral ibuprofen, with an option for intravenous ketorolac for patients unable to tolerate a diet.

Post-operative Phase

Early feeding seems heretical to generations of surgeons trained to wait for return of bowel function followed by a slow, stepwise introduction of first clear liquids, then full liquids, and finally a solid diet. There is a plethora of evidence that this traditional approach actually delays return of bowel function and is ultimately counterproductive. In fact, early feeding reduces complication rates in gastrointestinal surgery by 45% [54] and is safe in both colorectal and upper gastrointestinal surgery [55]. The traditional clear liquid diet increases post-operative nausea and vomiting in comparison to alternatives [56].

Multimodal pain management and close monitoring and control of hyperglycemia are continued in the post-operative period, as described above. Anecdotally, many trainees are taught to advance to oral pain medicine at the same time as a diet is ordered. This can be counterproductive in a setting with early feeding, as patients may have a diet order written but may not actually be taking much by mouth. We emphasize that the transition to an oral pain regimen begins when patients are actually tolerating an oral diet, typically on post-operative day 1–2 depending on clinical parameters. Similarly, intravenous fluids are stopped as soon as patients take greater than 500 mL of oral intake, typically within 24 h of surgery.

Early mobilization appears to significantly ameliorate the functional and physical decline seen after abdominal surgery [57]. In a recent RCT, a structured program of aerobic exercise along with resistance and flexibility training resulted in a 22% improvement in the percentage of patients able to walk unassisted 5 days following abdominal surgery, with a number needed to treat of five [58]. There is little evidence to date to specify what specific exercise or walking program is best. In our practice, we have patients out of bed on day 0 and ambulating day 1, with specific walking goals. Physical therapy is consulted on day 1 on all patients. Foley catheters tend to impair mobility and prolonged catheterization promotes development of catheter-associated urinary tract infections. We therefore recommend removal of Foley catheters on day 1. There is no need to keep Foley catheters routinely in place even in the presence of thoracic epidurals [59].

Standardized discharge criteria are important and help make sure that all members of the team, the patient, and the patient's support structure are all in alignment. There is no need to await bowel movement prior to discharge. Patient-friendly care maps can be posted on the wall or on a whiteboard in each room to help with communication of these goals, which typically are: (1) tolerating diet and taking sufficient oral intake, (2) on a sustainable oral pain regimen, and (3) able to assume self-care or has adequate help to ensure safety.

Patient Education

Patient and caregiver education is essential in any ERAS program, and this starts at the first pre-operative clinic visit. Good patient education results in shorter hospital stays, less need for analgesia, increased patient satisfaction, and increased patient compliance [60, 61]. Clear written guidelines should include specific goals for each day, the expected length of stay, and discharge criteria. These patient-friendly care maps should be designed for patients with potentially limited health literacy, include visuals and images, and ideally be available in multiple languages. They should also follow the patient into the hospital, and in our practice are posted in each patient's room in order to help with coordination and communication. Our hernia care map is seen in Appendix 2.

Design and Implementation of an ERAS pathway

Every hospital has its own institutional culture, and therefore each ERAS pathway will be to some degree unique in response to clinical practices, administrative support, and patient population [62]. A suggested plan and timeline for implementation can be found on the SAGES SMART website at https://www.sages.org/enhanced-recovery/sages-smart-implementation-timeline/ [63]. The development process should start with identification and recruitment of champions from a multidisciplinary team, including from surgery, nursing, anesthesia, pharmacy, physical and occupational therapy, nutrition, and information technology. The importance of administration buy-in cannot be overstated, and it can be particularly helpful to build a business-case to support the investment in time and money that implementation requires [64]. Current practices need to be reviewed, along with an assessment of evidence-based guidelines. After a draft protocol has been developed, it needs to be presented to relevant stakeholders and edited based on feedback. Once finalized it needs to be translated into actionable items, including standardized forms, templates, patient education materials, and order sets. Auditable metrics such as cost, length of stay, and readmission rates need to be identified and tracked well before the go-live date, in order to be able to measure any positive or negative impact of the

ERAS pathway [65]. It is important to set timelines for review and revision after go-live, and it is frequent for pathways to need to be modified based on patient outcomes, new practice patterns, or new developments.

Appendix 1: UW Medicine Hernia ERAS Protocol

Complex Hernia Clinical Pathway

Activities Before Surgery			
	Week-4 to -6	Day-5 to -6	Day-1
Clinic Visit	• Implement strong for surgery pre-hospital clinical interventions • RN teach class: Patient CareMap and reference Med Consult note – Tell patient to bring most current medication list to hospital for review and bring home medication bottles for review (cannot take in hospital) • Clinic provide patient with 2 × 8 oz of apple juice and directs patient to drink 1 × 8 oz before midnight night prior to surgery and 1 × 8 oz after parking at hospital day of surgery • PCC schedules follow-up visit for 2 weeks post-op (encourage patient to schedule 1-week post-op with PCP immediately following call) • Consent signed • MRSA/MSSA screen	• Impact drink 6 days prior (optional) • If MRSA/ MSSA positive, Intranasal Mupirocin for 5 days prior	
Diet			• Drink 1 × 8 oz of apple juice before midnight • No food after midnight, clear liquids as instructed
Medications			
Other			• Patient to follow pre-surgery shower and shaving instructions • Patient to bring 1 × 8 oz bottles of apple juice to hospital

Complex Hernia Clinical Pathway

Day 0: Pre-, Intra-, and Post-Operative Milestones		
	Pre-OP	Intra-OP
Pain	• 1000 mg Acetaminophen po (then po or IV q6h until discharge) • Gabapentin 300 mg po (continued once tolerating pills again) • Thoracic Epidural—aimed at upper level of incision (tested with 3 mL 1.5% Lidocaine w/Epi 1:200K)	• Pain: 1/16% Bupivacaine plus Fentanyl 2 μg/mL infused at 10 mL/h started ASAP after anesthesia induction. Avoid systemic opiates (especially Morphine and Dilaudid)
Diet	• Carbo loading: apple juice 2–3 h prior to surgery; patient directed to drink 1 × 8 oz immediately after parking at the hospital	
Fluids	• If IV in place, LR at 50 mL/h	• Induction period—7 mL/kg of LR over 30 min • During surgery—5 mL/kg/h of LR. Target a urine output of 0.3–0.5 mL/kg/h • Blood loss—replace with colloid (5% Albumin) mL for mL
Mobility		
Medications	• Abx per standard pre-op orders – If MRSA positive; administer Vancomycin and abx per standard pre-op orders • For Bowel Resection ONLY (5% of cases); minimum of 30 min prior: Alvimopan 12 mg po q12h until first B.M. or discharge – Unless chronic opioid user (on narcotics within 1 week of surgery) • Heparin 5000 units subcu	• Abx per standard intra-op orders
Vitals/ Monitoring	• Blood glucose check. If >100, recheck 30–60 min after incision. If >140 start insulin GTT	• Continue glucose management
Equipment	• Portable sequential compression devices on in pre-op	• Place Foley • No nasogastric tubes (remove at end of case if placed for gastric decompression) • Abdominal binder for comfort per surgeon discretion
Support Services		
Other	• Patients should be admitted in inpatient status • Have sleeve patients void prior to moving back to OR	

Complex Hernia Clinical Pathway

Day 0: Pre-, Intra-, and Post-Operative Milestones	
	PACU
Pain	• Changed to PCEA with 6 mL/h infusion • Breakthrough pain: Epidural Fentanyl (25–50 μg) (followed by 3 cm^3 NS) and infusion increased, by 2 mL/h—followed by increased Bupivacaine concentration (1/10% then 1/8%) if BP okay – If BP low or marginal or pressors ongoing talk with surgeons about ketorolac (vs. bleeding vs. nephrotoxic risks vs. anastomotic risk). If BP unable to be controlled with low dose pressors or fluid bolus (500 cm^3) "split" epidural (take fentanyl out of epidural infusion and add IV opiate PCA) in preparation for, or as start of, stopping epidural
Diet	
Fluids	• LR at 1 mL/kh/h • Target urine output of 0.3–0.5 mL/kg/h
Mobility	
Medications	
Vitals/Monitoring	• Continue glucose management
Equipment	
Support Services	
Other	

Complex Hernia Clinical Pathway

Inpatient Milestones: Target Post-op LOS = 3–4 Days		
	Day 0	Day 1
Pain		• PCEA and acetaminophen PO continued. After clear liquid lunch, start ibuprofen 600 mg po q6h (consider ketorolac 15 mg q6h if opiate side effects and NPO)
Diet	• Ice chips and sips of clears	• Advance diet as tolerated. General diet, if patient has no nausea, no distention, no belching/hiccups
Fluids		• LR at 1 mL/kg/h. Cease IV fluids asap. Saline lock IV fluids when oral intake greater than 500 or adequate urine output. Aim for early oral fluid intake
Mobility	• Edge of bed after last set of post-op VS (usually 6 h) with orthostatic VS	• OOB for all meals. Walk 3–4 times in the hall—Goal 9 laps. OOB 6 h/day
Medications	• Heparin 5000 units subcu q8h	• Start 17g Mirolax 1× daily
Vitals/ Monitoring	• Continue glucose management	• Labs Days 1–4, as clinically indicated

Inpatient Milestones: Target Post-op LOS = 3–4 Days		
	Day 0	Day 1
Equipment	• Incentive spirometer 10×/h while awake until discharge • Sequential compression devices on, unless ambulating until discharge	• DC Foley (just pull)
Support Services		• PT visit on day 1, latest
	Day 2	Day 3–4
Pain	• Epidural stopped and oxycodone started after breakfast tolerated (epidural pulled 4 h later)	• Gabapentin discontinued on day 3 • Do not prescribe Gabapentin at discharge • Acetaminophen and ibuprofen continued at discharge – Unless chronic opioid user (on narcotics within 1 week of surgery)
Diet	• Advance diet as tolerated. General diet, if patient has no nausea, no distention, no belching/hiccups	• Advance diet as tolerated. General diet, if patient has no nausea, no distention, no belching/hiccups
Fluids		
Mobility	• OOB for all meals. Walk 3–4 times in the hall—Goal 18 laps. OOB 6 h/day until discharge	• OOB for all meals. Walk 3–4 times in the hall—Goal 18 laps. OOB 6 h/day until discharge
Medications		• DC Alvimopan (if bowel movement) • Med rec on day before discharge
Vitals/ Monitoring		
Equipment	• JP drain teaching	
Support Services		

Appendix 2: Patient-Friendly Hernia Care Map

Complex Hernia Clinical Pathway

Activities Before Surgery			
	Week -4 to -6	**Day -5 to -6**	**Day -1**
Clinic Visit	∞ Implement Strong for Surgery pre-hospital clinical interventions ∞ RN teach class: Patient CareMap & reference Med Consult note ▯ Tell patient to bring most current medication list to hospital for review and bring home medication bottles for review (cannot take in hospital) ∞ Clinic provide patient with 2 x 8oz of apple juice and directs patient to drink 1 x 8oz before midnight night prior to surgery and 1 x 8oz after parking at hospital day of surgery ∞ PCC schedules follow-up visit for 2 weeks post-op (encourage patient to schedule 1 week post-op with PCP immediately following call) ∞ Consent signed ∞ MRSA/MSSA screen	∞ Impact drink 6 days prior (optional) ∞ If MRSA/MSSA positive, Intranasal Mupirocin for 5 days prior	
Diet			∞ Drink 1 x 8oz of apple juice before midnight ∞ No food after midnight, clear liquids as instructed
Medications			
Other			∞ Patient to follow pre-surgery shower and shaving instructions ∞ Patient to bring 1 x 8oz bottles of apple juice to hospital

Complex Hernia Clinical Pathway

Day 0: Pre, Intra, and Post-Operative Milestones		
	Pre-OP	**Intra-OP**
Pain	∞ 1000 mg Acetaminophen po (then po or IV q6h until discharge) ∞ Gabapentin 300mg po (continued once tolerating pills again) ∞ Thoracic Epidural – aimed at upper level of incision (tested with 3ml 1.5% Lidocaine w/Epi 1:200K)	∞ Pain: 1/16% Bupivicaine plus Fentanyl 2 micrograms/ml infused at 10 ml/hr started ASAP after anesthesia induction. Avoid systemic opiates (especially Morphine and Dilaudid)
Diet	∞ Carbo loading: apple juice 2-3 hours prior to surgery; patient directed to drink 1 x 8oz immediately after parking at the hospital	
Fluids	∞ If IV in place, LR at 50ml/hr	∞ Induction period – 7ml/kg of LR over 30min ∞ During surgery – 5ml/kg/hr of LR. Target a urine output of 0.3-0.5ml/kg/hr ∞ Blood Loss – replace with colloid (5% Albumin) ml for ml
Mobility		
Medications	∞ Abx per standard pre-op orders ▯ If MRSA positive; administer Vancomycin and abx per standard pre-op orders ∞ For Bowel Resection ONLY (5% of cases); minimum of 30min prior: Alvimopan 12mg po q12h until first B.M. or discharge ▯ Unless chronic opiod user (on narcotics within 1 week of surgery) ∞ Heparin 5000 units subcu	∞ Abx per standard intra-op orders
Vitals/ Monitoring	∞ Blood glucose check. If >100, recheck 30-60 min after incision. If >140 start insulin GTT	∞ Continue glucose management
Equipment	∞ Portable sequential compression devices on in Pre-op	∞ Place foley ∞ No nasogastric tubes (remove at end of case if placed for gastric decompression) ∞ Abdominal binder for comfort per surgeon discretion
Support Services		
Other	∞ Patients should be admitted in Inpatient status ∞ Have sleeve patients void prior to moving back to OR	

Complex Hernia Clinical Pathway

Day 0: Pre, Intra, and Post-Operative Milestones	
	PACU
Pain	∞ Changed to PCEA with 6ml/hr infusion ∞ Breakthrough Pain: Epidural Fentanyl (25-50 micrograms) (followed by 3 cc NS) and infusion increased, by 2ml/hr - followed by increased Bupivicaine concentration (1/10% then 1/8%) if BP okay ▯ If BP low or marginal or pressors ongoing talk with surgeons about ketorolac (vs. bleeding vs. nephrotoxic risks vs. anastomotic risk). If BP unable to be controlled with low dose pressors or fluid bolus (500 cc) "split" epidural (take fentanyl out of epidural infusion and add IV opiate PCA) in preparation for, or as start of, stopping epidural.
Diet	
Fluids	∞ LR at 1ml/kh/hr ∞ Target urine output of 0.3-0.5ml/kg/hr
Mobility	
Medications	
Vitals/ Monitoring	∞ Continue glucose management
Equipment	
Support Services	
Other	

UW Medicine | **Complex Hernia Surgery CareMap**

How to prepare and what to expect

The steps in this CareMap are for your healing, comfort, and safety.

Before Surgery Day

At your clinic visit:

- ❑ Surgery teaching ("Strong for Surgery")
- ❑ Review CareMap with nurse and talk about what to expect
- ❑ Be screened for bacterial infections (MRSA and MSSA)

6 days before surgery:

- ❑ Start drinking your Strong for Surgery Impact Advance Recovery drink

The day before surgery:

- ❑ In the afternoon, receive a call from the hospital with your assigned arrival time

The night before surgery:

- ❑ Take a shower with the antibacterial soap that was prescribed

- ❑ Before midnight, drink 8 ounces of apple juice
- ❑ After midnight, do not eat or drink anything (unless your surgeon told you to drink clear liquids)

Surgery Day

Before you leave home:

- ❑ Take another shower with the antibacterial soap that was prescribed

At the hospital:

- ❑ Check in at Surgery Registration at your assigned arrival time
- ❑ While you are checking in, drink 8 ounces of apple juice

- ❑ A nurse will call you to come to the Pre-Op area
- ❑ An IV tube will be placed in your arm to give you fluids and antibiotics
- ❑ An Anesthesiologist may talk with you about placing an epidural for giving you pain medicine
- ❑ You will be given a heating blanket to keep you warm, improve healing, and lower the risk of infection (keep the blanket on even if you feel warm enough)

- ❑ The Anesthesiology Team will take you to the operating room

After surgery, you will:

- ❑ Wake up in the recovery area
- ❑ Be moved to a bed in a hospital unit

You will have:

- ❑ An IV in your arm to give you fluids
- ❑ Compression devices on your legs to help with blood flow
- ❑ An epidural in your back to give you pain medicine (if this is part of your care plan)
- ❑ A Foley catheter in your bladder to remove urine

Your nurse will:

- ❑ Give you medicines to help with nausea and digestion
- ❑ Help you sit up on the side of your bed

- ❑ Encourage you to take sips of clear liquids and chew ice chips to get your digestion working
- ❑ Help you learn how to use your incentive spirometer and remind you to use it 10 times each hour every day while you are in the hospital

	Day 1	Day 2	Day 3 or 4: Discharge	At Home
Pain Medicine	❑ You will have control of giving yourself pain medicine	❑ When you start to eat a regular diet, you can take your pain medicines by mouth 		❑ Start to taper your pain medicines; take them only as needed ❑ While on pain medicines, take a stool softener ❑ If constipated, take Milk of Magnesia
Diet	❑ You will progress to a regular diet as you are able to handle it, and when your doctor says it is OK			
Activity	❑ A physical therapist (PT) will assess you ❑ Your goals today are to: - Be out of bed for all meals - Walk 9 laps around the unit - Be out of bed for a total of 6 hours	❑ Your goals from Day 2 until discharge are to: - Be out of bed for all meals - Walk 18 laps around the unit - Be out of bed for 6 hours a day 		❑ Keep being active – aim to walk at least 1 mile a day  ❑ Do not lift anything that weighs more than 15 pounds (about the weight of 2 gallons of water) until your surgeon says it is OK to lift more
Bathing	❑ Sponge bath	❑ Sponge bath or shower	❑ Shower by Day 3	❑ You may shower at any time
Catheter	❑ Your Foley catheter will be removed			
Drains		❑ If you have a JP drain, a nurse will teach you how to use it		❑ If you have a drain, measure output daily – call the clinic when output is less than 30 cc for 2 days in a row
Planning	❑ Ask to meet with a social worker if you have concerns about where you will go after discharge 			❑ Do not drive while taking prescription pain medicine

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11 Computed Tomography and Gross Anatomy of the Abdominal Wall (Including Planes for Mesh Hernia Repair)

Ryan M. Juza and Eric M. Pauli

Anatomy of the Abdominal Wall

Comprehensive knowledge of the abdominal wall anatomy is essential for the management of ventral hernias. As the population ages and surgical therapies expand, herniorrhaphy incidence and complexity have increased. Complex hernias come in the form of medically challenging patients, multiply recurrent hernias, tissue loss, infected fields, prior component separations, and enterostomies [1]. These complexities necessitate a thorough and comprehensive understanding of the abdominal wall structure both on physical examination and radiographically.

Myofascial Anatomy

The myofascial anatomy creates the bulk and structural integrity of the abdominal wall, and the complex layering is naturally adapted to hernia prevention. Three muscles create the lateral bulk of the abdominal wall. Beginning posterior in the paraspinous region, the transversus abdominis, internal oblique, and external oblique muscles wrap medially and converge at the lateral border of the rectus abdominis muscle creating the *linea semilunaris*.

The transversus abdominis muscle fibers orient transversely and contribute to the posterior rectus sheath in the upper one-third of the abdomen. In the lower two–thirds of the abdomen, the muscle fibers stop lateral to the rectus, and the transversalis fascia alone contributes to the posterior rectus sheath (Fig. 11.1). It is a common misconception that the transversus abdominis fibers stop lateral to the *linea semilunaris* due to incorrect drawings in popular anatomic texts. However, the presence of

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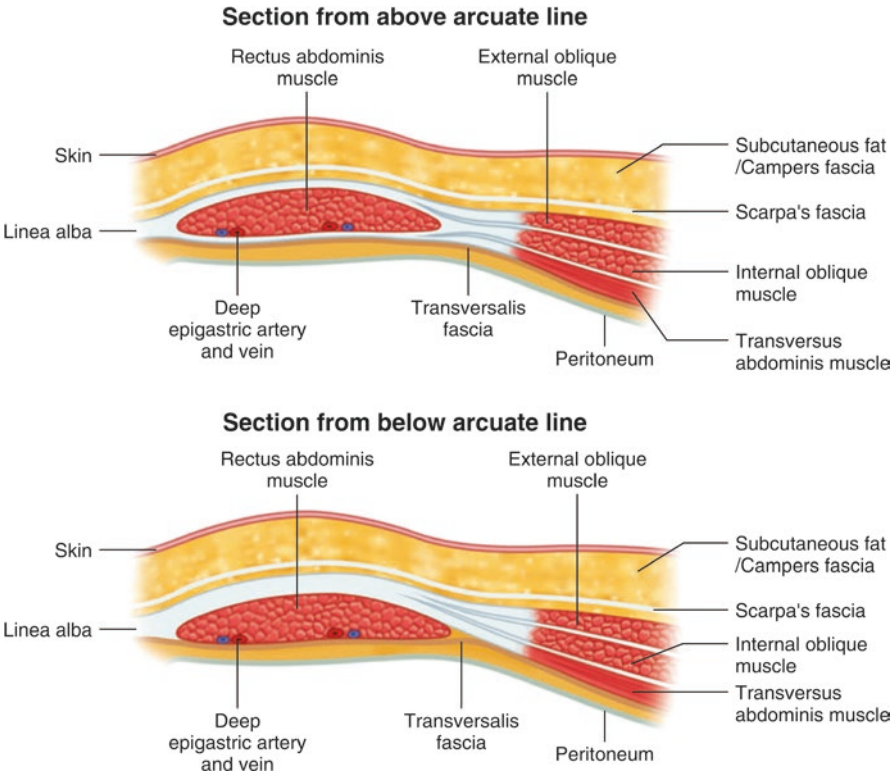

Fig. 11.1 Contribution of the transversus abdominis muscle to the posterior rectus sheath above and below arcuate line. *Novitsky, YW (2016). Hernia Surgery: current principles. Switzerland: Springer*

fibers medial to the *linea semilunaris* is the basis of a transversus abdominis release (TAR) posterior component separation (Fig. 11.2).

The internal oblique muscle fibers are obliquely oriented in a cephalad fashion and abruptly truncate at the linea semilunaris. The anterior and posterior fascial layers of the internal oblique muscle continue to become the anterior and posterior rectus sheath in the upper two–thirds of the abdomen. In the lower one–third of the abdomen below the level of the arcuate line (also called the linea semicircularis or the line of Douglas), the posterior component transitions anterior to the rectus abdominis muscles leaving only the transversalis fascial layer as the posterior rectus sheath (Fig. 11.3).

The external oblique muscle fibers are oriented perpendicular to the internal oblique fibers to further strengthen the lateral abdominal wall. Like the internal oblique muscle, external oblique muscle fibers end at the *linea semilunaris*, and the investing fascia creates part of the anterior rectus sheath. Below the arcuate line, the anterior rectus sheath is comprised of both the internal and external oblique fascia.

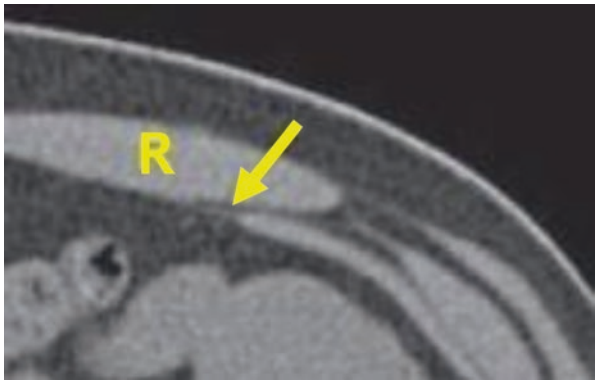

Fig. 11.2 CT imaging demonstrating transversus abdominis muscle fibers (arrow) extending beyond the *linea semilunaris* contributing to the posterior sheath of rectus muscle (R) in the upper abdomen

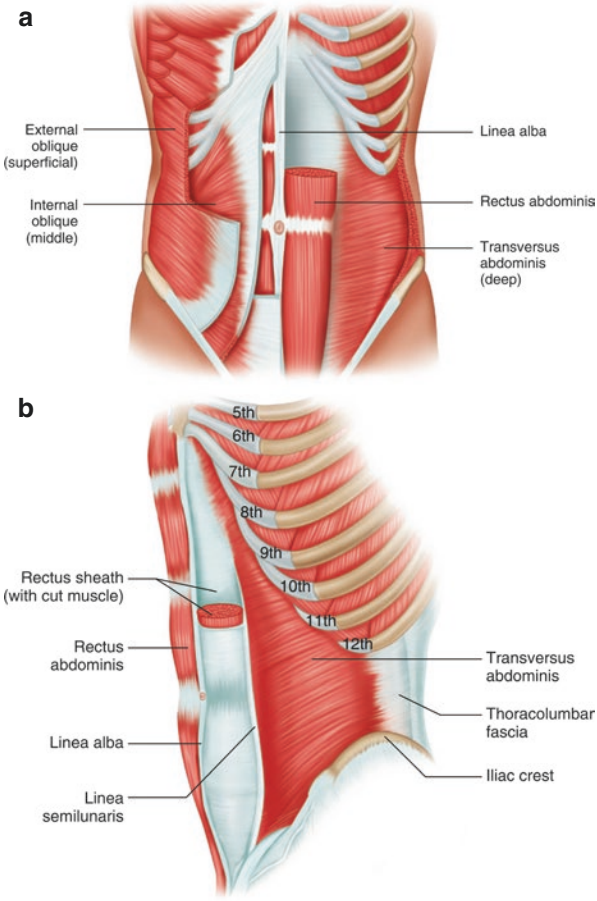

Fig. 11.3 Abdominal wall musculature. *Novitsky, YW (2016). Hernia Surgery: current principles. Switzerland: Springer*

The rectus abdominis muscles create the central core of the abdomen. As paired parallel muscles, they are bound laterally by the *linea semilunaris* and separated medially by the linea alba. They originate at the xyphoid and costal margin superiorly and insert at the pubic symphysis. The anterior and posterior rectus sheaths are created by the continuation of the external and internal oblique muscles as previously described.

The pyramidalis muscles are small paired triangular muscles that originate on the pubic crest and insert on the linea alba. They run anterior to the rectus muscle, but within the rectus sheath. They are rudimentary muscles in humans, absent in more than 20% of individuals, and are of virtually no clinical relevance for hernia repair [2].

Neurovascular Anatomy

While the neurovascular anatomy of the abdominal wall is not readily apparent, physiologically it supports the myofascial planes, and failure to pay attention to these structures can lead to denervation and devascularization of the myofascial and lipocutaneous structures, with resultant wound breakdown and other postsurgical complications (Fig. 11.4).

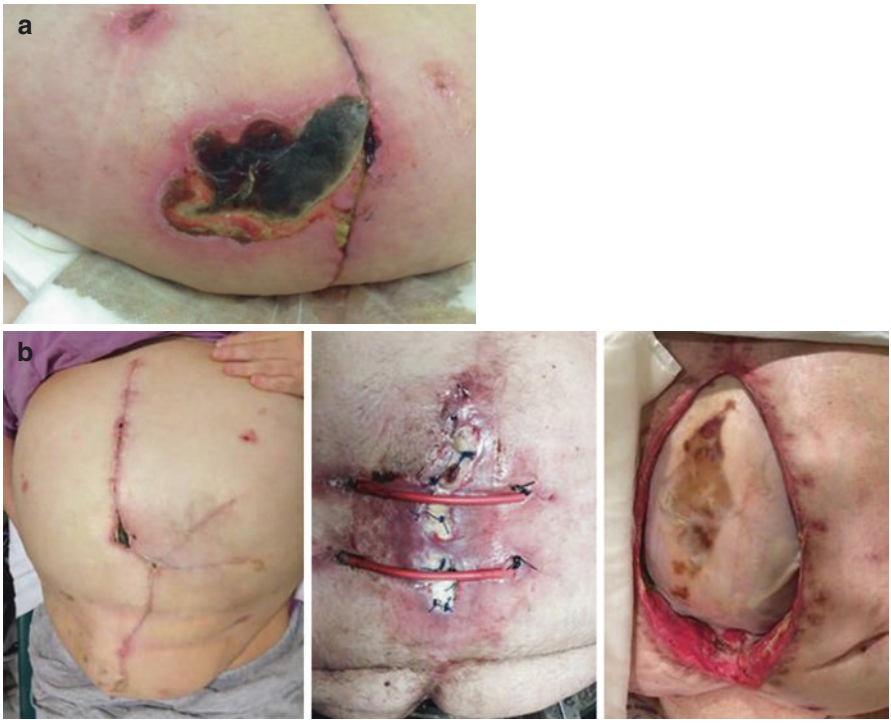

Fig. 11.4 (**a**) Wound ischemia and deep surgical site infection following anterior component separation with external oblique release (Photo courtesy of Dr. Luis J. Garcia, University of Iowa). *Novitsky, YW (2016). Hernia Surgery: current principles. Switzerland: Springer*. (**b**) Complications of tissue ischemia following abdominal wall reconstruction with compromised blood supply. *Novitsky, YW (2016). Hernia Surgery: current principles. Switzerland: Springer*

Vascular anatomy of the abdominal wall is divided into three zones based on the origin of the blood supply (Fig. 11.5).

Zone 1 is the central upper abdomen. Superiorly it receives blood supply from the descending superior epigastric artery, a branch of the internal mammary artery. Inferiorly it is supplied by the ascending inferior epigastric artery, a branch of the external iliac artery. As the superior and inferior epigastric arteries run posterior to the rectus abdominis muscle, they supply musculocutaneous perforating vessels (the so-called periumbilical perforator vessels) to the overlying tissues. The superior and inferior epigastric arteries converge in the supraumbilical region.

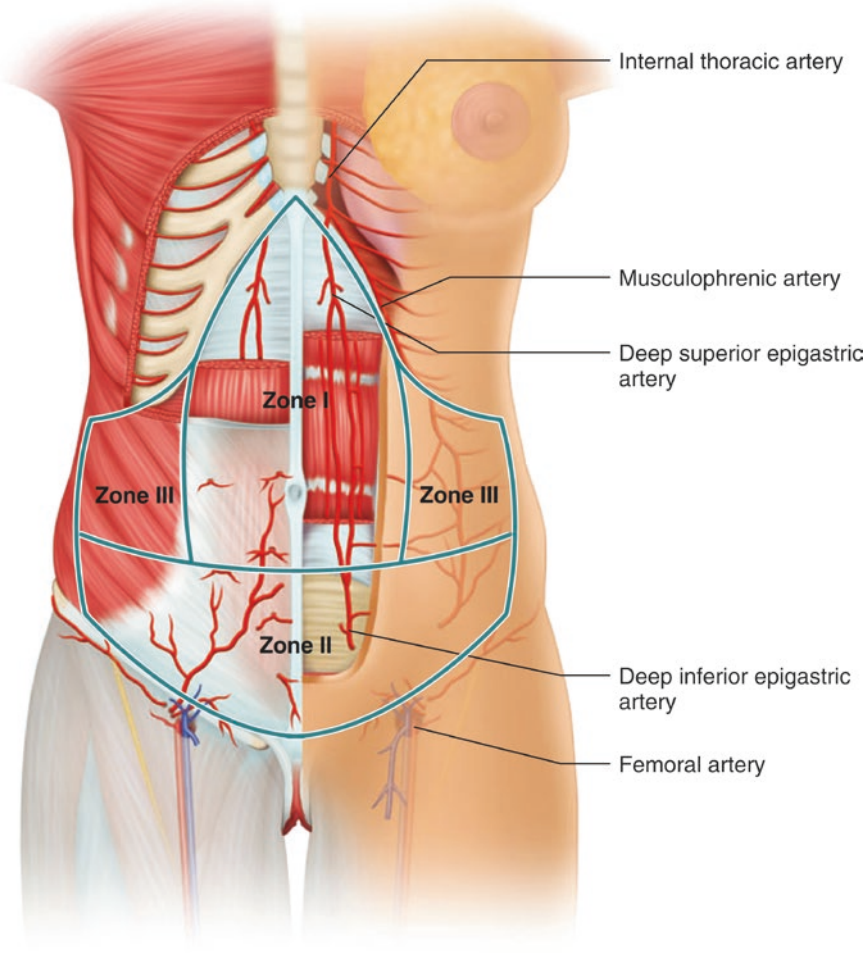

Fig. 11.5 Abdominal wall vascular anatomy by zones. *Novitsky, YW (2016). Hernia Surgery: current principles. Switzerland: Springer*

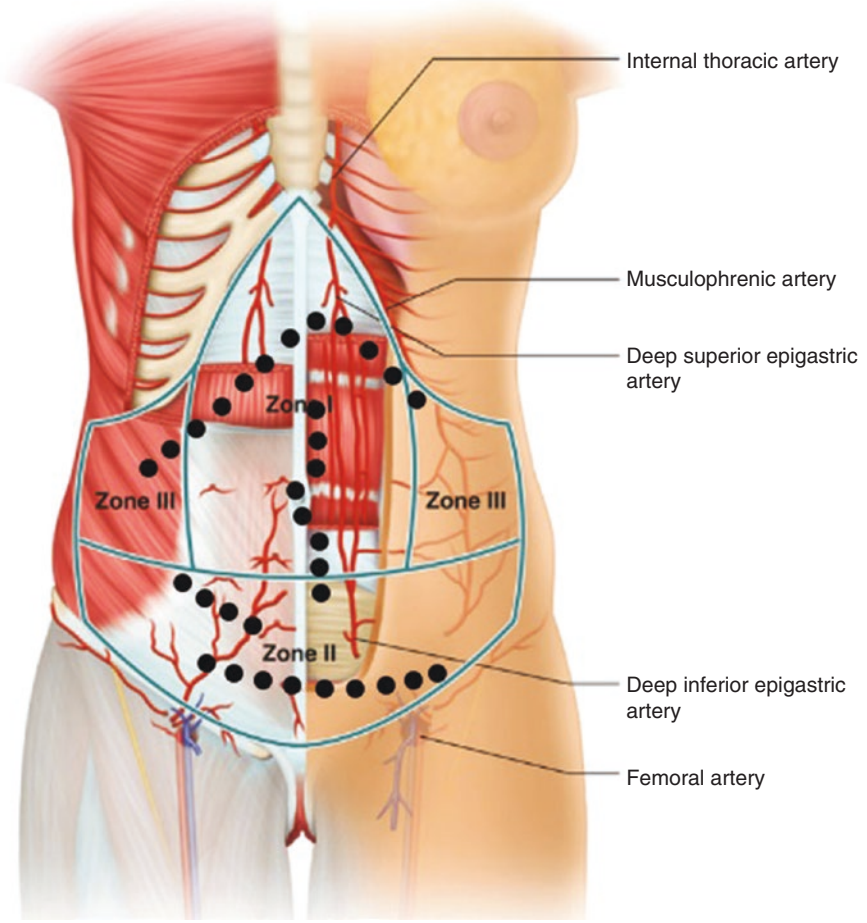

Fig. 11.6 Prior surgical incisions compromising abdominal wall vascular anatomy. *Novitsky, YW (2016). Hernia Surgery: current principles. Switzerland: Springer*

Zone 2 encompasses the suprapubic area below the arcuate line. The area is supplied medially by the superficial and deep branches of the inferior epigastric artery. Laterally, blood supply comes from the superficial circumflex iliac artery as a branch of the external iliac.

Zone 3 is the area superior the arcuate line and lateral to the *linea semilunaris*. It is perfused inferiorly by the deep circumflex iliac artery and superiorly by the musculophrenic artery as a lateral branch of the internal mammary artery.

When evaluating a patient who requires ventral herniorrhaphy, the blood supply to each zone should be considered as it may be comprised by prior surgical incisions (such as a panniculectomy or paramedian incision) or prior surgical procedure (such as epigastric ligation or abdominal aortic aneurysm repair) (Fig. 11.6).

Zones 1 and 3: Kocher and Chevron incisions generally divide the right and potentially left superior epigastric artery and must be considered in patients who have had open cholecystectomy, liver resection, or liver transplantation. In addition, patients who have had the internal mammary artery harvested for coronary bypass grafting, mediastinal dissection, or mediastinal chest tubes can disrupt the internal mammary, superior epigastric artery, or musculophrenic blood supply to Zones 1 and 3.

Zone 2: blood supply is at risk with prior paramedian, Mcburney, Rockey-Davis, and Pfannenstiel incisions.

Additionally the periumbilical region is a watershed area with tenuous blood supply in patients with large umbilical hernias and previous midline scars. Failure to excise compromised skin or scar can lead to wound breakdown and surgical site infections.

The nerves that innervate the abdominal wall run in the plane between the transversus abdominis and internal oblique muscles. Superiorly these nerves come from spinal roots T6-T12. Inferiorly, L1 nerve root provides innervation through the ilioinguinal and iliohypogastric nerves (Fig. 11.7). During a posterior separation of components, efforts should be made to preserve these nerves to avoid denervation injuries to the abdominal wall which can lead to unwanted laxity and poor function (Fig. 11.8).

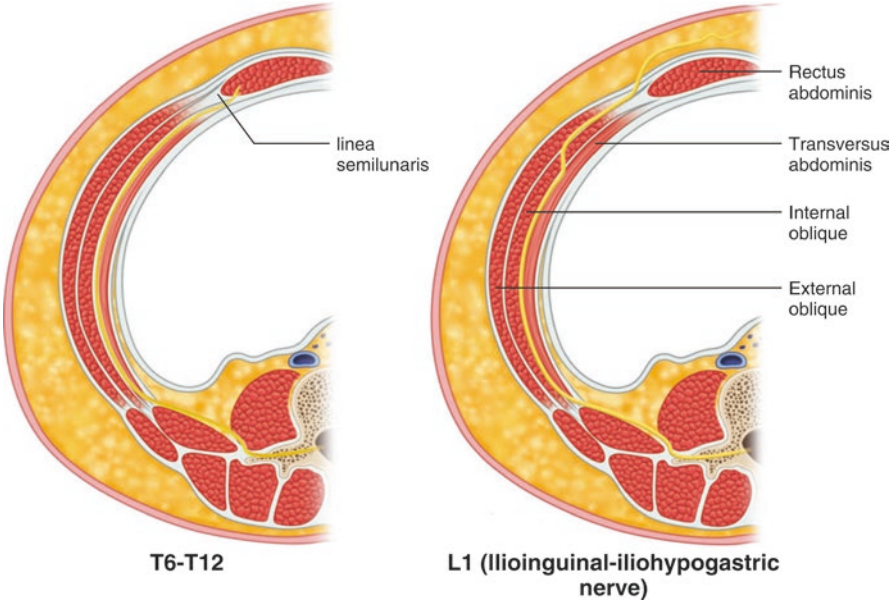

Fig. 11.7 Neurovascular anatomy of the abdominal wall. *Novitsky, YW (2016). Hernia Surgery: current principles. Switzerland: Springer*

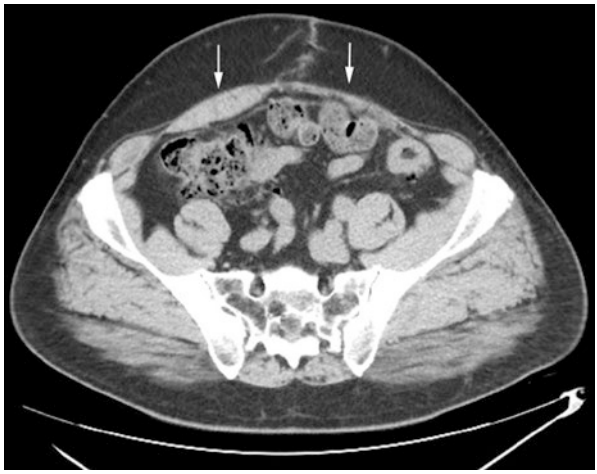

Fig. 11.8 Denervated left rectus muscle with atrophy in comparison to a normal right rectus abdominis muscle as a result of injury to the nerves traversing the *linea semilunaris*

CT Imaging in Ventral Hernia

Computed tomography (CT) imaging is widely used for preoperative evaluation of ventral hernias. As a commonly used imaging modality for other abdominal pathologies, surgeons are often well versed in the interpretation of the images. CT imaging is ideal as it provides good visualization of the abdominal wall tissue planes as well as underlying viscera and is relatively inexpensive compared with magnetic resonance imaging (MRI) [3]. Studies have described the use of ultrasound in the diagnosis and surveillance of incisional hernias with good results [4]. Ultrasound is an attractive imaging modality because it is relatively inexpensive and minimizes radiation exposure in a patient population that is often frequently irradiated. Unfortunately, ultrasound is highly user dependent, cannot estimate the size of larger hernias, and cannot help in the assessment of other findings (mesh location, bowel patterns, occult hernias) [5, 6]. While the application of CT imaging in ventral hernias is extremely common, the techniques for image acquisition, interpretation, and reporting are not standardized.

Characteristics of the hernia location, size, and type (incisional versus primary versus recurrent) are all pertinent to the preoperative evaluation but are rarely directly reported. Multiple classification systems have been proposed in the literature to aid the discussion [6–10]. A system proposed by the European Hernia Society is based on the defect location, size, and type (primary versus incisional) [6, 11]. Medial zones (located in the midline and within the rectus muscle itself) are labeled "M" and numbered 1–5 from superior to inferior. The xyphoid, umbilicus, and pubic bone act as landmarks to define boundaries. The linea semilunaris are considered the lateral borders of the medial zone. The lateral zones are labeled "L" and numbered 1–3 from superior to inferior at the lateral border of the rectus. Zone L4 represents posterolateral hernias such as Grynfeltt-Lesshaft and Petit lumbar hernias (Fig. 11.9).

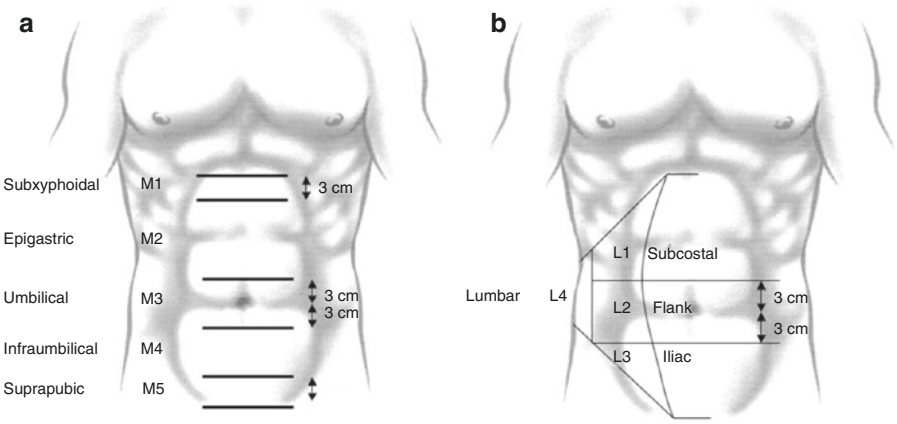

Fig. 11.9 Primary and incisional abdominal wall hernia naming guideline. *Muysoms FE*, et al. *Classification of primary and incisional abdominal wall hernias. Hernia. 2009 Aug;13 (4):407–14*

While this system was primarily developed to describe intraoperative findings, it is easily applicable to abdominal wall defects found on preoperative imaging. The EHS classification can provide an initial radiographic hernia diagnosis which can then be modified based on intraoperative findings.

Preoperative Planning

Physical examination alone is demonstrated to miss 20–30% of ventral hernias and has been shown to be inferior to radiologic imaging for the diagnosis of ventral hernias [12]. As the resolution of modern imaging modalities improves, the ability to visualize abdominal wall musculature, fascial planes, and even surgical mesh has improved [13]. The ability to preoperatively evaluate CT imaging and plan the most ideal herniorrhaphy based on CT findings represents a significant advancement in modern hernia care, but without concise definitions and standardized CT reporting of hernias, it is still a skill largely based on surgeon experience.

CT imaging can be used to predict both the complexity of repair required and potential for complications [14–16]. The width of the hernia defect is typically used to predict when fascial defects can be closed primarily or require separation of components to approximate the rectus muscles. Hernia width >8.3 cm or defect measuring >164 cm^2 was more likely to require separation of components to achieve midline closure [14]. This knowledge has substantial implications on operative planning as component separation represents a far more challenging and time-consuming operation than ventral herniorrhaphy without separation of components. Additionally, CT measurements of abdominal wall thickness have been correlated

with increased postoperative complications similar to other biometrics such as obesity, hyperglycemia, and smoking and could potentially be used for patient risk stratification [14].

Surgeon Versus Radiologists Image Interpretation

The lack of a standardized protocol for the interpretation and reporting of ventral hernias on CT scans creates a divide between surgeons and radiologists who approach patients from different vantage points. Interobserver variation in the assessment of CT images for ventral hernia recurrence demonstrated a greater than 70% rate of discordance at initial review by radiologists and surgeons [17]. Surgeons augment CT imaging with physical exam, operative experience, and knowledge of prior surgical procedures (including previous mesh placement). In contrast, radiologists' access to operative reports, operative experience, and physical examination is limited [18].

A retrospective review of completed radiology reports demonstrated that abdominal wall/ventral hernias were the second most common structure to be inaccurately reported on CT imaging and were the most commonly missed findings [18]. This disparity highlights the underappreciated complexity of abdominal wall anatomy. The comprehensive knowledge of both abdominal wall anatomy and the anticipated postoperative appearance of hernia repairs results in an advantage for surgeons when interpreting images. These findings highlight the importance of multidisciplinary management of patients with ventral hernias. Some have suggested that surgeon CT review in concert with the radiologist can lead to greater concordance as the majority of corrections to initial reports came after the provision of additional surgical history, as well as direct discussion with the ordering physician.

Our preference is to review the CT images without the radiologist's interpretation, to then compare old operative notes to the CT images in an attempt to locate mesh, to then examine the patient with the images available for immediate clinical correlation, and finally to review the radiologist report (primarily for non-hernia related but clinically relevant findings). In the event of gross discrepancy between surgeon impression and radiologist interpretation, we call the reading physician to discuss any concerns in the CT report (Appendix: CT Atlas).

Planes for Mesh Repair

Mesh reinforcement is the gold standard for ventral hernia repair as it provides the lowest rate of recurrence and best long-term outcomes [19, 20]. A number of techniques have been described for mesh placement based on the layers of the abdominal wall often with subtle differences. Each technique has merit, but the wide array of planes and an even wider array of terminology complicate the discussion of hernia surgeries. To strengthen the quality of data and unify reporting of hernia surgeries, several authors have proposed definitions for hernia repair based upon the

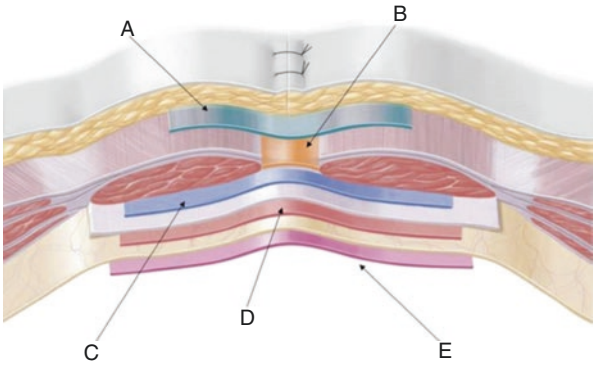

Fig. 11.10 International Hernia Collaboration consensus naming guidelines for mesh position. A. Onlay. B. Inlay. C. Retrorectus or retromuscular. D. Preperitoneal. E. Intraperitoneal. *Muysoms F, Jacob B. International Hernia Collaboration Consensus on Nomenclature of Abdominal Wall Hernia Repair. World J Surg. 2017 Jul 17*

location of mesh implantation [11, 21]. These efforts, unfortunately, have still resulted in confusion within the literature.

The International Hernia Collaboration, comprised of more than 3500 hernia surgeons, recently created a consensus naming guide for mesh position in hernia repair [11, 22] (Fig. 11.10). Mesh placed above the anterior rectus sheath is referred to as onlay. Mesh that is placed to bridge a gap between the rectus abdominis muscles is an *inlay* repair. Mesh placed behind the rectus muscles but anterior to the posterior rectus sheath is a *retrorectus* repair. When the mesh extends lateral to the *linea semilunaris* within this plane (by means of a posterior component separation), the term *retromuscular* is applied. Mesh that is placed behind the transversalis fascia but above the peritoneum is a *preperitoneal* repair, and mesh that is placed below the peritoneum in the abdominal cavity is an *intraperitoneal* repair.

Identifying Mesh on CT Scans

Mesh reinforced herniorrhaphy is the gold standard operative technique for ventral hernias [19]. This has led to a dramatic increase in the number of the different types of mesh available [23]. Despite the frequency of mesh use in ventral herniorrhaphy, there are few studies describing the appearance of different types of mesh on radiographic imaging [3, 13, 24]. Identifying indwelling mesh is an important step in preoperative planning for patients with recurrent ventral hernias as the type and location of mesh can significantly impact the complexity of the operation performed.

The appearance of mesh on CT radiologic imaging is in part determined by intrinsic mesh characteristics such as the base mesh material, mesh thickness, and presence or absence of mesh coatings [13]. Meshes that are thick, dense, coated, and reactive have increased radiopacity, aiding in the preoperative identification of mesh

Table 11.1 Visibility of common mesh types for ventral herniorrhaphy on CT imaging [3, 13, 24, 25]

Visible	Expanded PTFE mesh—thick, high-density material (>1 mm)	Thick contiguous radiopaque line	e.g., DUALMESH, DUALMESH PLUS
Intermittently visible	Coated, thin PTFE mesh (<1 mm)	Difficult to regularly identify. Correlation with operative report aides identification of subtle mesh appearance on imaging	e.g., Composix, Ventralex, Intramesh T1, Dulex
Indirectly visible	Coated polypropylene, polyester mesh	Isoattenuated—visibility determined by local tissue reaction to mesh coating rather than direct visualization of mesh	e.g. Parietex composite, Proceed, Sepramesh, Intramesh W3, Dynamesh, TiMesh, BardMesh, Prolene
Poorly visible	Lightweight polypropylene mesh	Isoattenuated, low inflammatory response makes identification difficult	e.g., Ultrapro, Vypro, Physiomesh

in plane. In cases of radiolucent mesh, a review of the operative report and direct discussion with the reviewing radiologist with special attention to the insertion plane can improve identification (Table 11.1). The appearance of biologic mesh on CT imaging is even less defined, and no reports were found on review of available literature for ventral hernias.

Mesh appearance on CT scan is also dependent in part to the tissue density surrounding the mesh. Mesh is most visible when it has fat contrast surrounding it (as opposed to direct contact with muscle and fascia) or when it has wrinkles that create clearly visible, nonanatomic lines within the patient. Radiopaque methods of mesh fixation (such as permanent metal tacks or staples) can also be used to locate the boundaries of previously implanted mesh (Appendix: CT Atlas).

Conclusion

Ventral hernia surgery has evolved as surgeons have improved upon and perfected various techniques of herniorrhaphy. The advances in hernia surgery can largely be attributed to a better understanding of abdominal wall anatomy and function combined with high-resolution CT imaging. These factors have optimized surgeon's preoperative planning, thus allowing the development of complex reconstructive procedures. In order to effectively treat ventral hernias, surgeons need to be well versed in abdominal wall anatomy and CT imaging. This chapter is meant to provide a comprehensive review of pertinent anatomy and physiology for hernia surgeons to improve the technique of ventral herniorrhaphy.

Appendix: CT Atlas

1. Wrinkled coated heavyweight polypropylene mesh (intermittently visible) is best identified where it is in contact with preperitoneal fat and as a result of the wrinkles from mesh contracture.
2. Thin expanded polytetrafluoroethylene mesh (small arrow), recurrent hernia in the midline (large arrow), and laparoscopic tacks (opaque dots).
3. Onlay mesh easily visible above the anterior rectus sheath due to interposed fat between the mesh and the fascia as well as by the presence of skin staples that were used to secure the mesh.
4. Laparoscopically placed left inguinal hernia mesh (lightweight polypropylene) visualized by fat density surrounding the mesh as well as by the metal tacks used to secure it.
5. Retromuscular polyethylene poorly visualized when in contact with the rectus muscle but that are visualized when adjacent to preperitoneal fat. Metal clips within the posterior sheet also hint as to the location in which dissection has occurred.
6. Heavyweight mesh visible on the abdominal wall and seen free floating in the abdominal cavity after failed ventral incisional hernia repair.

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Umbilical Hernia Options

12

T. J. Swope

Umbilical hernias are very common primary abdominal wall ventral hernias. These midline abdominal wall hernias are present in up to 50% of the population [1]. More than 350,000 ventral hernias are repaired each year in the United States. Seventy-five percent of those are primary ventral hernias including umbilical and epigastric hernias, but only about 11% of umbilical hernias end up getting repaired [2]. Approximately 175,000 umbilical hernia repairs are annually performed in the United States [3]. The European Hernia Society classification for primary abdominal wall hernias defines the midline hernias from 3 cm above to 3 cm below the umbilicus as umbilical hernia [4]. A direct or true umbilical hernia consists of a symmetric protrusion through the umbilical ring and is seen in neonates or infants. Indirect umbilical (paraumbilical) hernias protrude above or below the umbilicus and are the most common type of umbilical hernia in adults [5]. The most common symptom of umbilical hernias is pain at the umbilicus (44% of cases). Other complaints include pressure (20%) and nausea and vomiting (9%) [6].

Treatment options include observation versus surgical repair. Watchful waiting is usually not recommended except for very small asymptomatic hernias [7]. Primary repair is commonly performed for small umbilical defects, generally performed on defects <2 cm in size. Primary repair can be performed with simple suture closure of the fascial defect or by overlapping the fascia (Mayo repair). The Mayo repair was first described in 1901 consisting of the classic vest over pants in which the superior and inferior fascia are overlapped and sewn together [8]. When the umbilical fascial defects are closed primarily the fascial closure can be supported with mesh in either the intra-abdominal, pre-peritoneal, retro-rectus, or onlay location. Primary repair appears to have a higher recurrence rate vs. mesh repair. A multivariate meta-analysis compared 637 mesh repairs with 1145 suture repairs [2]. The recurrence rate in the

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pooled mesh group was 2.7% vs. 8.2% in the pooled suture repair group. There was a higher seroma rate (7.7% vs. 3.8%) and surgical site infection rate (7.3% vs. 6.6%) in the mesh group. Arroyo et al.'s randomized clinical trial revealed that the recurrence rate was lower after mesh repair than that after suture repair (1% vs. 11%) in a 64-month mean postoperative follow-up [9]. In a retrospective clinical series of 100 patients, the recurrence rates for the suture and mesh repair groups were 11.5% and 0%, respectively ($p = 0.007$), with similar results in the infection rates in favor of mesh repair [10]. Another study comparing laparoscopic mesh repair with suture repair found a 2-year recurrence rate of 0.0% in the mesh group and 8.7% in the suture repair group [11]. Lau et al. also found lower pain scores, morbidity, and shorter hospital stays with the laparoscopic group although the study size was limited. A review of the literature by Ponten et al. found that out of six studies regarding laparoscopic umbilical hernia repair with mesh, one reported a recurrence rate of 2.7% while there were no reported recurrences in the other studies at 2 years [12]. Two of these six studies were comparative studies between open and laparoscopic approaches and demonstrated lower morbidity and pain scores with the MIS approach.

Umbilical hernia repair can be approached with both open and minimally invasive surgery (MIS). The size of the defect and the size of the patient appear to be the two most common factors that push surgeons toward minimally invasive surgery (see Fig. 12.1). Surgeon preference trends toward an MIS approach with increasing defect size and body mass index. In a comparative study in obese patients, there was a decrease in wound infection rates in the laparoscopic mesh repair group versus the open mesh repair group (26% vs. 4%; $p < 0.05$) [13]. A lower recurrence rate was also identified in the obese in the laparoscopic group (0%) versus the open group (6%). The focus of this chapter is on how these hernias can be repaired with minimally invasive approaches rather than with open techniques. Figure 12.2 shows my umbilical hernia repair decision making flow chart based on defect size. This is a general guide and will vary based on defect size, abdominal wall compliance, and surgeon preference.

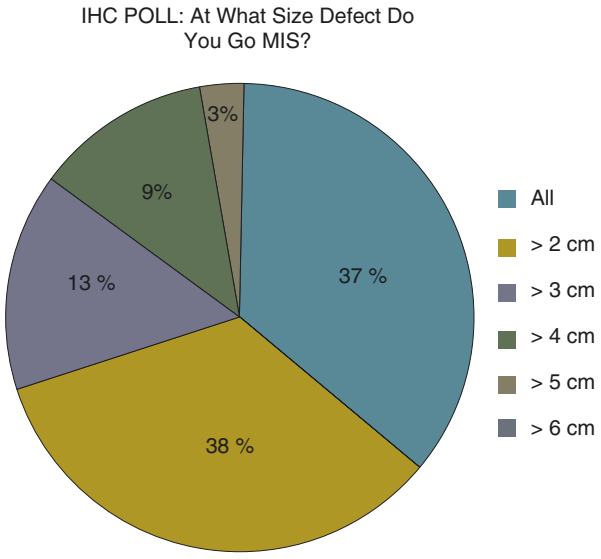

Fig. 12.1 Chart showing factors that favor an MIS approach to umbilical hernia repair

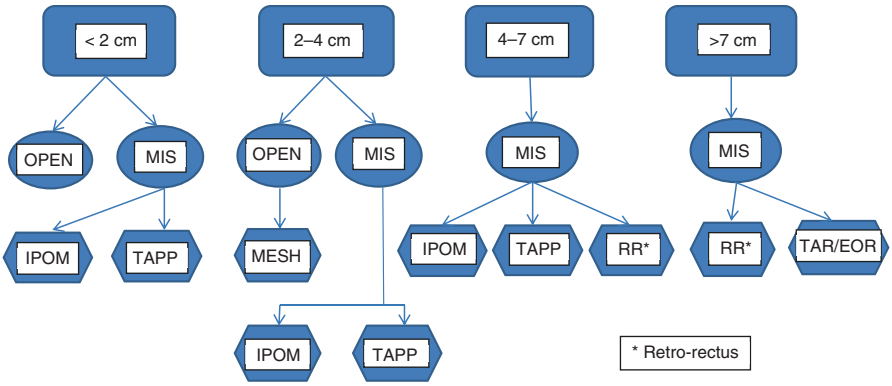

Fig. 12.2 Umbilical flowchart

MIS approaches include both robotic and laparoscopic surgery. There are several possible MIS approaches to umbilical hernia repair including intra-peritoneal onlay mesh (IPOM), transabdominal pre-peritoneal (TAPP), retro-rectus (Rives Stoppa), and component separation. Component separation may become necessary depending on the size of the defect and body habitus and is only utilized in larger defects where the fascia cannot be brought together without too much tension. Component separation includes transversus abdominis release (TAR) and external oblique release (EOR).

Getting Started

The IPOM approach is very commonly used to address umbilical hernias. The repair can easily be accomplished via a laparoscopic or robotic approach. Pneumoperitoneum is established by either Veress needle, Hassan cut down, or optically based on surgeon preference. Once pneumoperitoneum is established lateral trocar insertion is performed. Ideally, the trocars are located lateral enough to allow a 5 cm mesh overlap from the defect and still be able to maintain working space between the camera/instruments and the ipsilateral edge of the mesh. Therefore, being as far lateral as possible allows this approach to be performed as easily as possible. If the trocars are too close to the mesh, it makes securing the mesh to the ipsilateral abdominal wall difficult and may require placement of trocars on the opposite side to facilitate fully securing the mesh. My laparoscopic preference is to place a subcostal optical trocar near the anterior axillary line. Once safely inserted the camera port is placed far laterally near the peritoneal reflection and the inferior port is placed medial to the anterior superior iliac spine (see Fig. 12.3). One of the trocars needs to be a 12 mm trocar to allow passage of the mesh later in the case, while the other two trocars are 5 mm. Alternatively, three 5 mm trocars can be placed and a 12 mm assist trocar placed on the contralateral side to facilitate suture and mesh passage. At this point, the laparoscopic instruments are inserted and the dissection ensues.

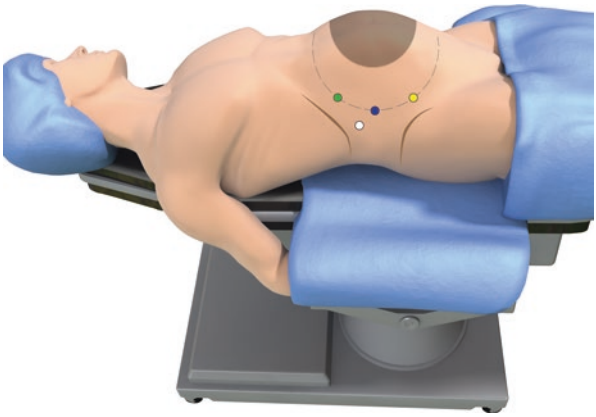

Fig. 12.3 Patient positioning for IPOM. Blue dot is camera port. White dot is optional accessory port

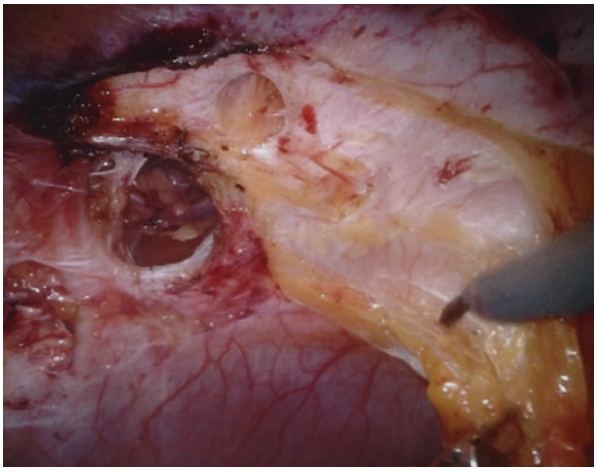

Fig. 12.4 Takedown of falciform ligament. Note the incidental hernias uncovered in addition to the known incisional hernia

Laparoscopic IPOM Repair

The falciform ligament and the peritoneum are taken down inferiorly and superiorly to allow 5 cm mesh overlap which allows the uncoated side of the mesh to come in direct contact with the fascia (Fig. 12.4). The reason for exposing the fascia is the concern that securing the mesh to the peritoneum can more readily permit mesh migration. Frequently occult primary periumbilical hernias will be uncovered and repaired, especially if there is an associated rectus diastasis. If left in place, the falciform ligament and pre-peritoneal fat can be read as a recurrent hernia on future CT imaging leading to patient and primary care MD confusion. The hernia sac itself can be reduced or left in place. Once the dissection is completed the defect is closed or left open depending on surgeon preference. If closing the defect, a small bite of the deep dermis can be taken while performing the fascial closure to reconstruct the umbilicus if suturing the defect closed laparoscopically. Fascial closure can be accomplished several ways. Depending on surgeon comfort and skill set the defect

can be sutured closed using a laparoscopic needle driver. Absorbable and permanent sutures are available based on surgeon preference. This is greatly eased using barbed suture, either 30 cm V-loc (Size 0, GS-21 needle) or 45 cm symmetrical Strattafix (Size 0 or 1, CT-1 needle). This can also be accomplished using non-barbed absorbable or permanent suture as well. Alternatively, a suture passer can be used to pass suture above and below the fascial defect allowing primary repair through a small stab incision near the umbilicus.

Once the defect is closed it is time to place the mesh. Coated mesh is required for IPOM to minimize adhesions between the underlying bowel and surface of the mesh. The size of the mesh should allow for 5 cm overlap. Based on surgeon preference that 5 cm overlap is added to the size of the original defect or to the length of the fascial closure providing a 5 cm overlap laterally, superiorly, and inferiorly. The mesh is then secured to the abdominal wall using a combination of trans-fascial sutures and tacs. Permanent or absorbable sutures and tacs can be used to establish fixation. A double crown pattern is utilized to secure the mesh around the periphery. This is done to prevent the mesh from folding down at the edges which prevents the bowel from adhering to the exposed uncoated mesh. Generally, these are spaced apart every 1–2 cm. Once the mesh is secured the trocars are removed and the fascia is closed at the 12 mm trocar site.

Robotic IPOM

When being performed robotically, it is very important to get the trocars as far lateral as possible. If the trocars are placed too close to the mesh, it makes it very difficult to suture the mesh to the abdominal wall on the ipsilateral side toward the trocars. I follow a similar pattern to the laparoscopic trocar placement (see Fig. 12.5). It is important to flex the table to open up the space between the costal margin and the iliac crest. This flexion also helps prevent the inferior operative arm from incidentally contacting the thigh. Pneumoperitoneum is established per surgeon preference. On the Xi platform, I place an 8 mm optical trocar subcostally at the anterior axillary line. The 8 mm camera trocar is placed as far lateral as possible. The

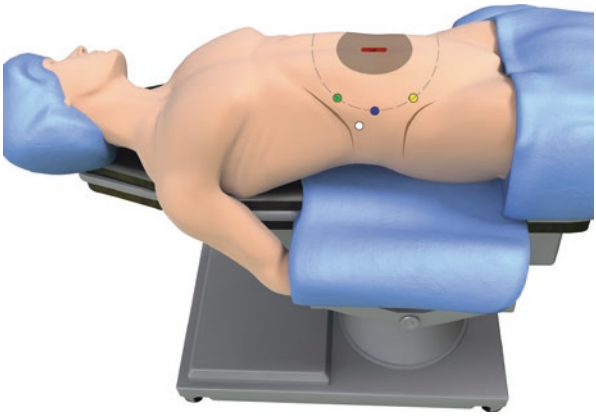

Fig. 12.5 Trocar positioning for IPOM repair

subcostal trocar is then replaced with a 12 mm standard length disposable trocar. The 8 mm subcostal trocar is then moved to the lower lateral abdominal wall medial to the anterior superior iliac spine. Care should be taken to stay a few centimeters medial to the anterior superior iliac spine to avoid nerve injury. An 8 mm trocar is placed inside the 12 mm port ("piggybacked") and the robot is then docked to all three 8 mm trocars. No monopolar energy should be used through the "piggybacked" trocar arrangement to avoid capacitive coupling and possible thermal injury. To avoid this piggybacked arrangement, alternatively three 8 mm trocars can be placed followed by a 12 mm assist port on the other side to assist with mesh and suture insertion. It is important to burp each robotic trocar before heading to the operative console. This is the last step I perform on EVERY robotic case before leaving the bedside. The reason for this is if the trocars are docked under tension a larger trocar site defect will be created due to arm motion possibly leading to a trocar site hernia. Burping all of the robotic arms creates no pre-existent traction on the abdominal wall and minimizes trauma to the abdominal wall from arm motion.

Once the robot is docked attention is turned toward the dissection. This is performed in a similar manner as described in the laparoscopic approach. Once the falciform ligament and pre-peritoneal fat are cleared in the midline the defect is sewn closed using barbed suture as previously described. Several bites must be taken in the opposite direction of the fascial closure once closure is achieved in order to ensure the barbed suture does not unravel. If the defect is larger and there is a large sac, small bites of the sac can be taken between fascial bites during the running closure. Care must be taken to avoid the dermis. Your first assist is the key to watching the skin during this time to ensure no skin dimpling is produced with the fascial closure. This will imbricate the sac and significantly reduce postoperative seroma formation. If possible, a small deep dermal bite can be taken with the fascial closure to reconstruct the umbilicus.

After measuring and allowing for 5 cm overlap, the mesh is introduced through the 12 mm port. The mesh can be held in place against the posterior abdominal wall using a pre-placed scaffold, with suture, or by reusing the needles from the fascial closure pinning the mesh in place against the abdominal wall. The mesh is sutured to the abdominal wall using 2-0 V-loc or spiral Strattafix suture. This can be performed using a running continuous barbed suture around the edge of the mesh. Several sutures may be required based on the size of the mesh chosen. Alternatively, a "dolphin" style stitch can be placed in a running mattress fashion. The possible advantages of the dolphin stitch are less exposed barbs and requiring slightly less suture material to secure the mesh circumferentially to the abdominal wall (see Figs. 12.6 and 12.7).

Transabdominal Pre-peritoneal (TAPP) Approach

Another MIS approach to the umbilical hernia is the TAPP approach. The pre-peritoneal plane is exposed and dissected out either laparoscopically or robotically (Fig. 12.8) The advantage of this approach is that uncoated mesh is placed in the

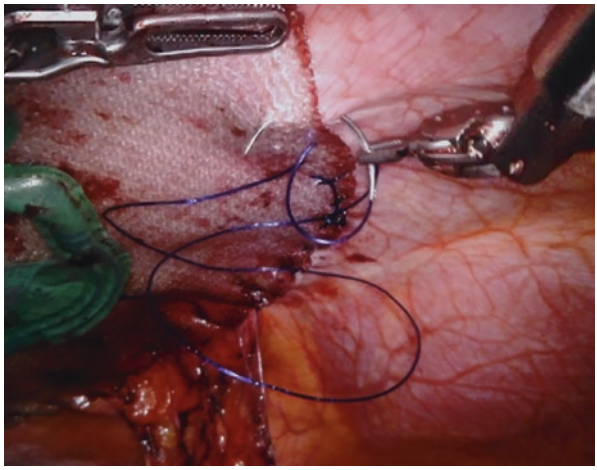

Fig. 12.6 Running whip stitch to secure the mesh to the abdominal wall. Results in more exposed barbed suture, but less fold down at the edges vs. dolphin stitch

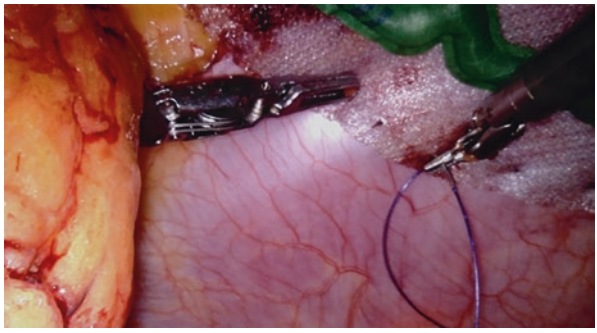

Fig. 12.7 Dolphin stitch to secure the mesh to the abdominal wall. Results in less exposed barbed suture

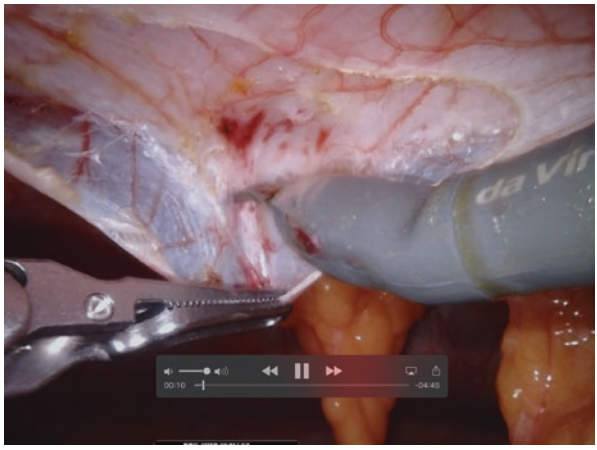

Fig. 12.8 Initial TAPP dissection. Care must be taken to avoid the retro-rectus space

pre-peritoneal space. This avoids direct mesh exposure to the underlying bowel. The proposed advantage is less adhesion formation to the bowel. Additionally, uncoated mesh is less expensive than the coated versions used in IPOM. The hernia sac is reduced as well which can lead to a decreased incidence of postoperative seroma formation by not leaving a mesothelial lined sac in the tissues anterior to the fascial closure. The down side to this approach is that it takes longer to perform than an IPOM. The dissection of the peritoneum especially over the ipsilateral posterior rectus sheath can be tenuous. The peritoneum tends to be very thin in this area which can lead to the creation of multiple defects. If not excessive, these defects can be closed primarily. Figure-of eight sutures are recommended vs. simple interrupted. The figure-of eight sutures create a more robust peritoneal closure which is less likely to breakdown vs. the simple interrupted suture. Alternatively, a 3-0 running barbed suture can be used if the peritoneal defect is larger. The peritoneum is opened far enough laterally on the trocar side of the defect to allow for a 5 cm mesh overlap. The dissection needs to provide enough space for the mesh to seat nicely without wrinkling which can lead to adhesion formation. Usually, sharp scissor dissection is used along with counter-traction to develop the plane of dissection. Care must be taken to ensure an adequately sized pocket has been created, and the mesh overlap is not being compromised in order to fit into a pocket that is too small (Fig. 12.9). If the peritoneum is not salvageable, the bail out procedure is to proceed to an IPOM. Next the fascia is closed primarily using running barbed suture (V-loc, Strattafix symmetrical) which can be done robotically or laparoscopically as previously described. Alternatively, a suture passer can be used to close to fascia in an interrupted fashion.

Mesh is placed once the fascia is closed. Uncoated mesh is used. Self-gripping mesh can be used here with the adherent side facing the fascia (ParietexProGrip). It is preferable to face the grippers anteriorly in case the peritoneum was to break down and leave the mesh exposed to the bowel. Non-self-gripping mesh can also used. Medium or heavyweight macroporous mesh is preferable (BardSoft mesh).

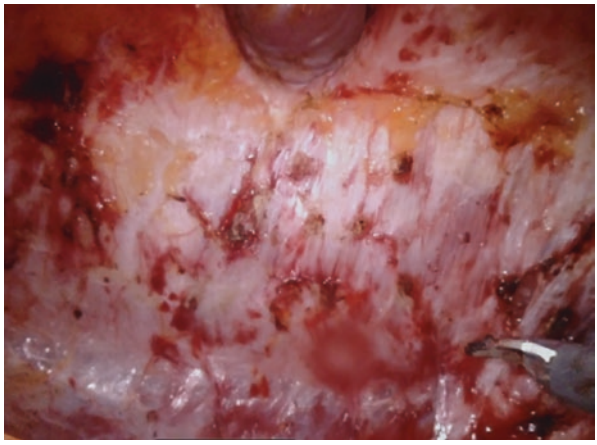

Fig. 12.9 Finished TAPP dissection with exposed defect and posterior fascia

The mesh can be fixed in place with tacs, laparoscopic suturing, or stay sutures if performed laparoscopically. If proceeding robotically, the mesh is sutured in place using cardinal point interrupted sutures or running barbed suture can be used. Alternatively, some surgeons use fibrin glue to fix the mesh in place while still others use no fixation and rely on the form fitting pocket to keep the mesh in place after the peritoneum is closed. Laparoscopic closure of the peritoneum can be accomplished using a tacker or by suturing the peritoneum back together based on surgeon preference. The peritoneum is closed using running 2-0 or 3-0 barbed suture (V-loc, Strattafix spiral) when closing robotically. The ports are then removed and the 12 mm trocar fascial defect closed.

Rives StoppaRetro-Rectus Repair

Some surgeons prefer to place the mesh in the retro-rectus location. As in the TAPP approach, the mesh is located within the abdominal wall and is not exposed to the bowel. This carries the possible advantage of less bowel adhesions and the use of less expensive uncoated meshes. Additional benefits include having the mesh against the rectus muscle. This is a very vascular space which is thought to allow fast ingrowth of the mesh. The other advantage is in the case of mesh infection. Mesh is much easier to salvage in the retro-rectus space vs. an IPOM location. The vascularity on both sides of the macroporous mesh much more easily allows the infection to be cleared after drainage, antibiotics, and wound management. The Achilles heel of this approach is the risk of an interparietal hernia secondary to breakdown of the posterior fascial closure. This is thought to be caused by too much tension at the time of the posterior fascial closure. This posterior fascial separation allows the bowel to slide between the posterior fascia and the mesh and exposes uncoated mesh directly to the bowel. The key to avoiding this is to make sure there is enough laxity on the posterior closure so that the fascia does not separate postoperatively. If a patient presents with obstructive symptoms in the early postoperative period, imaging should be obtained to rule this out right away with a return trip to the operating room if discovered.

There are several ways to accomplish a retro-rectus repair. The first is bilateral port placement. I find this approach very difficult and generally avoid it. Ports can be placed on both sides of the abdominal wall. Laparoscopically, the first step is to open the retro-rectus space on the contralateral side of where your starting ports are placed. Dissection is carried out laterally to the linea semilunaris. *Great care must be taken not to injure the nerves* at the lateral aspect of the rectus sheath and to not violate the linea semilunaris. This will denervate the rectus muscle and potentially destabilize the abdominal wall. An adequate dissection is performed allowing for 5 cm mesh overlap laterally, superiorly, and inferiorly. Mesh is then rolled, placed, and secured with cardinal point fixation. I usually place sutures at the corners and half-way between. Another loose stitch is placed just to hold the mesh in its rolled up state prior to rolling it out later during deployment. Once this is accomplished ports are placed on the contralateral side and a similar dissection is performed opposite the

initial dissection. When this is performed robotically, it requires the robot to be re-docked. It should be noted that the initially dissected side will have hanging posterior fascia which can interfere with dissection of the opposite side. To work around this, a suture or two may need to be placed to suspend the fascia/mesh and make exposure to the opposite side easier prior to re-docking. Alternatively, the second set of trocars can be placed just outside of the linea semilunaris and angled medially into the lateral retro-rectus space above the mesh. This eliminates having to deal with a hanging flap, but should only be used in patients with a sizeable rectus space as suturing will be difficult in a tight space.

Once the remaining dissection is complete, the anterior fascial closure is performed. This is done using size 0 or 1 barbed suture (V-loc, Strattafix). After the fascia is closed, mesh is spread out smoothly in the retro-rectus plane. Again self-adhering mesh can be used as well as uncoated plain macroporous mesh. Similar to the TAPP, the mesh can be fixed in place with glue, tacs, or suture. Some choose not to secure the mesh as it will be in a closed pocket with no room for movement. Once the mesh is secured the posterior fascia is closed. Again the key is to close it without excessive tension which can lead to breakdown of the closure and interparietal hernias.

Another retro-rectus approach is operating with just one set of ports. A host of options are available here. Intra-abdominal ports can be placed transversely above the defect (subxyphoid), below the defect (suprapubic), or laterally. Ports can also be placed directly into the retro-rectus space thus avoiding intra-abdominal trocar placement (eTEP). These approaches can be performed laparoscopically or robotically, but are much easier if approached robotically due to the increased range of motion provided by the robotic platform.

With the suprapubic and subxyphoid approaches, the ports should be placed at least 10 cm away from the defect when placing ports transversely above or below the defect. This allows for a 5 cm mesh overlap and enough working space for the instruments. When operating robotically, the lateral ports should be placed as far lateral as possible when operating to avoid collision with the thighs when using a suprapubic docking approach. I recommend using the longer trocars laterally as well which gets the robotic arms a little further away from the thighs. Self-adhering mesh, sutures, or glue can be used to secure the mesh. The peritoneum and posterior rectus sheath are opened transversely. Dissection is carried out laterally preserving the vessels and nerves at the lateral rectus sheath. Centrally, the pre-peritoneal plane is maintained behind the linea alba. The medial rectus sheaths are divided creating one posterior flap (Fig. 12.10). Any posterior defects in the flap are closed. The anterior fascia is closed and mesh is placed. The initial transverse incision is then closed using running barbed suture.

A robotic lateral approach can also be used. Ports are placed and the posterior rectus sheath is opened vertically. The vertical incision is made laterally and vertically along the posterior sheath toward the ports. The key is to go laterally, but avoid the vessels and nerves of the linea semilunaris. I generally divide the sheath 2/3 of the way toward myself (Fig. 12.11). Once the retro-rectus plane is dissected the medial sheath is opened and a pre-peritoneal dissection is carried out to reach the opposite rectus

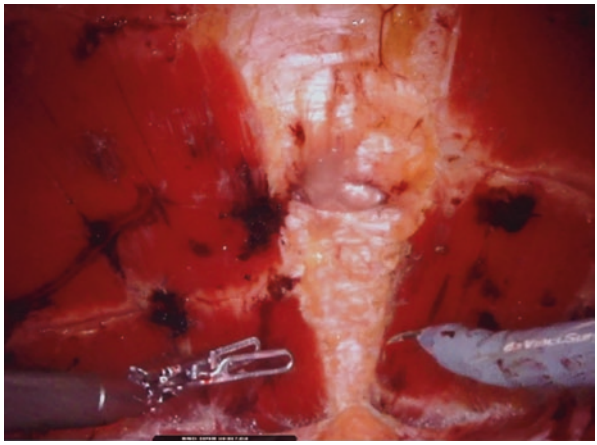

Fig. 12.10 Retro-rectus dissection. Finished superior view of dissection from suprapubic port location. Posterior rectus sheath and peritoneum make up the posterior flap

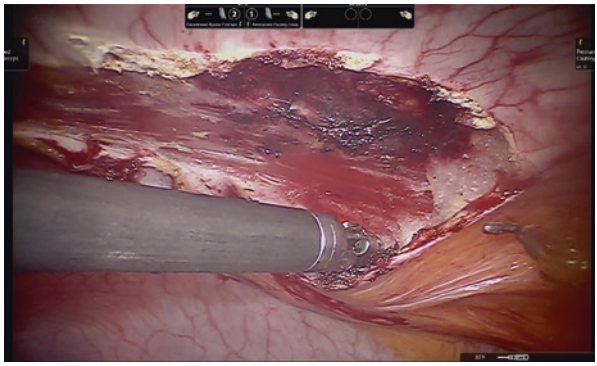

Fig. 12.11 Initial retro-rectus dissection. Avoiding the linea semilunaris is paramount

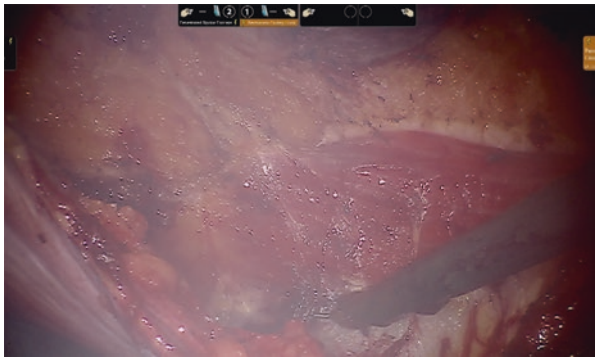

Fig. 12.12 Contralateral retro-rectus space. Avoid coming anterior to the opposite rectus sheath as you come across the midline to avoid an unintended subcutaneous dissection

sheath (Fig. 12.12). The hernia is reduced and the contralateral rectus space is entered. Once dissection is complete and the space has been created the anterior fascia is closed. A small deep dermal bite of the umbilical stalk is taken with the fascial closure to re-create the umbilicus. Mesh is placed and the posterior fascia is closed off the midline.

The endoscopic total extra-peritoneal (eTEP) approach avoids the Achilles heel of the Rives Stoppa repair by avoiding the posterior fascial closure. Trocar position and the number of trocars is quite variable depending on the width of the rectus space and the hernia location. Trocars are placed just outside of the linea semilunaris and angled medially and inserted into the posterior rectus space. The initial trocar can be placed superiorly, laterally, or inferiorly depending on hernia location. The trocar may be placed optically or with a cutdown technique. Blunt dissection then ensues using the camera or by placing a balloon dissector. A second trocar is placed once space is developed and used to dissect out the retro-rectus space. The medial rectus sheath is opened and a pre-peritoneal dissection is made until the contralateral retro-rectus space is entered. A third trocar can be placed to help with dissection to the contralateral side or it can be performed with one instrument and a third trocar placed in the opposite retro-rectus space. Instrument choices include sharp scissor dissection, hook cautery, harmonic scalpel, or Ligasure. Dissection is then carried to the defect which is reduced along with preserving the hernia sac if possible. The posterior flap consists of the posterior rectus sheaths with the peritoneum in between. The posterior rectus sheaths can be re-approximated, but generally are not to prevent tension. That layer is generally just used to keep the mesh isolated from the bowel. Laterally, the nerves are preserved at the linea semilunaris. An adequate space is created for mesh placement. The anterior fascial defect is closed. The mesh is placed and spread out smoothly and the trocars are removed.

For larger primary umbilical hernias, component separation may sometimes be necessary. The general idea is to bring the rectus muscles back to the midline and avoid a bridged mesh repair. This is reserved for larger defects which can't be closed primarily or with a retro-rectus dissection alone. This allows mesh to be placed and avoid contact with the bowel. These approaches will be covered in more detail in other chapters so I will only touch on the highlights of each.

The anterior component release involves cutting the external oblique aponeurosis. This can be performed laparoscopically. By performing this release in an MIS fashion vs. open surgery, there is a decrease in wound complication rates from 59 to 15% [14]. A cutdown is performed about 2 cm lateral to the rectus sheath in the subcostal location. The external oblique aponeurosis is opened creating the space to place a balloon dissector between the external oblique aponeurosis and internal oblique muscle. The balloon is advanced inferiorly and then inflated creating the working space. One or two more trocars are placed inferior and lateral to assist with dissection. The external oblique is then sharply divided vertically about 2 cm lateral to the rectus abdominis along with Scarpa's fascia. This release allows the rectus muscles to move medially. Subcostally, an additional 5–10 cm of medialization can be gained, another 10–15 cm around the umbilicus, and another 3–8 cm suprapubically [15].

Posterior Component Separation

Posterior component separation can be performed laparoscopically, but is very challenging and requires a very advanced skill set to perform. This approach is

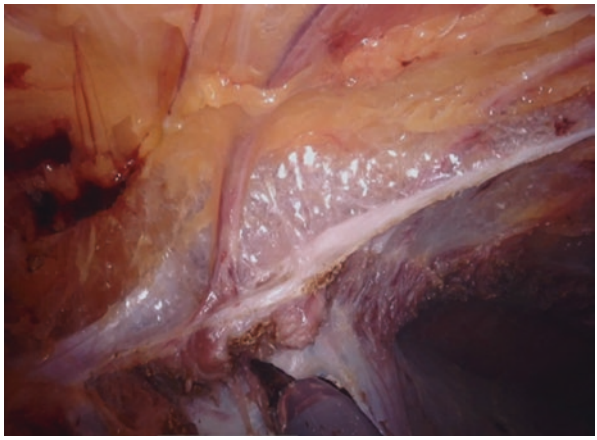

Fig. 12.13 Preservation of the perforating nerves. Note the divided posterior lamella of the internal oblique and transversus abdominis muscle

more easily performed using the robotic platform. The articulation and increased range of motion provided by the robot allows the complexity of the operation to be performed more easily versus the non-articulating laparoscopic instrumentation. The operation requires placement of three trocars on each side of the patient. The first three are placed laterally and a retro-rectus dissection is performed first on the contralateral side. The perforators are again preserved laterally (Fig. 12.13). Next the posterior lamella of the internal oblique is divided exposing the medial transversus abdominis muscle. The muscle is then divided exposing the transversalis fascia and peritoneum. The transversalis fascia and peritoneum are then dissected away from the transversus abdominis extending laterally and allowing medialization of the posterior rectus sheath. This dissection can be carried inferiorly into the space of Retzius and superiorly to the central tendon of the diaphragm if needed. Medium weight macroporous mesh is rolled and placed. I secure it with 2-0 vicryl at both corners and with a stitch centrally to the transversus abdominis. Once that dissection is done three trocars are placed through the lateral abdominal wall on the dissected side. The robot is re-docked to the newly placed trocars and the other side is dissected out in a similar manner. This provides massive posterior mobilization and permits a tension-free closure of the posterior rectus fascia. The fascia is commonly closed with a running barbed suture. My preference is 2-0 V-loc or spiral Strattafix.

After the posterior fascia is closed, attention is turned closure of the anterior fascia. V-loc or spiral Strattafix can be used to close the fascia. Closure is started at either pole. Multiple loose bites are taken and then sequentially tightened like a pulley system starting at the apices and working toward the middle of the closure. Once the anterior fascia is closed the mesh is unfolded and secured. The mesh can be secured using sutures or fibrin glue based on surgeon preference. Drains can then be placed based on surgeon preference.

Plication of rectus diastasis can also be performed at the same time as the umbilical hernia repair. The rationale behind this is to bring the rectus muscles back to the midline and reinforce the weakened linea alba. There is a tendency to develop new hernias above the umbilical repair along the thinned out linea alba. Kohler found

that patients with rectus diastasis suffered from a significantly increased rate of hernia recurrence vs. those that had no diastasis (29/93 vs. 9/108; $p < 0.001$). Frequently, occult primary periumbilical and epigastric ventral hernias will be discovered when taking down the peritoneum in the midline while exposing the fascia. Just superior to the umbilicus and at the insertion of the falciform ligament are common areas to find an occult primary hernia.The type of suture can influence hernia recurrence rates. Kohler et al. found a lower incidence of recurrence with the use of permanent suture vs. absorbable suture (12/111 vs. 26/90); $p = 0.001$ [16].

The diastasis repair can be approached several ways. From a *lateral approach* the falciform ligament is dissected away between the medial border of the rectus muscles exposing the posterior rectus sheath and the linea alba. After dropping the intra-abdominal pressure, the medial posterior rectus sheath is re-approximated using running barbed suture bringing the rectus muscles back to the midline. Small bites of the thinned out linea alba are taken as the midline is crossed. This allows the tissue to "accordion" together and minimizes postoperative bulging along the midline (Fig. 12.14). The potential downside to this approach is only taking bites of the posterior fascia and not the anterior rectus sheath. The fascial defect is closed by incorporating it with the diastasis repair as well. A deep dermal umbilical bite is taken while closing the fascial defect to reconstruct the umbilicus. The whole plicated midline fascia is re-inforced with mesh secured using the IPOM approach. Alternatively, a TAPP approach can be utilized to repair the diastasis and hernia. Once the pre-peritoneal space is dissected out the medial posterior rectus fascia is brought together and the defect is closed. Uncoated mesh can be placed and the peritoneum is closed to exclude the mesh from the viscera.

A suprapubic approach can also be utilized. A TAPP approach can be performed starting the dissection transversely below the defect allowing for a 5 cm inferior mesh overlap. The suprapubic port should be at least 10 cm from the inferior aspect of the fascial defect in order to allow enough room for mesh placement and peritoneal closure. To avoid contact with the thighs, the lateral trocars are placed as far lateral as possible when proceeding robotically. The other maneuver is to flex the table. The peritoneum is opened transversely below the defect and the

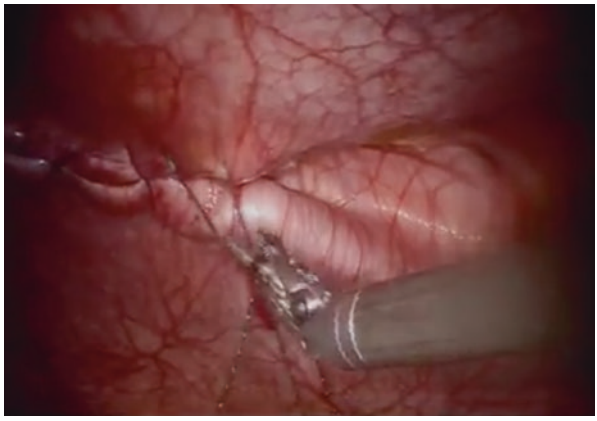

Fig. 12.14 Diastasis repair. Attempt should be made to get bites of the anterior rectus sheath without incorporating the skin

pre-peritoneal space is dissected heading superiorly to the xyphoid process. Once an adequate space has been created to allow for a 5 cm lateral mesh overlap, the diastasis and hernia are repaired and the uncoated mesh is placed. The peritoneum is then closed transversely.

Another option when proceeding with the suprapubic approach is to perform a retro-rectus dissection. The retro-rectus spaces are developed below the defect and the medial rectus sheaths are opened into the pre-peritoneal plane centrally creating one large posterior flap up to the xyphoid process. The midline peritoneum makes up the flap between the posterior rectus fascias. Once the dissection is performed the diastasis is repaired taking bites of the anterior rectus sheath. The accordion technique is used to plicate the diastasis. The potential advantage with this approach is getting bites of the anterior rectus sheath, but the potential downside is the opening of intact fascial planes and "burning the bridge" on the retro-rectus approach if needed in the future.

The last option for umbilical hernia repair with diastasis plication is a subcutaneous onlay approach. A small cutdown is performed suprapubically down to the fascia. The fat is then dissected off of the fascia superiorly and laterally making room for two laterally placed suprapubic subcutaneous trocars. Next dissection along the anterior fascia is performed. The umbilical hernia sac is dissected free from the umbilical stalk. Dissection is then carried superiorly over the linea alba and the medial anterior rectus sheath up toward the xyphoid process. Next the anterior medial rectus sheaths are sewn together using running barbed suture starting superiorly and running back toward the camera. This essentially mimics an abdominoplasty without the skin resection. Care must be taken to only take the anterior fascia and avoid taking a deep bite which could lead to bowel injury. The umbilical fascial defect is closed along the way. Next a drain is placed and the umbilical stalk is reattached to the anterior fascia. The advantage of this approach is avoidance of entry into the abdominal cavity and potential bowel injury. This approach does require drain placement due to the increased risk of postoperative seroma formation.

Cirrhosis

Umbilical hernias in patients with cirrhosis represent a challenging clinical scenario. Ascites contributes both to the formation of umbilical hernias as well as complicating their repair. Strangulation is a complicated presentation is non-cirrhotic patients, but is especially life-threatening in a cirrhotic. Another complication in a cirrhotic with ascites is ulceration of the skin over the defect and the development of a skin breakdown and ascites leak. Control of the ascites is the key to repair both in the pre-op time period as well as postoperatively.

Pre-operative control includes diuresis and parascentesis. If refractory to medical management, a transjugular intrahepatic portosystemic shunt (TIPS) can be performed, but does increase the risk of encephalopathy after the procedure. Once the ascites has been controlled an elective repair should be performed, especially if there

is no immediate plan for a liver transplantation. Hernia repair with mesh is associated with lower recurrence rate, but with higher surgical site infection when compared to hernia correction with conventional fascial suture [17]. There is no consensus on the best abdominal wall layer in which the mesh should be placed: Onlay, sublay, or underlay. Many studies have demonstrated several advantages of the laparoscopic umbilical herniorrhaphy in cirrhotic patients compared with open surgical treatment.

Conclusion

Umbilical hernia repair can be approached in a variety of MIS approaches including IPOM, TAPP, retro-rectus, and component separation. The use of mesh appears to lower recurrence rates. An MIS approach is favored with increasing hernia size and patient BMI.

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Bridging Versus Closing the Defect During MIS Ventral Hernia Repair: Pros and Cons

13

Morris E. Franklin Jr, Miguel A. Hernández, and Philip Mason Hamby

Introduction

The effective repair of ventral and incisional hernias is a challenging and dynamic field that continues to advance with research and innovation. Primary suture repair of ventral hernias has now largely been abandoned due to high recurrence rates. Prosthetic mesh placement is now the standard of care for all but the smallest ventral hernias. Mesh placement has been described above, below, and within each layer of the abdomen. Intraperitoneal onlay mesh (IPOM) technique places a mesh within the peritoneal cavity and below the peritoneum. Once implanted, the mesh forms an inflammatory reaction with the peritoneum, creating a durable and tensile prosthesis. Literature has shown IPOM to be an efficacious repair with reduced complications. Here we discuss the origins of the IPOM as well our experience and technique using the IPOM repair.

History

Laparoscopic ventral and incisional hernia repair was introduced in 1993 with the findings of LeBlanc and Booth who described laparoscopic IPOM [1]. The adhesions were reduced laparoscopically, and a mesh was placed, bridging the defect with a generous overlap of mesh on the lateral margins. This was a marked improvement from the open technique, because it avoided an extensive soft tissue dissection. In addition to this, the technique had a relatively short learning curve, low postoperative complication rate, and attractive long-term durability. Many patients developed seromas in the unclosed hernia sacs. These often resolved but in some

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cases remained as chronic cavities or developed infection. Additionally, patients occasionally develop an anterior bulge mitigating perceived cosmesis [2, 3].

To address these issues, some surgeons advocated reapproximation of the hernia edges before mesh placement. Seromas would still form in the hernia cavity, but by approximating the hernia edges, an additional tissue barrier was created between the mesh and seroma cavity. In addition, the mesh was even further dislocated from the superficial subdermal layers, theoretically lowering the risk of mesh involvement with the skin or infection. Another significant advantage of defect closure was restoration of natural abdominal contour resulting in improved perceived cosmesis [4–7].

Studies assessing laparoscopic ventral hernia repair show that recurrence rates usually range from 4.2 to 16.7% [6, 8, 9]. In some literature recurrence rates can be as low as 0–2.9% [10, 11]. Data also shows that IPOM provides patients with many of the expected benefits of minimally invasive surgery. Hospital length of stay is shortened, and patients have less postoperative pain.

Research has also specifically addressed reapproximation of hernia edges. In 2011, Novitsky et al. published a "shoelacing" technique for ventral hernia repair and reapproximation of the hernia edges. They described their technique in 47 patients in a period of 32 months with no wound-related complications, no seromas, no infections, and zero recurrences in a mean follow-up of 16.2 months [12]. Some published data are not as optimistic. A recent study found that approximation of hernia edges before mesh placement did not reduce recurrence, postoperative pain, or surgical site infection, when compared with a bridging mesh applied in IPOM technique [11].

At the Texas Endosurgery Institute, we have more than 25 years of experience performing laparoscopic ventral hernia repair, likely representing one of the largest series worldwide. In 2004 we published a scientific paper including 384 patients. Ninety-six percent of the procedures were completed laparoscopically. We had 11 (2.9%) recurrences during a mean follow-up of 47.1 months [7]. Currently, in our database and ready to publish, we have 1107 patients. We have reviewed 699 (63%) laparoscopic ventral and incisional hernia repairs and 408 (37%) laparoscopic umbilical hernia repairs. The mean follow-up has been 52.3 months. We had 23 (2%) recurrence cases, 16 of them in incisional and ventral hernias and 7 in umbilical hernias. Eight of these patients had chronic obstructive pulmonary disease (COPD). We found 17 (1.5%) with seromas, all of them treated conservatively.

Technique

Preoperative Management and Patient Selection

All patients undergo routine preoperative laboratory studies, complete blood count, blood chemistries, chest radiography, electrocardiogram, and CT scan. Preparation for surgery includes preoperative antibiotics and formal bowel preparation, if the bowel is significantly involved in hernia and the patient is not obstructed.

Procedure

General anesthesia is used, and nasogastric tube and Foley catheter are placed. The patient is placed in supine position and firmly attached to the table to allow changes in position such as Trendelenburg, reverse Trendelenburg, and side-to-side rotation. We prefer to secure the patient to the table with tape at the shoulder level. Sequential compression devices are applied to the legs. Video monitors are positioned at the foot of the table or at a place convenient for viewing by all of the surgical team.

Insufflation is obtained with a Veress needle, usually from a non-midline location. The initial 5 mm ports are placed lateral to the rectus muscles. The adhesions opposite the initial ports are carefully taken down, and additional ports are placed as adhesions are cleared. Each of these additional trocars should be considered as a port through which a stapler or laparoscope can be placed. Therefore, any port can be upsized to 10–12-mm trocars when needed. Bleeding must be meticulously controlled and bowel injury avoided as the anterior abdominal wall is being cleared. The hernia defect is localized, and the adhesions and hernia sac are dissected before starting to close the defect (Figs. 13.1 and 13.2).

We close the defect with strong suture, even if only a partial closure is possible. In our practice, this is usually accomplished percutaneously, using the Carter-Thomason (Inlet Medical, Inc., Eden Prairie, MN, USA) suture passer with placement of #1 (PDS) polydioxanone (Ethicon, Somerville, NJ, USA) as individual and horizontal sutures 1.5–2 cm apart (Figs. 13.3 and 13.4).

Once the sutures are placed in the edges of the defect, the pneumoperitoneum pressure is lowered to 6 mmHg; this allows for easier closure of the defect with decreased tension. The corners of the defect are tied first, while the assistant holds tension on the middle sutures to approximate the defect. This facilitates large defect closure without tearing the fascia (Figs. 13.5 and 13.6). Almost all defects can be

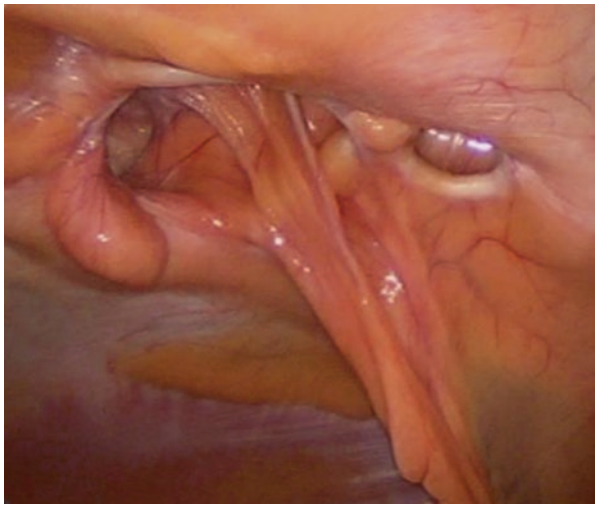

Fig. 13.1 Hernia defect

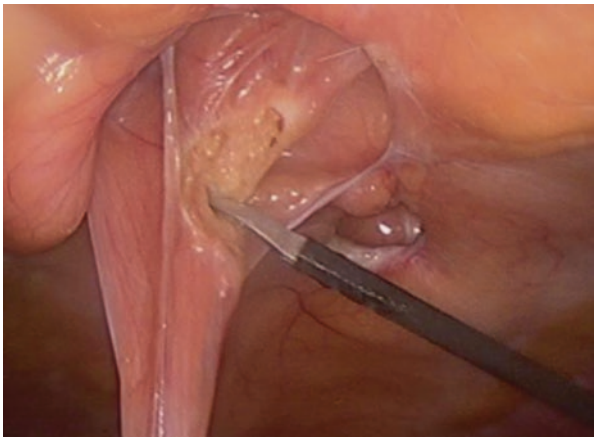

Fig. 13.2 Dissection of hernia sac

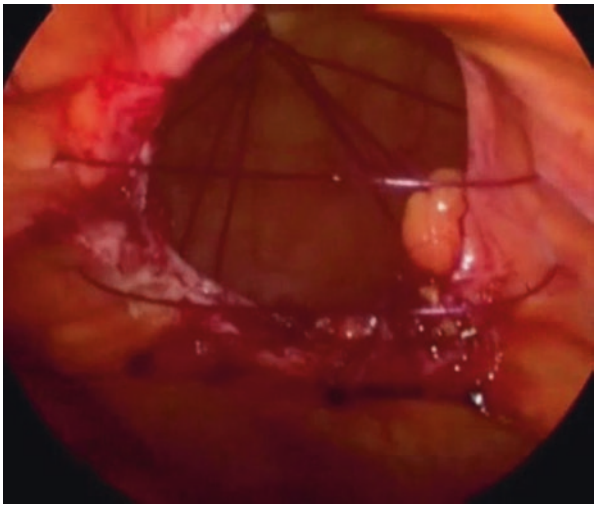

Fig. 13.3 Suture placement

closed by this method; however, there are circumstances where the defect is not closed, such as a rigid abdomen or in loss of abdominal domain. After defect closure, pneumoperitoneum is reestablished to 12 mmHg.

A mesh is selected to cover as many defects as possible and to provide a minimum overlap of 3–5 cm circumferentially around each side of the defect (Figs. 13.7 and 13.8). Although one piece of mesh is ideal, it may not be possible in all instances, especially those abdomens where extensive, multiple, or widely spaced defects are present. The mesh is affixed over the defect with staples or tacks and, in some cases, transfascial circumferential sutures using nonabsorbable suture (2-0 Prolene) (Figs. 13.9, 13.10, 13.11, and 13.12).

All trocar sites greater than 5 mm should be carefully and completely closed and the abdomen desufflated after covering the mesh with omentum. The omentum serves as barrier to separate the mesh from the bowel and to allow adhesions to

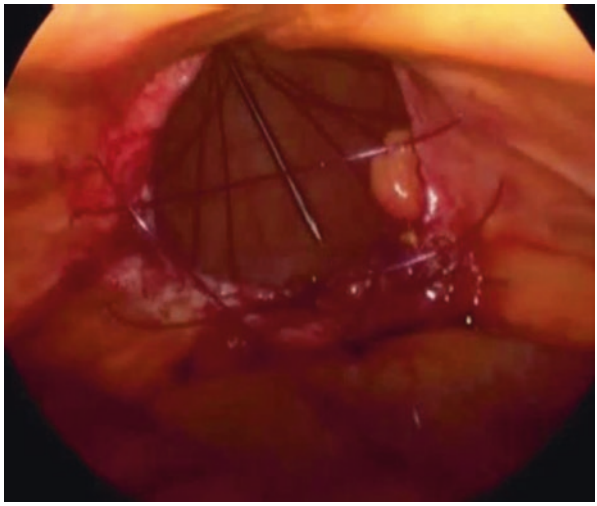

Fig. 13.4 Using suture passer

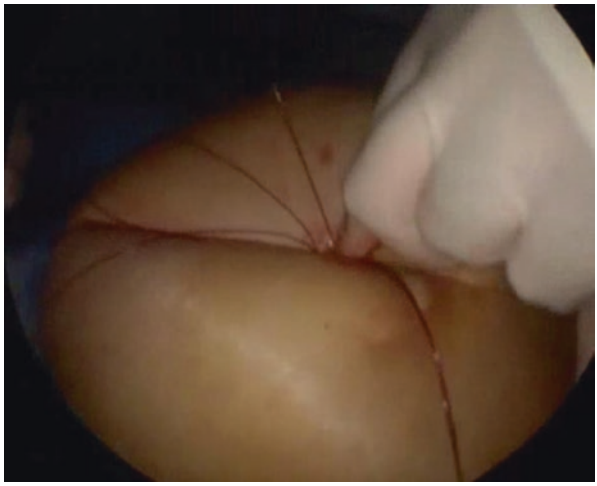

Fig. 13.5 Tying sutures

preferentially form with omentum rather than bowel. Operating times vary with severity of adhesions, number of defects, bowel involvement, and need for concurrent procedures.

Postoperative Management

The postoperative course is relatively straightforward. The nasogastric tube and Foley catheter are removed in the recovery room in most instances. We fully explain to patients that seroma formation is common and watch this expectantly without drainage. The patient is given a diet when bowel sounds are present. Patients are

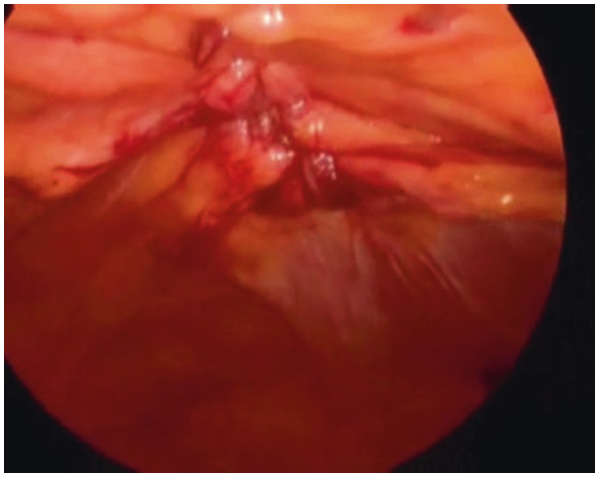

Fig. 13.6 Closed hernia defect

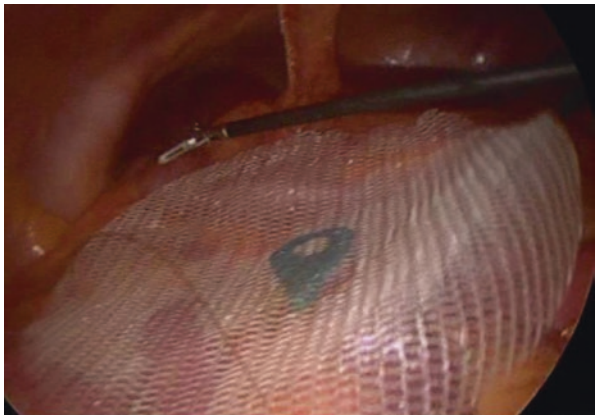

Fig. 13.7 Mesh in the abdomen

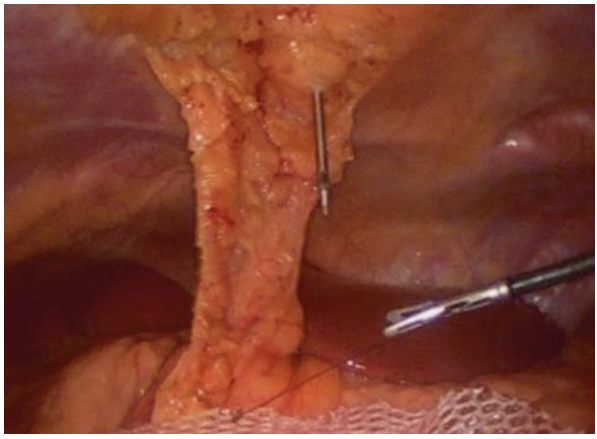

Fig. 13.8 Pulling the mesh

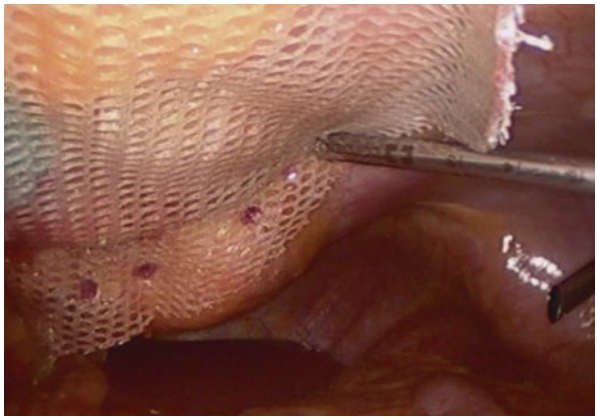

Fig. 13.9 Mesh fixation with tackers

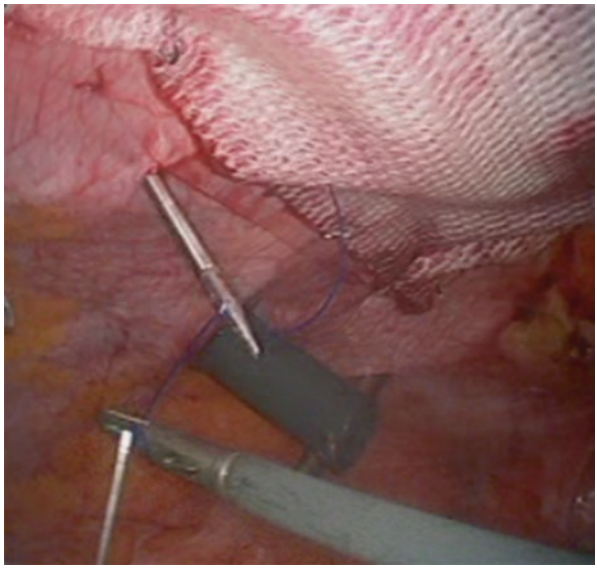

Fig. 13.10 Mesh fixation with staples

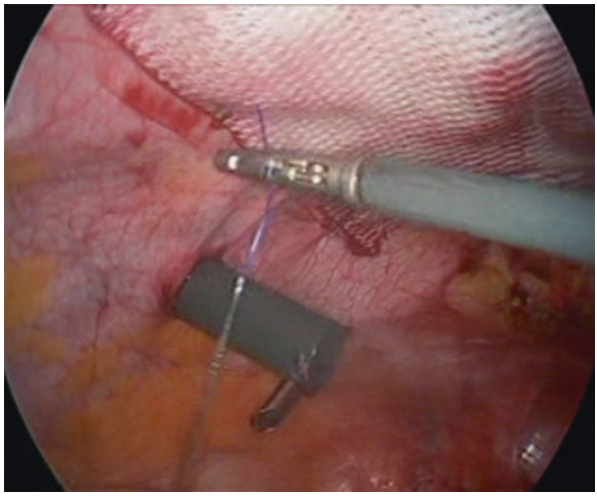

Fig. 13.11 Transfascial suture

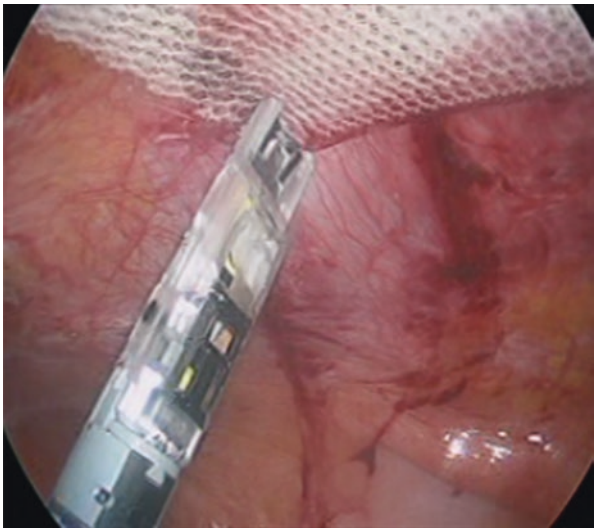

Fig. 13.12 Transfascial suture

allowed to go home when they are afebrile, their wounds are clean, a regular diet is tolerated, and only minimal pain is present.

Patients are routinely seen back in the clinic by the operating surgeon at 2 weeks, 1 month, 3 months, 6 months, and yearly thereafter.

Complications

The most common complication encountered is the seroma formation. Many patients develop a small, sterile fluid collection that does not require further treatment and eventually reabsorbs. Another commonly described complication is the

conversion to an open procedure. Many times this is secondary to poor visualization from dense adhesions and in some cases from profound bowel dilatation.

Hernia repair is associated with a significant risk of enterotomy, and complications related to a missed enterotomy can have devastating effects. Multiple adhesions or prior abdominal surgery increases the risk of bowel injury. Other described complications include trocar site infection, prolonged ileus, urinary tract infection, pseudo-obstruction, and pulmonary problems. Less commonly, patients can also have recurrent pain and suture-site neuralgia. Mesh infections are relatively rare and are usually associated with enterotomy.

Conclusions

Overall, in our experience, we have consistently noted decreased complications and morbidity with the IPOM repair using reapproximation of hernia edges. Patients are well satisfied with repair cosmesis, and from our data, the repair has an enviably low recurrence rate.

In our experience, reapproximation of hernia edges during IPOM technique appears to reduce recurrence and provide improved cosmesis. Our data from the past 25 years is one of the largest case series worldwide that clearly supports closure and reapproximation during IPOM ventral hernia repair.

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Robotic Technique for Intraperitoneal Onlay Mesh (IPOM)

14

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Overview

Laparoscopic ventral hernia repair (LVHR) with intraperitoneal onlay mesh (IPOM) is an accepted technique for ventral/incisional hernia (VIH) repair. LVHR can improve wound morbidity, shorten hospital length of stay (LOS), and lower the rate of surgical site occurrence (SSO) compared to certain open approaches for small- and medium-sized VIH [1, 2]. However, at least 2% of patients report significant pain lasting more than 2–8 weeks postoperatively [3–6]. Most often, patients describe the pain as localized to a specific dermatome, burning, and/or tugging/pulling at the site of transfascial sutures or tacks. Prolonged or severe postoperative pain after LVHR represents a potential area for improvement, and robotic ventral hernia repair (RVHR) with IPOM may help decrease the frequency and/or severity of this sequalae [6, 7].

At the time of this writing, one robotic platform is approved for use in the United States (da Vinci® Surgical System, Intuitive Surgical, Sunnyvale, CA), so the following descriptions relate to three models (Si, X, and Xi). It is the opinion of the authors that the robotic surgical platform offers advantages to traditional laparoscopic instrumentation including, but not limited to, additional degrees of motion, three-dimensional imaging, a stable operating construct, and preferred ergonomics.

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Studies demonstrate the relative ease and precision of intracorporeal suturing when securing mesh to the abdominal wall with the robotic surgical platform compared to traditional laparoscopy [3, 8, 9].

There are several perceived benefits of intracorporeal suturing compared to traditional transfascial suture fixation of mesh to the abdominal wall. The method of IPOM fixation seems to play a role in the perception of postoperative pain when comparing RVHR and LVHR. During RVHR, mesh is sutured in a continuous circumferential fashion to the posterior rectus sheath. This stands in contrast to LVHR during which mesh is secured using transfascial sutures spaced at 2–5-cm intervals and tacks (absorbable or permanent). Less acute pain after RVHR can have downstream benefits including less use of narcotic pain medications, shorter hospital LOS, fewer complications, and earlier return to physical activity compared to traditional LVHR [10–13].

Additional potential benefits of RVHR include the relative ease of enterolysis when considering surgeon ergonomics and fascial defect closure, minimizing the need to bridge defects with mesh [14]. Recent studies demonstrate an increased frequency of defect closure with RVHR compared to LVHR and less acute postoperative pain [10]. Closure of the fascial defect may portend a lower risk for SSO, specifically symptomatic seroma, and potentially hernia recurrence. This chapter will detail the perioperative considerations and technical tips for RVHR with IPOM for VIH repair.

Patient Selection

Patient selection is broken down into two phases. The first phase is prehabilitation, which connotes improving the overall medical condition of the patient with VIH. The second phase is choosing the operative approach. Before selecting RVHR, the operating surgeon must consider the medical and surgical history, hernia characteristics, as well as individual training and experience. When these two phases are combined, the correct patient is matched to the correct operative approach, leading to the best possible outcomes.

Preparing patients for VIH repair is critical to minimize risk for SSO and hernia recurrence. Reviewing the medical history is critical before choosing RVHR with IPOM. For example, patients with inflammatory bowel disease (Crohn's disease or ulcerative colitis) may be a relative contraindication to IPOM with permanent synthetic biomaterial. In general, patients should be smoke-free for at least 4 weeks preoperatively to minimize the risk for surgical site infection (SSI). In addition, those patients with body mass index (BMI) greater that 40 kg/m^2 who wish to undergo RVHR should be counseled regarding medically supervised or surgical weight loss before VIH repair. Surgeons have an opportunity to impact patients with morbid obesity by offering appropriate counseling and referral to weight loss specialists and/or bariatric surgeons. Operating on morbidly obese patients without first discussing and requiring weight loss misses a critical opportunity to improve the quality and quantity of life of patients suffering from morbid obesity. Besides smoking cessation and weight loss, patients are assessed for other risks associated with SSI including diabetes mellitus and history of

wound infection. Patients with hemoglobin A1c greater than 8% are referred to a primary care provider or endocrinologist for better blood glucose control before considering elective VIH repair. Those with a significant history of SSI, especially when infected or carrying methicillin-resistant *Staphylococcus aureus* (MRSA), may benefit from preoperative MRSA eradication and/or antibiotic treatment. The decision to eradicate MRSA and/or treat with preoperative antibiotics may be made in conjunction with infectious disease specialists as needed. The operating surgeon should also consider the patients' nutritional status before undertaking RVHR. Patients are at risk of SSI and/or poor outcomes when nutritional status is poor. These individuals can be sent for formal evaluation by a dietician and given preoperative dietary supplements to improve protein intake and overall catabolic status.

The choice of operative approach depends on patient and surgeon factors. While a complete algorithm for choosing an operative approach to VIH repair is beyond the scope of this chapter, it is important to detail the specific indications for RVHR with IPOM. Once the patient is prepared appropriately for operation, the next step is to determine the type, size, and location of the VIH. Following a thorough history and physical examination, the surgeon must decide if computed tomography (CT) is indicated. The authors feel a preoperative CT is beneficial in patients with large primary ventral hernias as well as all incisional and recurrent hernias. CT also permits determination of defect type and size and may identify concurrent defects missed on physical examination. The authors feel that with regard to hernia location and size, RVHR with IPOM and defect closure is most appropriate for primary ventral hernia located in the anterior abdominal wall and measuring less than 6 cm in diameter. Other indications may be off-midline defects such as small- or medium-sized Spigelian, flank, and parastomal hernias with the caveat that other more advanced surgical techniques are not warranted or possible.

Operative Technique

The key to successful RVHR with IPOM includes appropriate patient selection and understanding and exploiting the layers of the abdominal wall. Working high on the anterior abdominal wall is feasible using laparoscopic instrumentation; however, it is technically easier and ergonomically less challenging using a robotic surgical platform. Methods to approximate the fascia and secure the mesh, particularly suturing, are less burdensome to the surgeon and potentially less painful to the patient. RVHR with IPOM is most often performed in conjunction with primary closure of the defect, though this is not mandatory. As experience with RVHR grows, an increasing number of surgeons elect to close the fascial defect before IPOM.

Required Equipment and Room Setup

The orientation of the operating table within the operating theater may vary depending on the model and mobility of robotic equipment as well as room size. Assuming a square-shaped operating room, the operating table is placed in the middle of the

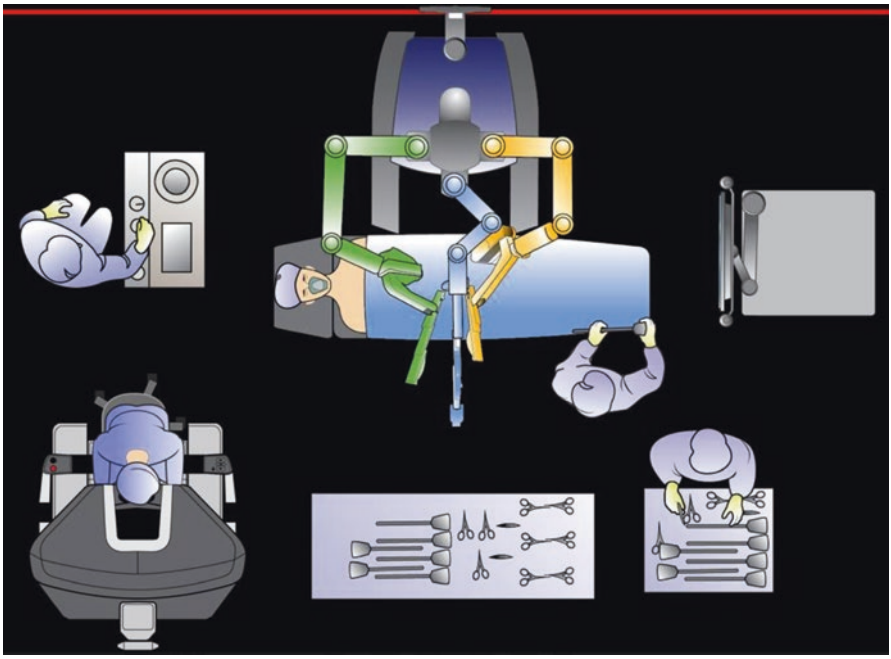

Fig. 14.1 Room setup for robot-assisted ventral/incisional hernia repair with intraperitoneal mesh using the da Vinci® Si robotic surgical platform

room. When using the Si or X model, all anesthesia personnel and equipment are located at the patient's head. Docking occurs from the patient's side. The robotic platform can be positioned perpendicular to the operating table from the patient's left or right side (side-docking). If the hernia defect is off midline, the robotic platform should be docked from the ipsilateral side. When using the Xi model, operating room and equipment setup and docking direction become less critical. The Xi and its ability to side dock or parallel dock allows for anesthesia equipment and providers to remain at the patient's head, and the robotic platform is docked from the patient's left (preferred by the authors) or right side (Fig. 14.1).

Patient Positioning

Patients are positioned supine on the operating table with bilateral lower extremity sequential compression devices. The patient should be situated such that the mid-abdomen overlies a flex joint in the operating table. Clipping of hair can be performed based on local practice routines. Some aspects of patient positioning are common to all RVHR; however, certain key patient and hernia-related factors must be considered.

Patient factors impact positioning, so these issues should be addressed before placing sterile drapes. In most cases, the patient's arms are tucked with care to protect intravenous access and provide padding of pressure points. One tip is to avoid

bulky anterior and medial padding of the arms, as this may limit access to the lateral abdominal wall (or flank), a region commonly chosen for trocar placement. When present, large pendulous breasts can be elevated cephalad and secured with wide silk tape in a crisscross fashion so that breast tissue is not impacted (or injured) by robotic arms. Very thin patients, especially those with medium-sized ventral hernias requiring a lateral trocar position, can be positioned off-center on the operating table with both arms tucked. This off-center positioning minimizes the risk for collision of the robotic arms against the operating table once docked. For patients with a short torso (distance between the anterior superior iliac spine and costal margin) and limited space to insert trocars along the anterior axillary line, it may be beneficial to flex the operating table and elongate the torso slightly. Keep in mind that too much flexion of the operating table and elongation of the torso decreases intraperitoneal working space. In some patients, the leg ipsilateral to the operative site may impede a robotic arm. By pushing both legs together away from the operative site, a greater angle at the hips allows for more mobility of the inferior robotic arm.

Trocar Placement

Proper trocar placement is important for successful RVHR. Several factors influence the type, number, and location of trocars placed. The type and size of trocars may vary by robotic surgical platform, diameter of camera lens, and availability of instruments. One strategy is to use the fewest number and smallest diameter trocars that permit a safe, effective operation. At least three trocars are required for RVHR with IPOM. Most often these trocars are placed along the anterior axillary line in a staggered fashion, with the camera trocar most posterior. A general rule is to space these trocars 6–8 cm from one another. A disposable laparoscopic trocar (assist port) can be placed opposite the robotic trocars when necessary for passage of large or heavyweight mesh, removal of foreign body mesh, or other assistance. Trocar location may vary based on patient surgical history, body habitus, torso length, and hernia size and location (Fig. 14.2).

Docking

Docking position depends on the platform model, correct room setup, and hernia characteristics. The Si and X platforms may need to be arranged in the operating room on the side opposite the desired location for trocar placement. This simple docking strategy is effective for midline ventral and incisional hernias, but defects located in more challenging locations (flank, subxiphoid, suprapubic) may require alternative docking strategies (Fig. 14.2).

In certain situations, parallel docking or alternate-site docking may facilitate repair of hernias in difficult anatomic positions. For subxiphoid ventral hernia, RVHR can be performed with trocars placed in the hypogastrium (at or below the arcuate line). In that case, docking the Si or X platform over the patient's left or right

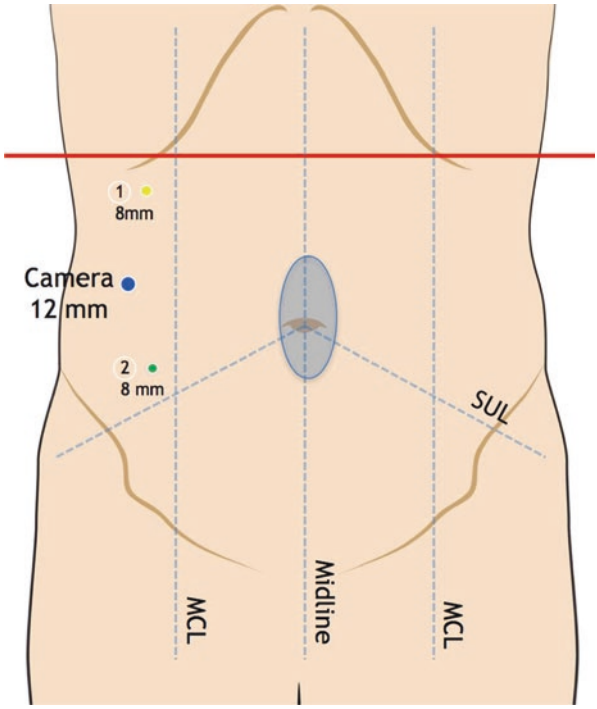

Fig. 14.2 The most common trocar positioning for robot-assisted ventral/incisional hernia repair with intraperitoneal mesh using the da Vinci® Si robotic surgical platform

shoulder may facilitate in-line visualization and dissection as well as minimize robotic arm collisions. Alternatively, the Xi platform can be side-docked without limiting robotic arm movement. Suprapubic VIH defects can be approached through trocars placed in the subcostal region. If trocars are placed in the subcostal area, the Si and X platforms can be docked diagonally from the hip or between the patient's legs (low lithotomy position). Again, the Xi platform can be side-docked without limitations. Flank hernia repair may require adjustments to patient position and docking. Most often, the robotic surgical platform is side-docked on the side opposite the defect to allow for complete dissection of these challenging hernias. The use of the patient clearance feature unique to the Xi platform allows for improved range regardless of hernia location.

Dissection

After correct patient positioning, trocar placement, and docking, RVHR with IPOM is dependent on careful enterolysis and reduction of hernia content. One tip to reduce issues with dissection and eventual mesh placement is "ranging the robot," which entails inserting all instruments and moving both instruments as far cephalad and caudad on the ipsilateral side of the camera as possible. The point of "ranging the robot" is to assure that the surgeon will be able to use both instruments to secure a sufficiently large mesh to the anterior abdominal wall.

Peritoneal structures such as the medial umbilical ligaments and falciform ligament as well as an intraperitoneal fat should be dissected free from the anterior abdominal wall to facilitate localization of mesh. The use of cut current at low voltage is preferred compared to coagulation current for dissection of peritoneum from fascia. The rationale for this recommendation is that cutting current results in vaporization of tissue making dissection easier and more precise, while coagulation current causes annealing of peritoneum to fascia making separation of tissue more difficult. During dissection, care is taken to avoid disrupting the posterior fascia. The operating surgeon may choose to dissect and reduce the hernia sac, though this is not required. It is the opinion of the authors that any surgeon who attempts more advanced approaches such as robotic transabdominal preperitoneal (TAPP) VIH repair or posterior component separation must be proficient with RVHR plus IPOM.

Defect Closure

Once enterolysis and dissection of peritoneal structures are complete, the next step is defect closure. First, the surgeon inspects the linea alba for diastasis recti. It is the opinion of the authors that diastasis recti should be addressed with VIH repair to improve postoperative cosmesis, facilitate abdominal wall function, and lower the risk of hernia recurrence.

Following inspection, the defect is measured to determine appropriate mesh size. The choice of suture for plication of diastasis recti and defect closure may vary, but the authors choose slowly absorbable barbed suture (#0 V-Loc™ 180 Wound Closure Device, Medtronic Inc., Minneapolis, MN) on a GS-21 needle measuring 30–45 cm. Sutures are used according to manufacturer's instructions for use. Often multiple sutures are required to plicate the diastasis recti and close the fascial defect. Tips to facilitate proper fascial approximation include decreasing the pneumoperitoneum to 8–10 mmHg, ensuring adequate visualization of the anterior rectus sheath with each stitch, and adhering to the short-stitch technique (Fig. 14.3). When approximating

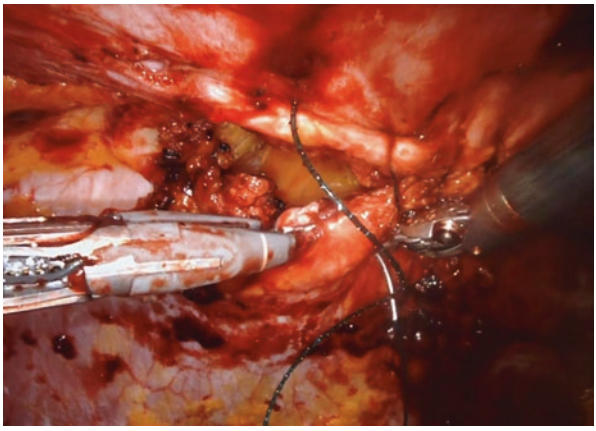

Fig. 14.3 Robot-assisted ventral/incisional hernia repair with fascial defect closure using absorbable suture (#0 V-Loc™ 180 Wound Closure Device, Medtronic, Minneapolis, MN) on a GS-21 needle. The small-bite, short-stitch technique allows for dispersion of tension across a larger cumulative surface area

diastasis recti, full-thickness stitches of abdominal wall to include anterior rectus sheath are crucial to medialize the rectus abdominis muscles. To facilitate defect closure (or diastasis recti plication), pull each self-locking suture through the fascia after each stitch, rather than throw multiple stitches before pulling suture through the fascia.

Mesh Placement and Fixation

Following fascia approximation, the next step is mesh implantation. For IPOM, the authors prefer a barrier-coated permanent synthetic mesh (medium- or heavyweight polypropylene) for most defects. When using barrier-coated permanent synthetic mesh, there are several keys to ensure the correct size, location, and fixation.

Mesh size is determined by hernia defect length and width prior to defect closure. For example, a defect measuring 5 cm wide by 10 cm long would necessitate a mesh 15 cm wide by 20 cm long to ensure adequate overlap. Next, mesh location is centered about the defect by marking the center of the mesh with a permanent marker, as well as the long axis of the biomaterial such that both are identifiable during manipulation and implantation. This assures the mesh is not fastened or secured to the abdominal wall in a location that is off-center to the defect, a technical issue of utmost importance to prevent hernia recurrence. The mesh can be positioned on the anterior abdominal wall using traditional transfascial sutures or with assistance from a mesh positioning device. Once positioned, monofilament suture is introduced to the peritoneal cavity through the same trocar as the robotic needle driver. The suture is usually 45 cm long, such that the tail of the suture extends out the robotic trocar and is secured with a hemostat. A needle driver is then inserted for suturing of mesh to the anterior abdominal wall and the hemostat removed. This technique facilitates initial stitching of the mesh without excessive suture in the field of view. With this technique, it is necessary to remove the needle driver and insert suture as needed until the mesh is secured to the abdominal wall. Alternatively, multiple sutures can be placed in the peritoneal cavity at the outset and each suture used to secure mesh to the anterior abdominal wall.

Finally, the mesh is secured to the anterior abdominal wall using one of several fixation strategies that include suture fixation with multiple interrupted transfascial stitches, circumferential fascial stitches, and/or tacks (absorbable or nonabsorbable). The authors choose circumferential fascial stitches without tacks to avoid fixation options that may be costlier, increase short-term postoperative pain, or potentially increase hernia recurrence risk. If the mesh is larger than 10×15 cm in size, the authors use additional fixation in the form of a midline running stitch that secures the long axis of the mesh to the linea alba. This tightens the mesh against the anterior abdominal wall and may decrease the space available for accumulation of seroma (Fig. 14.4).

At the completion of mesh implantation, it is important to inspect for gaps around the perimeter of the mesh. If there are significant gaps ($\geq$2 cm) between stitches, additional stitches are warranted to minimize risk for herniation of omentum and/or

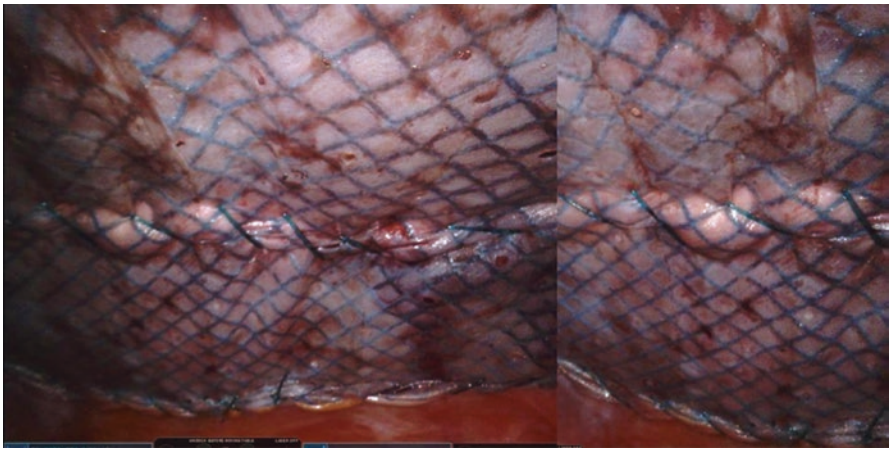

Fig. 14.4 Intraperitoneal onlay mesh (Zenapro® Hybrid Hernia Repair Device, Cook Medical, Bloomington, IN) secured with absorbable fascial sutures (#0 V-Loc™ 180 Wound Closure Device, Medtronic, Minneapolis, MN) in a circumferential running fashion. An additional stitch secures the IPOM to the linea alba in an effort to increase mesh-tissue interface and decrease space for seroma formation

bowel, which can lead to incarceration and strangulation in the acute postoperative period. Once the mesh is secured under tension to the anterior abdominal wall, the robotic surgical platform is undocked. At this time, the authors recommend closure of all fascial defects measuring greater than 1 cm, which would include all 10–12-mm trocar sites; however, there may be reasons to close 8-mm trocar sites, but this decision is left to the discretion of the operating surgeon.

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Ventral, Incisional, and Atypical Hernias Using a Robotic Transabdominal Preperitoneal Approach

15

Stephanie Bollenbach and Conrad Ballecer

Introduction

It is from the laparoscopic transabdominal preperitoneal repair (TAPP) for the treatment of groin hernias that the robotic transabdominal preperitoneal repair (rTAPP) for ventral hernias was adapted, integrating methods gained both from open and conventional laparoscopic ventral hernia repairs. With the robot, the dissection of the individual layers of the abdominal wall is done with greater visualization, ergonomics, and precision. The transabdominal preperitoneal approach is designed around the placement of uncoated mesh in a preperitoneal position, providing protection from the intra-abdominal content. This allows decreased risk of visceral adhesions to the mesh and potentially eliminating the requirement for significant fixation of the mesh. In this chapter, rTAPP will be discussed for the repair of ventral hernias.

Anatomy

A full comprehension of the layers of the abdominal wall is a fundamental component of rTAPP. Beneath the transversalis fascia or posterior sheath, a preperitoneal avascular plane is established with the initial dissection and further developed using blunt and sharp dissection. A sufficient overlap of 5 cm is created circumferentially to the fascial defect. Once the hernia sac is reduced and the preperitoneal plane is extended to allow an appropriately sized mesh, the dissection is complete. The use of mesh allows for reinforcement and may be secured to the abdominal wall with

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sutures or tacks. The peritoneal flap is then re-approximated, providing coverage of the mesh. The technique is most appropriate for ventral hernias of small to medium size, as well as atypical hernias such as subxiphoid, suprapubic, flank, and Spigelian defects.

Preoperative Considerations

In devising a plan for surgical repair, a thorough history and physical exam are imperative. Comorbidities must be individually assessed, including BMI, smoking history, prior hernia repairs, and immunocompromised states, which may be crucial in determining optimal nonoperative versus operative approach. A thorough history and physical exam are typically adequate in preoperative evaluation of those with small primary hernias. CT imaging of the abdomen and pelvis may be helpful, particularly in patients with large and recurrent incisional hernias. In our practice, we have found the rTAPP to be ideal for ventral fascial defects measuring 1–5 cm in any location. Defects greater in size, 5–8 cm, may be more optimal for a robotic Rives, and those measuring 8–16 cm or those with midline and lateral defects are often better served with the roboTAR technique. Older individuals or those with significant comorbidities or low functional capacity are good candidates for the IPOM with or without closure of the fascial defect.

Operative Steps

1. **Umbilical Hernias**

   Positioning, Port Placement, Docking, and Instrumentation

   The patient is placed on the operating room table in supine position with both arms tucked. Elevating the kidney rest located at the level of the umbilicus can extend the space between the costal margin and the pelvic rim, allowing more ideal separation between the trocars. The same goal may be accomplished by flexing the bed. Foley catheter placement may be considered, especially if the case is expected to be prolonged.

   Intra-abdominal access is obtained via a 5-mm Optiview trocar at Palmer's point in the left or right upper quadrant, with or without initial Veress insufflation. Pneumoperitoneum is accomplished, with a pressure of 15 mmHg. A 12 mm robotic port is placed under laparoscopic visualization in the mid-lateral abdomen, at a minimum of 15 cm from the defect. An 8-mm port is placed in the left or right lower quadrant, after which the 5-mm Optiview port is exchanged for an 8-mm robotic port (Fig. 15.1).

   Over the contralateral side, the robot is docked in line with the ports. A 30° scope is used facing upward for initial dissection of the ipsilateral abdominal wall. In order to better facilitate preperitoneal dissection on the contralateral side, the scope may be adjusted to 0° or downward facing 30° scope.

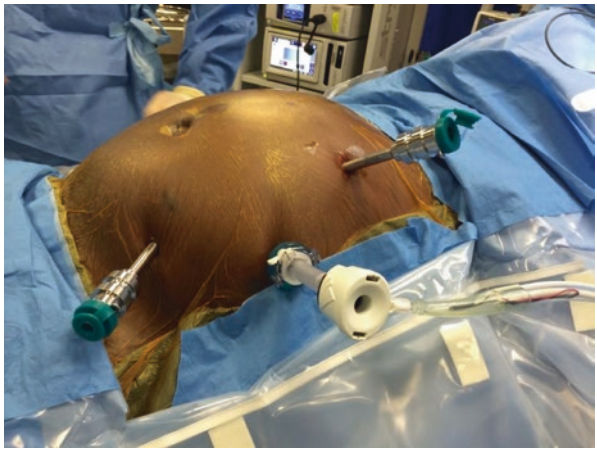

Fig. 15.1 Patient docking/trocar placement for umbilical/midline ventral hernia

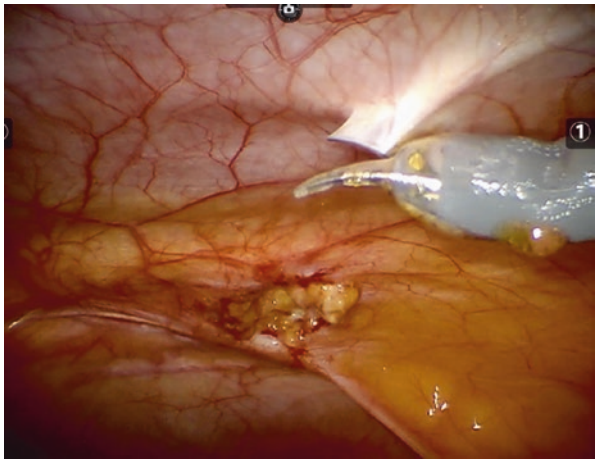

Fig. 15.2 Development of preperitoneal space at least 5 cm from hernia site

Preperitoneal Plane Dissection, Primary Repair of Defect, and Mesh Placement

In order to fully visualize the hernia defect, adhesions are lysed with care. Using monopolar scissors, the peritoneum is incised at a minimum of 5 cm from the nearest edge of the hernia defect (Fig. 15.2). The avascular preperitoneal plane is dissected with blunt and sharp dissection, while using electrocautery very cautiously in order to avoid peritoneal and posterior sheath rents. Dissection of this plane may be done safely and easily with blunt sweeping and adequate counter traction. With development of the preperitoneal plane both cephalad and caudad to the fascial defect, the hernia sac is defined (Figs. 15.3, 15.4, and 15.5). The sac is reduced methodically in order to avoid tears in the peritoneum.

Once the hernia sac is fully reduced, the peritoneal plane is further established on the contralateral abdominal wall. Dissection must be continued until an

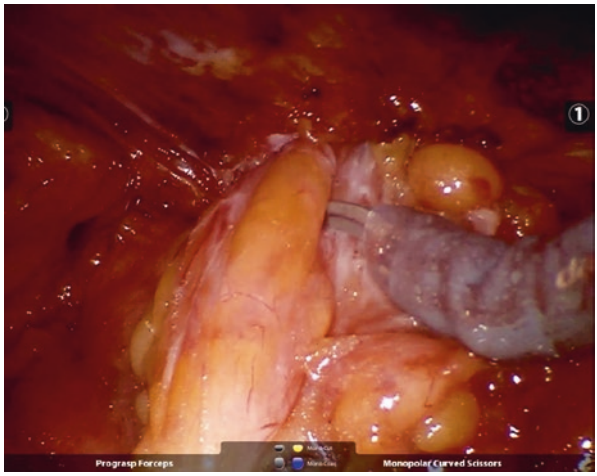

Fig. 15.3 Gentle reduction of hernia contents

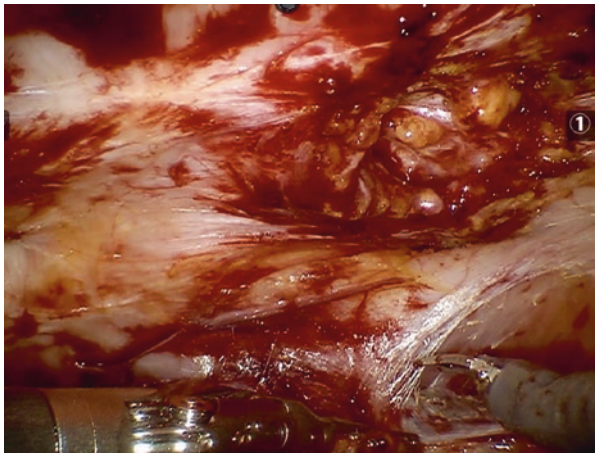

Fig. 15.4 Continuation of preperitoneal dissection past hernia defect with use of tension-countertension

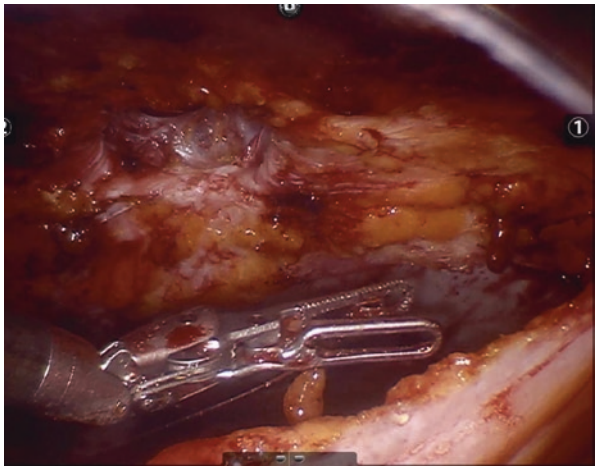

Fig. 15.5 Completed preperitoneal dissection with reduced hernia

adequately sized mesh may be placed with a minimum of 5 cm overlap in each direction. The development of a large flap is beneficial due to a redundancy in the peritoneum, thereby facilitating its closure.

Once there is felt to be adequate preperitoneal dissection, the hernia defect is closed, typically with absorbable barbed suture in continuous fashion (Fig. 15.6). The dead space of the hernia defect noted anteriorly may be obliterated with thin bites of subcutaneous tissue, recreating an inverted umbilicus. Absorbable suture may be used to close small peritoneal disruptions.

Through the 8 mm trocar, an appropriately sized uncoated mesh can be inserted. After the mesh is positioned against the abdominal wall in the preperitoneal space, it is then fixated with tacks or sutures positioned at cardinal points (Fig. 15.7). The peritoneum is then re-approximated with tacks or sutures, covering the mesh. Absorbable suture is used to close the fascia of the 12 mm port site.

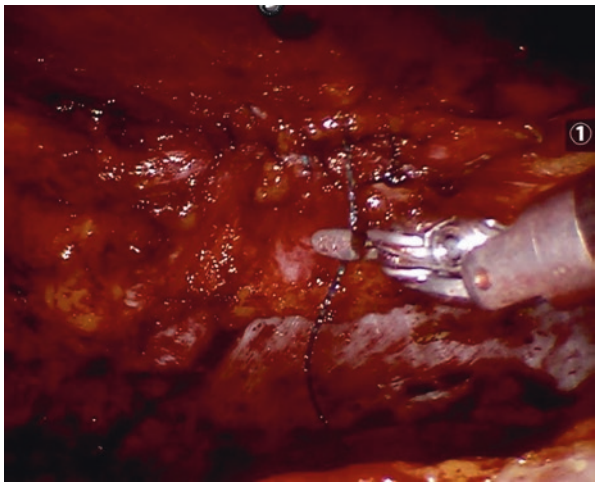

Fig. 15.6 Primary repair of suture defect with absorbable locking suture

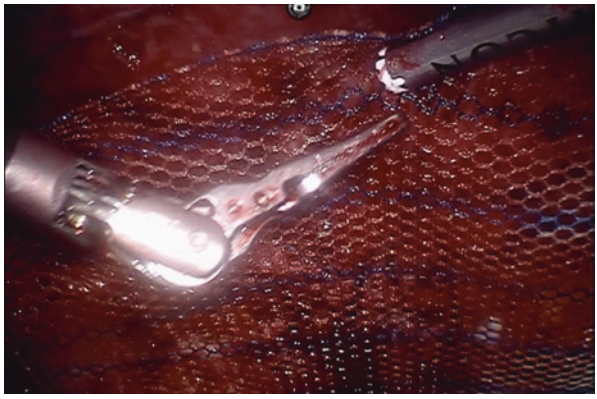

Fig. 15.7 Mesh fixation with tacker at cardinal points on anterior abdominal wall

2. **Subxiphoid Hernias**

Positioning, Port Placement, Docking, and Instrumentation

Subxiphoid, Morgagni, and other such atypical hernias are very appropriate for the rTAPP approach. By positioning the mesh between layers of the abdominal wall, the lack of fixation points does not cause any difficulty. The patient is placed on the operating room table in supine position with both arms tucked. In order to attain more optimal space between trocars as well as separation from the hernia site, a kidney rest may be used at the level of the umbilicus, or the table may be flexed should the patient have a short torso. A Foley catheter can be considered if a prolonged case is expected.

A midline camera port is situated at a minimum of 15 cm from the hernia defect in order to gain intra-abdominal access. Two 8 -mm ports are placed under laparoscopic vision at or near the same level of the camera port. The robot is brought in over the patient's shoulder. A 30° upward scope is preferred for optimal visualization of the anterior abdominal wall.

Preperitoneal Plane Dissection, Primary Repair of Defect, and Mesh Placement

Bowel and omental adhesions are dissected with care to in order to fully visualize the abdominal wall anatomy and the hernia fascial defect. The hernia is safely reduced of any content in order to avoid iatrogenic injury. At a minimum of 5 cm from the edge of the facial defect, the peritoneum is incised with scissors. An avascular preperitoneal plane is established using blunt and sharp dissection in a caudal to cephalad direction. As mentioned before, cautery should be utilized with caution in order to avoid peritoneal and fascial defects. The peritoneum is separated from the posterior sheath safely via meticulous blunt sweeping motions with appropriate traction and countertraction. The hernia sac is fully reduced, continuous with the peritoneal flap. The falciform ligament may be dissected from the anterior abdominal wall and mobilized in order for more optimal visualization. The ligament can then be used to cover any peritoneal defects.

After dissection is completed with at least 5 cm overlap in all directions, the fascial defect is closed primarily, typically with absorbable barbed suture in continuous fashion.

Through an 8 mm trocar, an appropriately sized uncoated mesh may be inserted and placed in the preperitoneal space against the abdominal wall. The mesh is secured with tacks or sutures at cardinal points and subsequently covered with the peritoneum re-approximated with tacks or sutures.

3. **Suprapubic Hernias**

Positioning, Port Placement, Docking, and Instrumentation

The rTAPP approach to atypical suprapubic hernias highlights the robot's ability to establish large preperitoneal planes, ultimately hiding the mesh from visceral content with re-approximation of the peritoneal flap.

The patient is placed on the operating room table in a supine lithotomy position, with both arms tucked. A Foley catheter is recommended not only to optimize visualization but also to help with identification and possibly reduction of the bladder from within the hernia.

At least 15 cm from the hernia defect, a midline camera port is placed in order to gain intra-abdominal access. Two 8-mm ports are placed in the upper quadrants bilaterally and 10 cm laterally from the midline port (Fig. 15.8).

With the patient in Trendelenburg position, the robot is docked between the patient's legs (Fig. 15.9). A 0 or 30° scope is used for visualization of the abdominal wall.

Preperitoneal Plane Dissection, Primary Repair of Defect, and Mesh Placement

In order to fully visualize the abdominal wall anatomy and the hernia fascial defect, bowel and omental adhesions are dissected with care. The hernia is safely

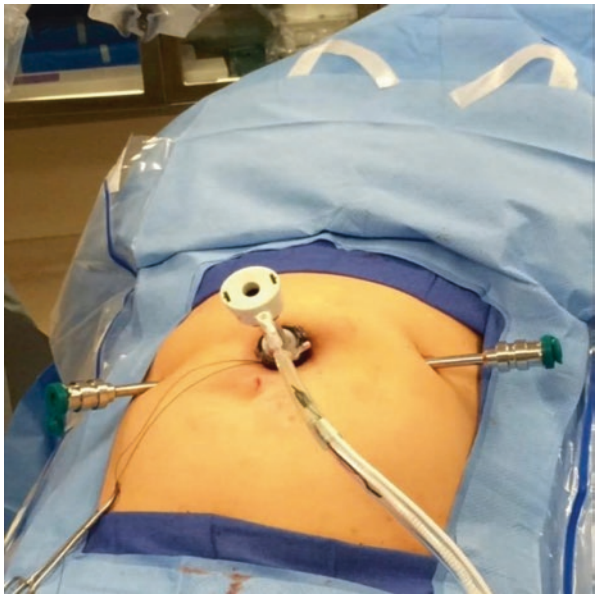

Fig. 15.8 Suprapubic hernia trocar placement

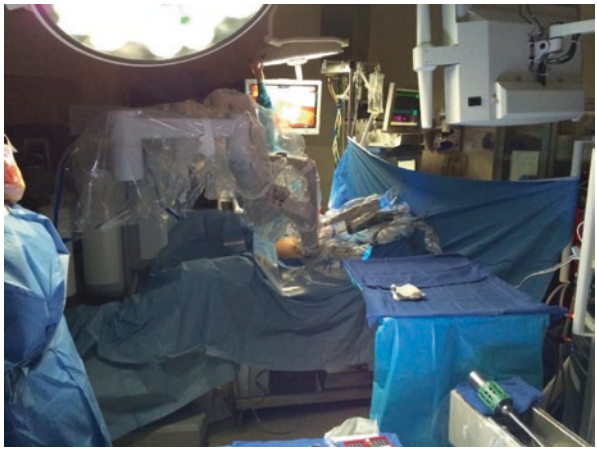

Fig. 15.9 Suprapubic hernia trocar placement and docking

reduced of any content to prevent iatrogenic injury. The peritoneum is incised with scissors at a minimum of 5 cm from the edge of the fascial defect. Blunt and sharp dissection is done with a grasper and monopolar scissors. An avascular preperitoneal plane is established, involving the medial umbilical ligaments bilaterally at a minimum. Dissection is continued widely in the retropubic space and the space of Retzius to allow adequate mesh coverage.

Thorough appreciation and visualization of the inguinal anatomy are important, including identification of the bladder and exposure of Cooper's ligaments within the retroinguinal space. The cautery should be used with caution while establishing the peritoneal flap, in order to avoid peritoneal defects as well as potential injury to the bladder, cord structures, blood vessels, and nerves.

Once dissection is complete with at least 5 cm overlap surrounding the hernia, the fascial defect can be repaired primarily, performed typically with absorbable barbed suture in continuous fashion. Desufflation of the pneumoperitoneum to 6–10 mmHg may help in closing large suprapubic defects.

An appropriately sized uncoated mesh can be inserted through an 8 mm trocar and placed in the preperitoneal space against the abdominal wall. The mesh is subsequently fixated at cardinal points as well as Cooper's ligaments. Fixation in proximity to the bladder and triangles of doom and pain must be avoided. The mesh is covered with the re-approximation of the peritoneal flap, secured with tacks or suture. Absorbable suture is used to close the fascial defect of all port sites larger than 8 mm.

Conclusion

The management of ventral, incisional, and atypical hernias with rTAPP is an emerging surgical method; therefore studies are currently ongoing. These evolving techniques stem from well-developed open and laparoscopic principles and exhibit clear proposed benefits. With the preperitoneal approach, the mesh is protected from intra-abdominal contents, and full-thickness transfascial sutures can be avoided. This repair requires access of a preperitoneal plane, without which this technique is limited and other techniques may be applied. This is a safe and adaptable method for repair of abdominal wall hernias. In comparison to laparoscopic techniques, the robot allows enhanced ergonomics, precision, and visualization, as well as comparable patient satisfaction and improved quality of life and physician satisfaction.

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Technique: Posterior Rectus Sheath Release

16

Samuel P. Carmichael II and J. Scott Roth

Introduction

Approximately 4–5 million laparotomies are performed each year in the United States, 2–20% of which are complicated by incisional hernia (IH) [1]. IH is the most common complication of laparotomy requiring reoperation at a ratio beyond bowel obstruction of 3:1 [2]. The vast majority of hernias develop 6 months to 3 years after laparotomy and are associated with wound infection, obesity, tobacco abuse, immune suppression, and suture closure technique [3, 4]. As such, roughly 200,000 incisional hernia repairs are performed annually with a recurrence rate of 45–50% inclusive of all techniques and 20–30% with mesh repair in all-comers [1, 5, 6]. Factors impacting the success of operative repair include management and optimization of medical comorbidities (i.e., obesity, diabetes, smoking, pulmonary function, MRSA colonization) [2]. Tension-free mesh repair is currently the accepted standard of care given prohibitively high recurrence with suture repair alone [1, 6]. However, despite the groundbreaking work of many herniorrhapists over decades of research, the gold standard of mesh herniorrhaphy remains subject to debate [2].

Mesh herniorrhaphy of IH was first introduced 60 years ago at Baylor University by general surgeon Dr. Francis Usher and colleagues with Marlex knitted polyethylene mesh placed deep to the rectus musculature [7]. Parallel to this, anatomist and surgeon Jean Rives under the guidance of Bourgeon further delineated the implementation of this sublay technique with the use of Mersilene polyester fiber at the French University of Algiers [8]. Rives described ventral incisional hernia as a

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disease spectrum ("eventration disease") encompassing multiple factors as follows: (1) predisposing systemic disorders, (2) injury and atrophic change to subcutaneous and abdominal wall layers, and (3) disordered ventilation due to loss of complementary abdominal wall and diaphragmatic function [9, 10]. He contended that the achievement of good operative result required a multidisciplinary approach to medical management with systemic risk reduction prior to the time of surgery [9, 10]. Simple closure of abdominal wall defects >5 cm was notably ineffective, and best results were associated with the use of nonabsorbable macroporous mesh [11]. Thus, the main objectives of mesh herniorrhaphy according to Rives, and synchronously Rene Stoppa, are severalfold: (1) defect closure without tension, (2) anatomic re-approximation of abdominal wall musculature through insertion of a mesh prosthesis, (3) avoidance of intra-abdominal hypertension upon closure, (4) wide overlap of mesh within retrorectus (Rives) or preperitoneal (Stoppa) spaces, and (5) avoidance of intra-abdominal placement of nonabsorbable mesh, given potential for visceral complication or mesh migration [11, 12].

Utilization of the retrorectus dissection facilitates two notable advantages in IH repair: (1) approximately 2 cm of medial mobilization of the anterior rectus sheath to facilitate closure and (2) provision of an easily dissectible and well-vascularized potential space for mesh placement, a discriminating feature from the anterior rectus space [4, 13]. In addition, the retrorectus space provides for a two-layered closure of the abdominal wall [4]. Interestingly, contemporary animal model preparations of IH demonstrate reversal of the associated rectus muscle atrophy and fibrosis described by Rives following mesh herniorrhaphy [14]. Moreover, types I and III collagen proliferation is more robust within the retrorectus space in comparison with onlay mesh placement [15]. Lastly, insertion of intraperitoneal mesh has been recently redemonstrated to significantly increase the rate of subsequent laparotomy versus preperitoneal mesh (76% vs 29%). Of the re-operative group, 21% of the patients with intraperitoneal mesh required small bowel resections versus none in the preperitoneal group [16]. Lastly, two patients with intraperitoneal mesh were also noted to develop enterocutaneous fistula at the time of re-laparotomy [16].

Following the pioneering work of Drs. Rives and Stoppa in France, Dr. George Wantz, a surgeon from Cornell University, studied the retrorectus technique under Stoppa and Flament, a protégé of Rives. His academic sabbatical in 1985–1986 resulted in the popularization of the retromuscular IH repair in the United States. In 1991, Dr. Wantz published his experience in a series of 30 patients with defects >10 cm. He placed overlapping polyester fiber (Mersilene) mesh within the retrorectus space, securing it with interrupted transfascial sutures. He contended that the repair prevented recurrence via two mechanisms: (1) adherence of the implant to the peritoneum making it "indistensible" and (2) mesh consolidation of the abdominal wall [17].

The major advantage to the retrorectus repair is the creation of a reinforced abdominal wall with reestablishment of the native anatomic midline. As postulated by Rives and Stoppa, sizing of the prosthesis for adequate overlap of the defect facilitates restoration of the abdominal wall as a dynamic functional unit [5]. As such, Wantz concluded that the retrorectus repair paradoxically exploits the abdominal forces subserving hernia creation to prevent its recurrence.

Technique

Preoperative planning for surgery includes optimization of medical comorbidities and prevention of infection [18]. Patients are counseled for cessation of tobacco and alcohol usage for a minimum of 4 weeks. Nutritional counseling includes blood glucose control, weight loss with a goal of BMI < 35, and Impact AR TID for 5 days prior to surgery. MRSA prophylaxis includes Hibiclens shower for 5 days and Mupirocin 2% intranasal ointment BID for 5 days in patients with a history of MRSA colonization. Postoperatively, pain control is approached via multimodality, intravenous fluids are minimized, and early ambulation is a requirement.

Following intubation, the abdomen is surgically prepared with chlorhexidine and draped in standard fashion. After sharp incision, dissection is carried out in the midline with Bovie electrocautery, taking care not to violate the hernia sac. Occasionally, the underlying hernia sac is densely adherent to the deep dermal tissues requiring sharp dissection for mobilization. A portion of the skin and dermis may need to be resected in this setting to prevent eventual necrosis following wound closure. Once the fascial defect and neck of the hernia sac have been defined at the level of the fascia, rectus musculature is identified via palpation, and the fascia is elevated with Kocher clamps (Fig. 16.1). Anterior rectus sheath is incised medial to the rectus muscle, and the retrorectus space is opened (Fig. 16.2) and inferior epigastric vessels exposed (Fig. 16.3). Incision is extended cephalad to the costal margin and xiphoid with inferior dissection below the arcuate line and into the space of Retzius, as appropriate for insertion of prosthetic. Lateral dissection is carried out bluntly with Kittner to the semilunar line, as identified by perforating neurovascular

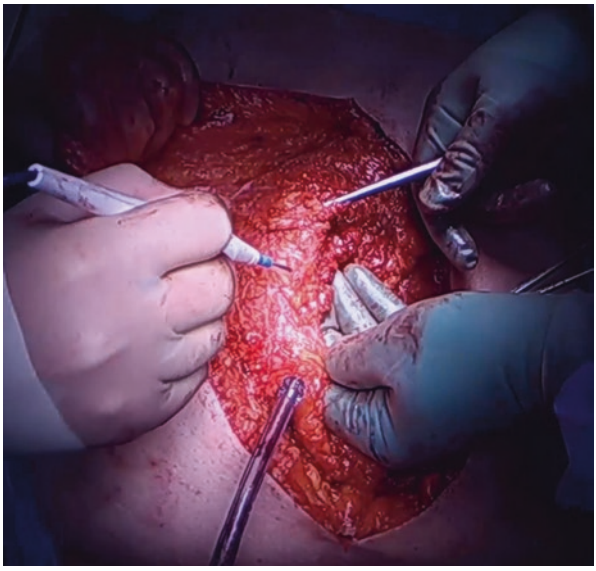

Fig. 16.1 Fascial incision for access to retrorectus space

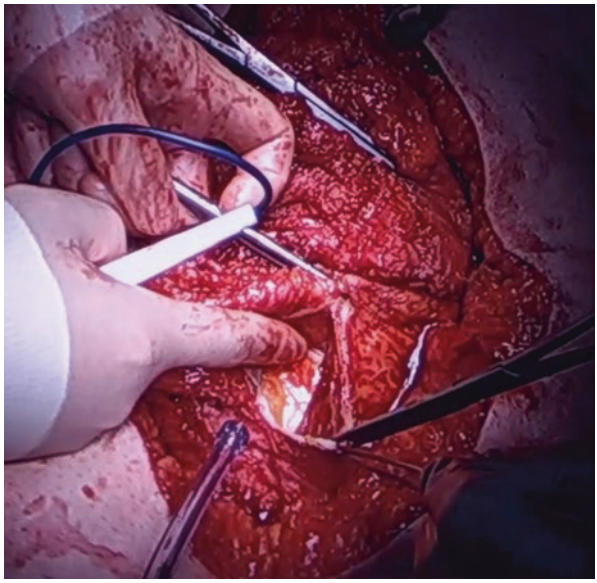

Fig. 16.2 Incision of the retrorectus space

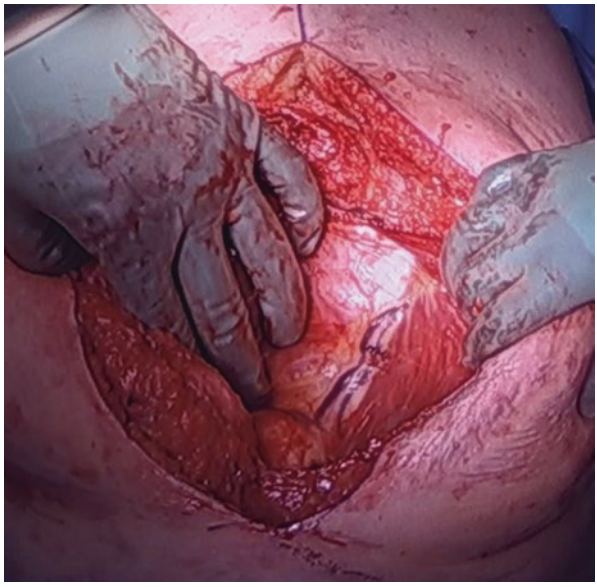

Fig. 16.3 Exposure of the inferior epigastric vessels

structures (Fig. 16.4). This procedure is repeated on the contralateral side. At the conclusion of this portion of the dissection, the posterior rectus sheath is re-approximated in the midline between Kocher clamps for an estimation of physiologic tension with closure.

If the posterior sheath is unable to be re-approximated without significant tension upon the tissues, hernia sac or omentum may be interposed to facilitate separation from viscera. Alternatively, an absorbable mesh may be selected to safely

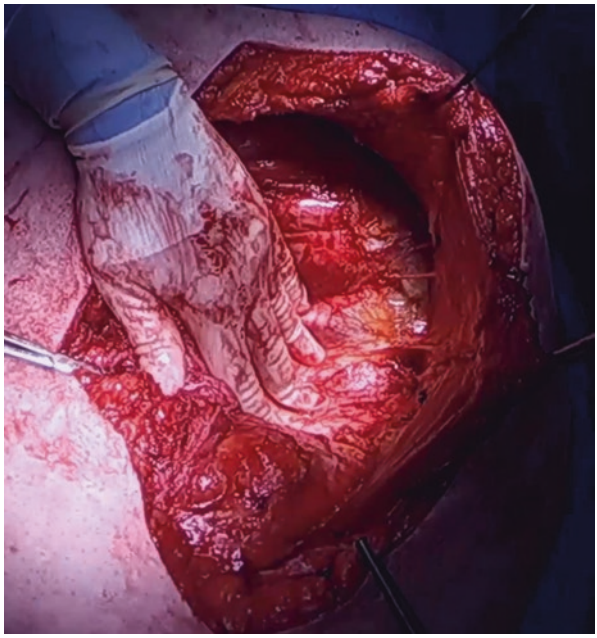

Fig. 16.4 View of the retrorectus space upon completion of lateral dissection to semilunar line

bridge the posterior rectus sheath for visceral protection from the permanent mesh [4]. The primary function of this material is to reconstruct the posterior sheaths until the parietal peritoneum forms and prevents bowel contact with the mesh. When reconstructing the posterior sheath, it is essential to choose a prosthetic that may be safely placed adjacent to viscera. It is our practice to avoid permanent synthetic mesh when reconstructing the posterior sheath as to avoid the potential for chronic seroma between the definitive hernia repair mesh and the mesh utilized for posterior sheath reconstruction.

Classically, the Rives-Stoppa technique describes dissection via midline laparotomy and separation of the posterior rectus sheath from rectus musculature following transgression of the peritoneum. Alternatively, the totally extraperitoneal (TE) approach, currently performed in our practice, allows for the same dissection without violation of the peritoneum. Though the transabdominal dissection remains necessary in several settings (i.e., removal of intra-abdominal mesh or concomitant intra-abdominal procedure), the TE approach confers the advantage of decreased operative time with associated benefits, as discussed below (Fig. 16.5).

The TE approach commences with dissection of the hernia sac from the surrounding subcutaneous tissues. Dissection is continued until the neck of the hernia sac is fully identified. Although dissection of the hernia sac from the subcutaneous tissues will result in some undermining of the skin flaps, we feel that residual hernia sac in the subcutaneous tissues is likely to result in prolonged seroma and should be avoided. All peritoneal defects created during the dissection are closed with absorbable suture prior to completion of fascial closure. This step is imperative for prevention of intraparietal hernia development. Although uncommon, intraparietal

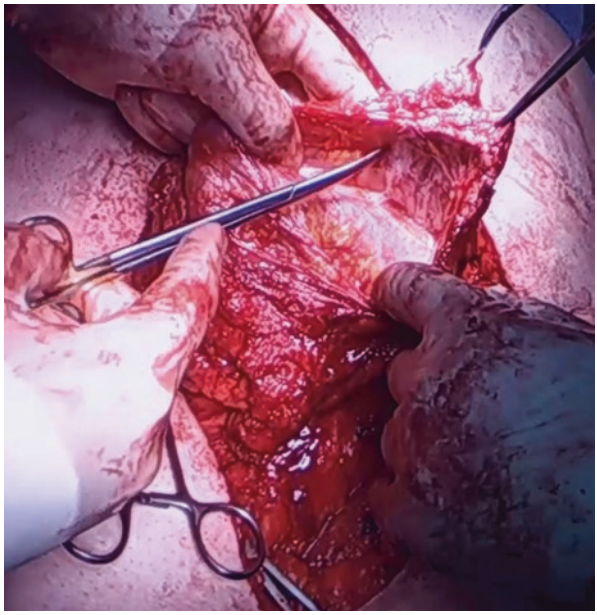

Fig. 16.5 Sharp dissection of the hernia sac for extraperitoneal ventral hernia repair

herniation of viscera through a peritoneal defect may result in pain, obstruction, incarceration, or strangulation, and therefore it is essential to identify and close any defects within this peritoneal layer. Intraparietal hernias are generally only detectable by radiographic evaluation due to the intact mesh and abdominal wall musculature above the peritoneum and accordingly should be considered in the event of a postoperative bowel obstruction.

Following dissection of the hernia sac and retrorectus space, the posterior sheath is approximated thus imbricating the hernia sac. This is typically performed with a running 2-0 Vicryl suture (Fig. 16.6). As the peritoneum has not been entered and adhesiolysis has not been performed, it is essential to judiciously place sutures in the posterior rectus sheath so as to avoid injuring the underlying viscera. In many cases, it is relatively easy to ascertain the degree of adhesions to the peritoneal layer based upon palpation. Nevertheless, wide shallow stitches are placed in the posterior sheath to avoid injury to the intestines.

Following closure of the posterior sheath, the retrorectus plane is measured, and mesh is selected to allow for placement of a prosthetic mesh with a minimum of 5 cm mesh overlap in all dimensions. However, it is our current practice to place the largest mesh that our dissection will accommodate for maximum coverage in all dimensions. It is important to ensure that the mesh extends not only 5 cm laterally beyond any hernia defect but also 5 cm superior and inferior to the hernia defect. Although a single prosthetic mesh is preferred, occasionally the hernia defect will require the use of two mesh sheets that can be sutured together with a permanent suture.

Interrupted "U" sutures for transfascial fixation consisting of number 1 PDS are attached to the mesh at superior and inferiormost positions in the midline. An

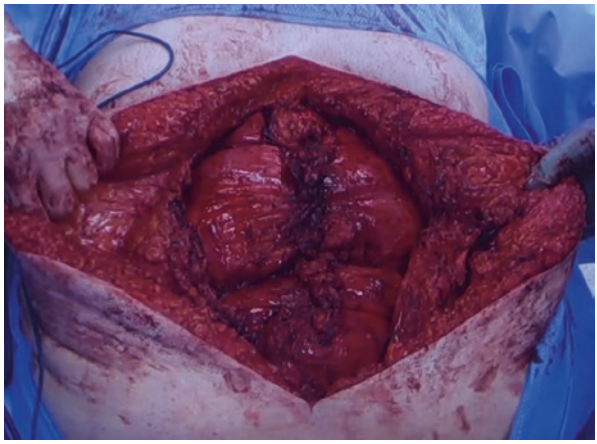

Fig. 16.6 Closure of the posterior rectus sheath with hernia sac imbrication

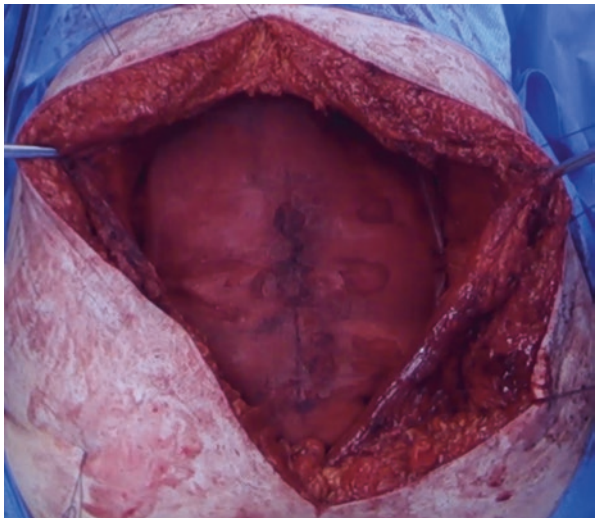

Fig. 16.7 Completion view of mesh placement in the retrorectus space. Note transfascial sutures placed circumferentially around periphery of mesh

additional six sutures are evenly spaced along the lateral portion of the mesh, approximately 1–2 cm from the mesh edge. Small skin incisions are created on the abdominal wall skin with the 11 blade scalpel at points corresponding to the periphery of the mesh. Subsequently, the Reverdin needle is used to pass suture through the abdominal wall to fixate the mesh. It is essential that individual sutures should pass through the abdominal wall via separate tracts, exiting across a common stab incision to provide adequate fixation of the mesh (Fig. 16.7). Suture knots are tied loosely in the subcutaneous tissue so as to prevent superficial nerve entrapment which may result in chronic pain.

A single channel drain is placed in the retrorectus space overlying the mesh and exteriorized through the anterior sheath and subcutaneous tissue in the left upper quadrant. The use of a drain is controversial and some surgeons will omit this step. It is our

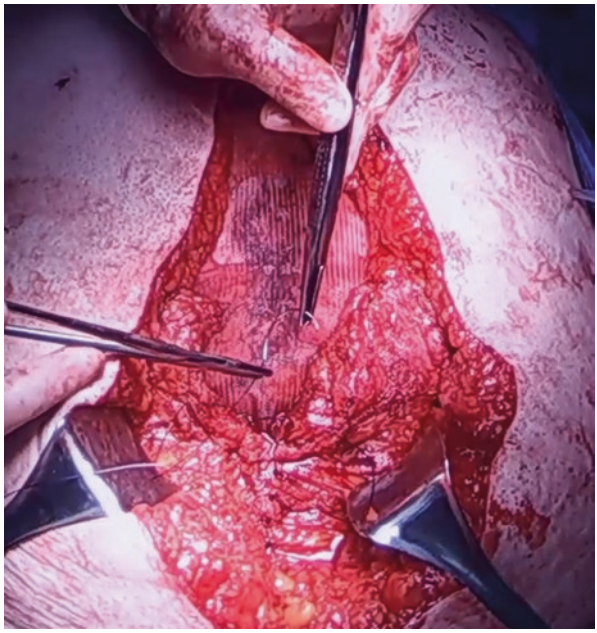

Fig. 16.8 Closure of the anterior rectus sheath

practice to leave a single drain in this space with drain removal prior to hospital discharge. The linea alba or anterior rectus sheath is then re-approximated in the midline with interrupted single-armed number 1 PDS suture in figure-of-eight fashion (Fig. 16.8).

It is not uncommon that, upon completion of hernia repair, redundant skin and subcutaneous tissue are present at the midline. As such, abdominoplasty is performed following marking skin with tension in apposition (Fig. 16.9). Excess tissue is resected and passed off the field. Depending upon the extent of the redundancy, skin excision may be accomplished via a vertically oriented ellipse or a transverse incision. When significant skin redundancy is anticipated, it is our practice to orient the initial skin incision transversely so as to facilitate subsequent skin resection. In the event that the hernia sac has created significant undermining of the skin flaps resulting in potential space, a channel drain is placed in the subcutaneous space and externalized in right upper quadrant. Approximation of the overlying dermis to the fascia utilizing progressive tension sutures will help reduce drain output and seroma formation. Scarpa's fascia and dermal tissues are approximated using interrupted absorbable sutures, and the skin is closed with a running absorbable monofilament suture and a skin adhesive (Fig. 16.10). Drains are generally removed once output from each is less than 30–40 mL per day for 2 consecutive days.

Patient Selection

The Rives-Stoppa repair is suitable for the majority of incisional hernias, both primary and recurrent, and is ideally suited for moderately sized midline defects. However, many factors including patient goals, comorbidities, and surgical history

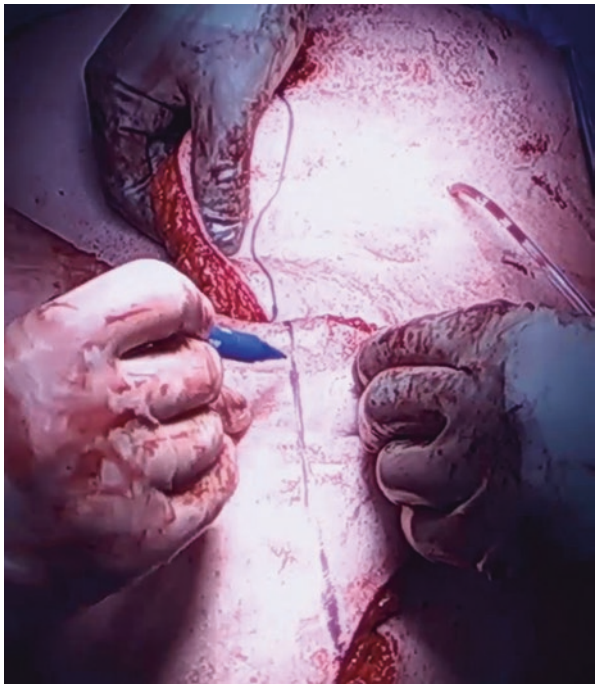

Fig. 16.9 Abdominoplasty with excision of excess skin and subcutaneous tissue

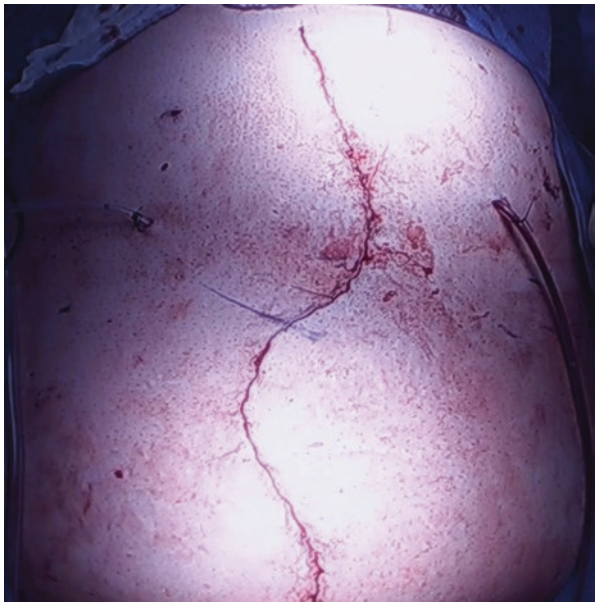

Fig. 16.10 Completion of repair

will influence our decision to perform this technique. Although many patients will undergo imaging prior to ventral hernia repair, we typically reserve CT scan for those patients with complex or recurrent hernias. In our experience, the Rives-Stoppa approach will generally be suitable for hernias with a transverse dimension up to approximately 8 cm. The cranio-caudal dimensions of the hernia do not influence our decision to utilize this technique. However, intraoperative assessment of midline tension and ability to close the linea alba is performed after completion of the dissection bilaterally. In the event that the midline is either not amenable to closure or creates unacceptable tension, additional releases can be performed (i.e., transversus abdominis release, external oblique release). Patients with combined midline and off-midline hernias (e.g., parastomal hernias) are not well suited for the Rives-Stoppa approach and are generally considered for posterior component separation via transversus abdominis releases. Patients with small hernia defects or those with multiple honeycomb defects may also be considered for a Rives-Stoppa approach but are better suited for a laparoscopic repair, in our opinion. However, patients with small defects requiring scar excision or excision of redundant soft tissues (i.e., panniculectomy) are also good candidates for the Rives-Stoppa repair.

The extended-view totally extraperitoneal ventral hernia repair (*eTEP,* Chapter 20) has evolved as a minimally invasive approach to performing a Rives-Stoppa repair or a traditional laparoscopic repair with intraperitoneal mesh. This eTEP technique is best suited for small to moderate hernias with a more limited surgical history. The eTEP technique combines the advantages of the dissection of the Rives-Stoppa repair with the patient benefits of a laparoscopic hernia repair. However, at the present time, this technique is performed in limited centers and thus conclusions regarding its efficacy remain speculative.

Outcomes

In a recent review of the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) database, the incidence of major operative morbidity after abdominal wall reconstruction is 13.4% ($n = 1706$) with return to the operating room in 7.7% and readmission after discharge in 5–11% [19, 20]. Patient factors associated with postoperative morbidity included advanced age, functional status, malnutrition, anemia, obesity, smoking, diabetes, organ failure, and hypertension. Skin and soft-tissue infections (SSI) are the commonest postoperative complications overall at 8.9% (range in the literature 0–18%) and are the most common reasons for readmission [19–21]. Operative factors correlating to postoperative morbidity and cost included concurrent procedure, preoperative open wound, CDC wound class (>1), American Society of Anesthesiologists (ASA) fitness classification (>3), and operative time [19, 20].

Outcomes data from Rives and colleagues' original operations with retrorectus mesh prosthesis demonstrated an overall recurrence of 2.6% in a review of 388 patients by Flament and 8.6% by the Congrès Français de Chirurgie between 3 and 10 years postoperatively [11]. Wantz published a comprehensive summary of his

experience in 1999, following practice implementation of the retrorectus technique in 1991. Of his 206 repairs for incisional hernia, 106 were performed for midline defects (61% primary IH, 39% recurrent IH). Mersilene mesh was used in 89% and polypropylene mesh in 11%. Of these, he reported hernia recurrence in two midline hernias and one lumbar hernia [22].

Recurrence rates after Rives-Stoppa sublay repair in contemporary review of the literature range from 0 to approximately 4% [21]. These outcomes are consistent when the procedure is performed in the re-operative abdomen and in special surgical populations (i.e., inflammatory bowel disease) [23, 24]. A recent meta-analysis comparing sublay versus onlay techniques revealed fewer infections and IH recurrence in the sublay group [25]. Furthermore, wound complications and seroma formation were higher in a single-center prospective experience of onlay versus sublay repair (49% vs 24% and 45% vs 24%, respectively) [26]. Of the four available locations for mesh herniorrhaphy (i.e., onlay, inlay, sublay, and underlay), the Rives-Stoppa repair confers superior protection from SSI and intra-abdominal complication while demonstrating lowest overall recurrence [24].

In review of our own 5-year experience (2009–2013), approximately equal numbers of transabdominal (TA, $n = 45$) versus TE ($n = 40$) Rives-Stoppa repairs were performed. Groups were matched by age and comorbidity. Findings revealed no difference in enterotomy frequency between the two groups and that the TE approach confers reduced operative duration. Notably, more patients in the TA group had undergone prior hernia repair (73% vs 45%). Overall mesh size was larger in the TE group (625 ± 234 cm^2 vs 424 ± 214 cm^2), as accounted for by change in practice from 5-cm overlap to placement of largest mesh possible within the dissected plane [27].

Overall, unplanned enterotomy or bowel resection (EBR) complicates 7.3% of mesh herniorrhaphy and is associated with an increased rate of 30-day complications, including SSI, return to the operating room, hernia recurrence, and enterocutaneous fistula formation [28–30]. The incidence of EBR is increased in re-operative abdominal wall reconstruction and chronic steroid use [29]. There was a reduction in EBR within our series of TE herniorrhaphy; however this difference was not statistically significant. Though theoretical concern exists for a change in geometry of intra-abdominal adhesions in the absence of transgression of the peritoneum, adhesiolysis is known to increase both operative time and the risk of intestinal injury [29]. Moreover, equal mobility of the visceral sac may still be achieved with preperitoneal dissection. Neither TA or TE groups were complicated by postoperative bowel obstruction in our cohort.

We found seroma formation to be twice as common in the TE group, likely owing to intact peritoneum precluding intra-abdominal drainage. However, this difference was not significant in comparison with the TA repair and did not correlate with return to the operating room. Arguably, the greatest advantage of the TE approach is decreased operative times due to avoidance of adhesiolysis. Given that prolonged surgical duration causes increased physiologic stress and is associated with an increased risk of postoperative SSI, reduction in OR time provides potential benefit of decreased major complication [19, 31].

Lastly, previously placed mesh is often encountered in the re-operative abdomen. Its removal should be based upon surgical judgment in the absence of data supporting universal excision. Placement of new prosthesis in a well-vascularized plane is our guiding principle, which often necessitates excision of prior graft though transabdominal approach [27].

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Ventral Abdominal Hernia Repair: Technique—External Oblique Release

17

Mark W. Clemens and Charles E. Butler

Introduction

Traditionally, laparotomy closures, large tumor ablations, congenital anomalies, and trauma led to unacceptable rates of ventral hernia and abdominal wall morbidity. Primary fascial coaptation and mesh reinforcement of hernia defects have been demonstrated to significantly reduce both short- and long-term hernia recurrence rates in prospective series. However, wide abdominal defects can present a challenge where fascial approximation is not possible under physiologic tension. In 1990, Ramirez and colleagues introduced the technique of components separation and brought about one of the greater paradigm shifts forward in abdominal wall reconstruction [1]. Components separation exploits the anatomic planes of the abdomen to create musculofascial advancement flaps which assists in fascial closure. Long-term outcomes support components separation for maintaining the strength and integrity of the abdominal wall while preserving innervated muscle function without tension [2–4]. This chapter focuses on planning, techniques, and outcomes of components separation.

Indications/Contraindications

Indications for abdominal wall reconstruction are multifactorial and include hernia tumor ablation, congenital anomalies, and trauma. Proposed risk factors for the development of hernias included tobacco use and a strong family history of hernia, which suggests a genetic predisposition [5]. Studies have suggested that

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mechanical strain on load-bearing tissues can induce secondary changes in tissue fibroblast function that in turn can result in failure of abdominal wall repairs. The general indications for performing a components separation of the abdominal wall include a deficiency of the abdominal wall fascia, which would require a bridged repair without fascial release [6]. Components separation is a fascial release of the external oblique fascial with creation of musculofascial advancement flaps [7]. This creates an autologous flap option for fascial coaptation which is beneficial particularly in the presence of mesh reinforcement. Relative contraindications include lateral abdominal wall hernias patients with ostomies directly in line with a planned components separation. In these situations, a unilateral components separation performed on the contralateral hemi-abdomen may be sufficient to achieve fascial coaptation. It is not possible to perform components separation in patients that have lost the anatomy required for such a fascial release such as complete loss of abdominal tissue which can be seen in pancreatic fistulas or necrotizing soft tissue infections and the anterior abdominal fascia. Radiated tissue is not an absolute contraindication but does have higher rates of wound dehiscence, infection, necrosis, and delayed wound healing [8]. Patients with multiple previous abdominal wall surgeries or unclear reconstructive surgical history and anatomy should be approached cautiously [9]. Violation of the rectus complex such as with an ostomy through the rectus abdominis muscle, elevation of a transverse rectus abdominis muscle (TRAM) flap or vertical rectus abdominis muscle flap (VRAM) flap does not preclude the use of components separation [10].

Preoperative Planning

Physical examination should be performed to assess the patient's general condition, the abdominal wall integrity, the extent and location of any abdominal wall abnormalities, and the presence of scars that could become an obstacle to raising reliable tissue flaps. Routine laboratory tests and a nutritional workup are advised. Correct diagnosis of abdominal wall defects is critical to proper management. Preoperative computed tomography (CT) to examine the defect characteristics, abdominal wall anatomy, and vascularity is helpful for surgical planning [11]. CT scans allow for visualization of intra-abdominal organs, and the abdominal wall, three-dimensional data sets, and multiplanar reformation capabilities. CT scans may assist in detecting fluid collections, bowel obstruction, incarceration, strangulation, and traumatic wall hernias. Magnetic resonance (MR) imaging also permits the detection of soft tissue defects and abdominal wall hernias though this modality does not usually offer further sensitivity and therefore may be cost prohibitive. Thromboprophylaxis should be administered based upon a patient's particular risk for a thrombotic as evaluated by the Caprini risk assessment tool. Prospective randomized controlled data is unavailable regarding routine antibiotic prophylaxis. Most centers including ours regularly prescribe prophylactic antibiotics intraoperatively for all patients. Bowel preps may be beneficial in patients with anticipated violation of the gastrointestinal tract.

Surgery

Preoperative/Markings

Patients should be marked in the preoperative holding area, and it is beneficial to evaluate patients in a recombinant and supine position for complete evaluation of abdominal wall defects. The anatomy of the abdominal wall is covered in depth in previous chapters; however the pertinent landmarks are recounted here. Markings may delineate anatomical boundaries such as the pelvis, midline, and costal margin as well as the fascial extent of any intra-abdominal defects. Once the patient is transported to the operative room, they are placed supine on the operative table, sedated, and intubated. Intraoperative intravenous antibiotics are initiated. The abdomen is widely draped and prepped to expose the patient's flanks and from the pelvis to the mid-sternal area. Patients should receive sequential compression devices and or compression hoses for deep vein thrombosis prophylaxis. Patients requiring greater exposure should have room temperatures maintained above 75 °F to minimize postoperative infections.

Surgical Technique

Critically important to a hernia repair is the reestablishment of the abdominal domain integrity with complete fascial coaptation. All attempts should be made to avoid a bridged mesh repair because there is a clear association with higher recurrence rates compared with when the fascia can be reapproximated over a mesh repair. Understanding all of the approaches for abdominal wall reconstruction and particularly myofascial advancement flaps is critically important to determine the least invasive procedure to provide a long-lasting repair with an excellent functional outcome for the patient. Ramirez and colleagues' description of the surgical technique of components separation facilitates medicalization of the rectus musculofascia and thus midline abdominal closure by releasing the external oblique aponeuroses and posterior rectus sheath bilaterally [1] (Fig. 17.1). Although components separation will often allow for midline fascial reapproximation, which is the optimal situation, occasionally this will not be possible, particularly for larger hernias; and the myofascial edges will need to be bridged with mesh. Data have shown that defect size reduction, especially if less than 150 cm^2, will lead to the lowest recurrence rates. There are several other theoretic advantages to reapproximating the linea alba. If one considers the linea alba as the tendinous insertion of the rectus and oblique muscles and borrows from the concepts of tendon repair, then it seems logical that the physiological tension of the abdominal wall should be restored during ventral incisional hernia repair. Although every attempt to reestablish the midline is advisable, accomplishing that goal is not always feasible, and not all patients can tolerate the intraperitoneal compression required (which can result in intraperitoneal hypertension, pulmonary compromise, or abdominal compartment syndrome). Once the mesh is inserted peripherally, the midline fascia will be reapproximated, and the mesh and its inset will bear the majority of the tension.

Open Components Separation

Myofascial advancement techniques, or components separation, take advantage of the laminar nature of the abdominal wall and the ability to release one muscular or fascial layer to enable medial advancement of another [12, 13]. If the lateral abdominal compartment must be released, release can be done by open or minimally invasive components separation. A minimally invasive components separation can be performed in various ways, but all of the techniques (to a certain degree) maintain the blood supply to the skin from the underlying rectus abdominis muscles [14]. In contrast, an open components separation is performed by raising large subcutaneous flaps to expose the external oblique fascia (Fig. 17.1). The cutaneous perforators emerging from the anterior rectus sheath are ligated and divided to facilitate exposure of the linea semilunaris

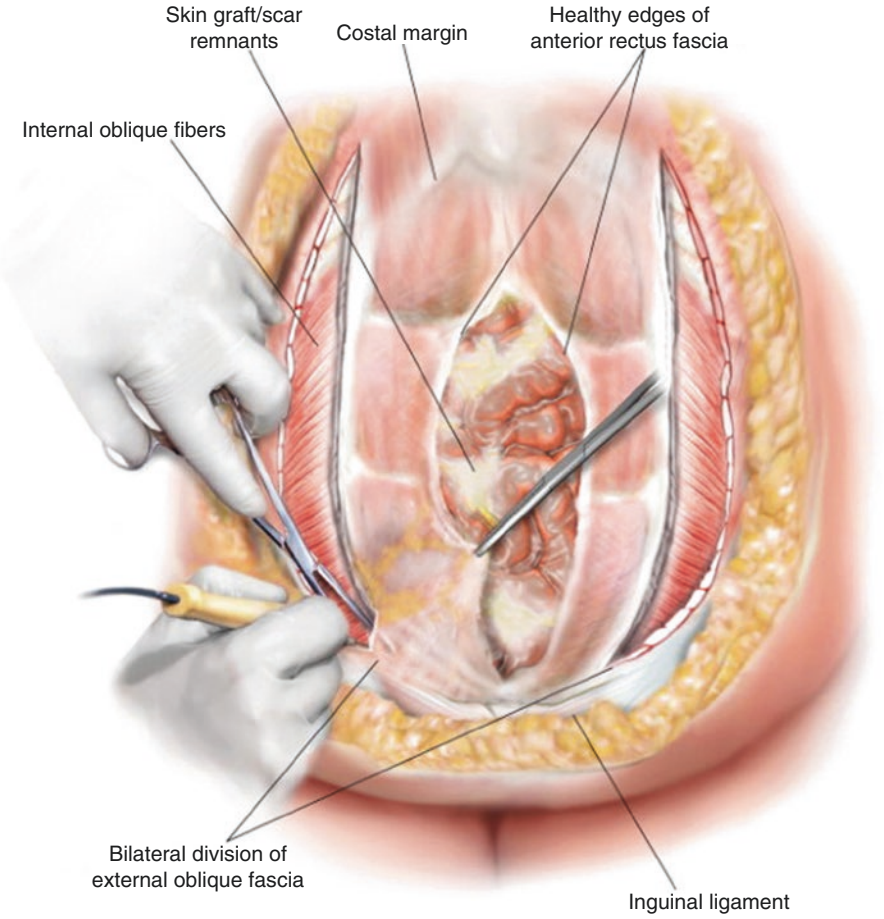

Fig. 17.1 Open component separation. Subcutaneous flaps are elevated off the anterior rectus sheath to expose the external oblique aponeurosis. The external oblique aponeurosis is released from the inguinal ligament inferiorly to above the costal margin superiorly. This allows exposure of the internal oblique muscle fibers once the external aponeurosis is incised (Adapted with permission from Rosen MJ. Atlas of Abdominal Wall Reconstruction, Elsevier 2011)

in its entirety [15]. These flaps are carried laterally past the linea semilunaris. This subcutaneous dissection itself can provide some medial advancement of the abdominal wall skin. An anatomically precise external oblique aponeurotomy is made 1–2 cm lateral to the linea semilunaris on the lateral aspect of the external oblique aponeurosis from several centimeters above the costal margin to the pubis. It is important to confirm that the incision is not carried through the linea semilunaris, as this would result in a full-thickness defect of the lateral abdominal wall, which is very challenging to repair. The external oblique aponeurosis is then bluntly separated in the avascular plane away from the internal oblique aponeurosis to the midaxillary line, allowing the internal oblique and transversus abdominis muscles with the rectus abdominis muscle or fascia to advance medially as a unit. These techniques, when performed bilaterally, can yield up to 20 cm of mobilization in the mid-abdomen.

Once the mesh inset and fascial closure are performed, the subcutaneous skin flaps are advanced and closed at the midline. To reduce subcutaneous dead space, interrupted quilting sutures should be placed between the Scarpa fascia and musculofascial repair. This technique also decreases shear stress, which is thought to contribute to postoperative seroma formation, and decrease the total drain output, allowing the surgeon to place fewer drains and leave them in for a shorter period. After paramedian skin perfusion is critically assessed, a vertical panniculectomy may be performed so that the skin is reapproximated in the midline without redundancy.

A major limitation of open components separation is the wound morbidity associated with the large skin flaps necessary to access the lateral abdominal wall. To avoid this morbidity, several reports have described innovative minimally invasive approaches to components separation. These approaches are designed to gain direct access to the lateral abdominal wall without creating large skin flaps, creating dead space, or interrupting the primary blood supply to the central abdominal skin by ligation of the rectus abdominis perforator vessels.

Laparoscopic Components Separation

Laparoscopically, components separation is performed through a 1 cm incision below the tip of the 11th rib overlying the external oblique muscle (Fig. 17.2) [16, 17]. The external oblique muscle is split in the direction of its fibers, and a standard bilateral inguinal hernia balloon dissector is placed between the external and internal oblique muscles and directed toward the pubis. Three laparoscopic trocars are placed in the space created, and the dissection is carried from the pubis to several centimeters above the costal margin. The linea semilunaris is carefully identified, and the external oblique aponeurosis is incised from beneath the external oblique muscle at least 2 cm lateral to the linea semilunaris [18]. The muscle is released from the pubis to several centimeters above the costal margin. This procedure is performed bilaterally.

Periumbilical Perforator-Sparing Technique

A periumbilical perforator-sparing technique of components separation may be performed to preserve the blood supply to the anterior abdominal wall skin near the

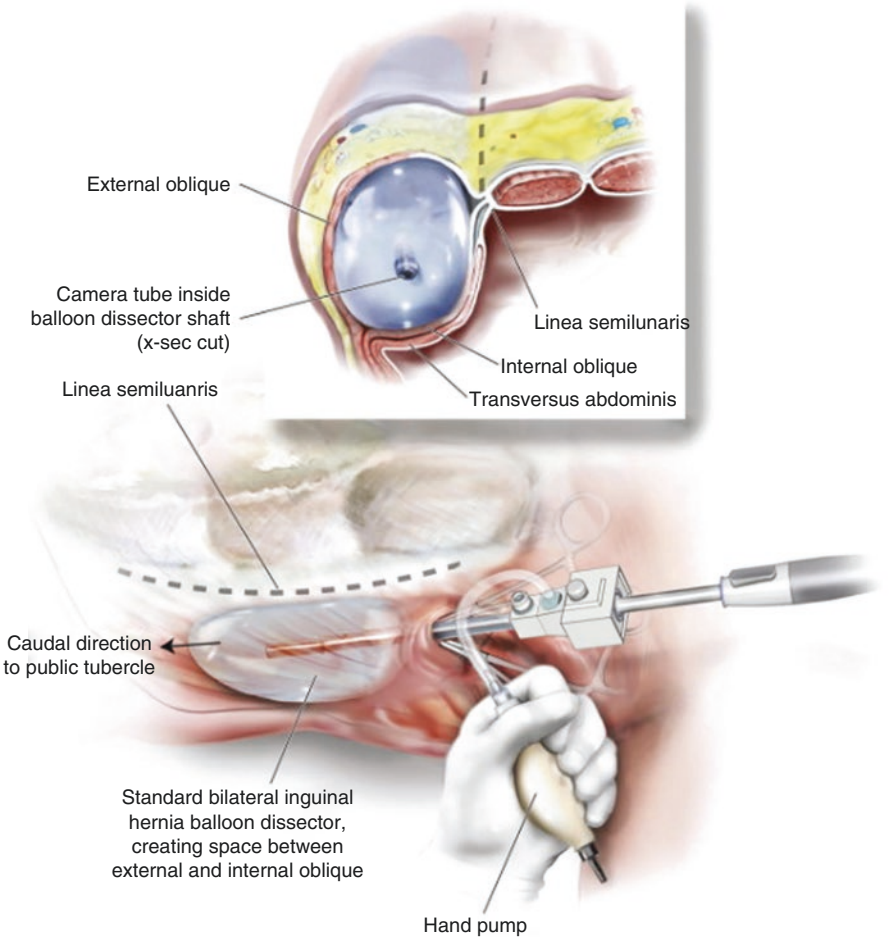

Fig. 17.2 Endoscopic component separation. Access to the external oblique aponeurosis is achieved through a small incision at the costal margin through which a balloon dissector is placed. The external oblique aponeurosis is then divided from the pubis to above the costal margin. This minimally invasive approach preserves the attachments of the subcutaneous tissue (including myocutaneous perforators) to the anterior rectus sheath throughout its course. Credit: (Adapted with permission from Rosen MJ. Atlas of Abdominal Wall Reconstruction, Elsevier 2011)

midline and is based primarily on perforator vessels from the deep inferior epigastric vessels. Cadaver dissections and radiographic studies have confirmed that the majority of these vessels are located within 3 cm of the umbilicus. With preservation of these vessels, ischemic complications involving the subcutaneous flaps are significantly reduced. To avoid injury to the periumbilical perforator vessels, a line is marked no less than 3 cm cephalad and 3 cm caudal to the umbilicus. The periumbilical perforator tunnels are begun at the epigastric and suprapubic regions. Subcutaneous tunnels are created using lighted retractors to identify the external oblique fascia. The superior and inferior tunnels are connected using cautery and retractors while maintaining the subcutaneous attachments of the periumbilical region. The linea

semilunaris is identified by palpation, and the external oblique is incised 2 cm lateral to this junction. The aponeurotomy is extended several centimeters above the costal margin and to the pubis. The external oblique muscle is separated from the internal oblique muscle in an avascular plane toward the posterior axillary line. The periumbilical perforator-sparing approach has several limitations. One of the benefits of minimally invasive components separation is to reduce subcutaneous dead space. The periumbilical perforator-sparing technique creates considerable dead space and sacrifices more perforator vessels to the skin than other minimally invasive techniques [19]. When skin mobilization is necessary, adequate advancement occasionally can be difficult to achieve because the midline skin is still invested in the periumbilical region. Additionally, the placement of a wide piece of mesh as an underlay can be difficult given the large subcutaneous paddle that is still attached.

Minimally Invasive Components Separation (MICS)

Butler and colleagues modified the standard open Ramirez-style procedure that further reduces the subcutaneous dead space and maximize the blood supply to the abdominal skin with rectus perforator preservation [20, 21]. The minimally invasive components separation (MICS) technique is designed to avoid division of the musculocutaneous perforators overlying the rectus sheath and thus maintain perfusion to the paramedian skin. After lysis of adhesions and identification of the fascial edges, bilateral, 3 cm wide, subcutaneous access tunnels are created over the anterior rectus sheath from the midline to the linea semilunaris at the level of the costal margin (Fig. 17.3). Through these access tunnels, the external oblique aponeurosis is vertically incised 1.5 cm lateral to the linea semilunaris. The tip of a metal Yankauer suction handle (Cardinal Health, Dublin, OH), without suction, is inserted through the opening in the avascular plane between the internal and external oblique aponeuroses, separating them at their junction with the rectus sheath. The suction tip is advanced inferiorly to the pubis and superiorly to above the costal margin. Dissection is performed between internal and external oblique muscles with a sweeping motion of the Yankauer suction handle. A narrow Deaver retractor is used to create a narrow (2.5 cm) subcutaneous tunnel overlying the planned line of external oblique aponeuroses release inferiorly and superiorly. The external oblique aponeuroses are then released superiorly with electrocautery and inferiorly with scissors (Fig. 17.4). Next, lateral dissection between the internal and external oblique muscles is performed to the midaxillary line. Minimal subcutaneous skin flaps are then elevated over the anterior rectus sheath circumferentially to the medial row of rectus abdominis perforator vessels, and a retrorectus or preperitoneal mesh inlay is generally used. If a preperitoneal inset is used, the preperitoneal fat is dissected from the posterior sheath circumferentially to allow the mesh to be inlaid directly against the posterior sheath or rectus abdominis muscle (below the arcuate line). Mesh is inserted to the semilunar line with #1 polypropylene sutures via the horizontal access tunnels and the cranial and caudal aspect of the defect. Next, the myofascial edges are advanced and reapproximated over the mesh with sutures placed through the myofascia. Interrupted resorbable 3-0 sutures can be placed to affix the posterior sheath to the mesh, thereby obliterating dead space and reducing the potential for fluid collection. Closed-suction

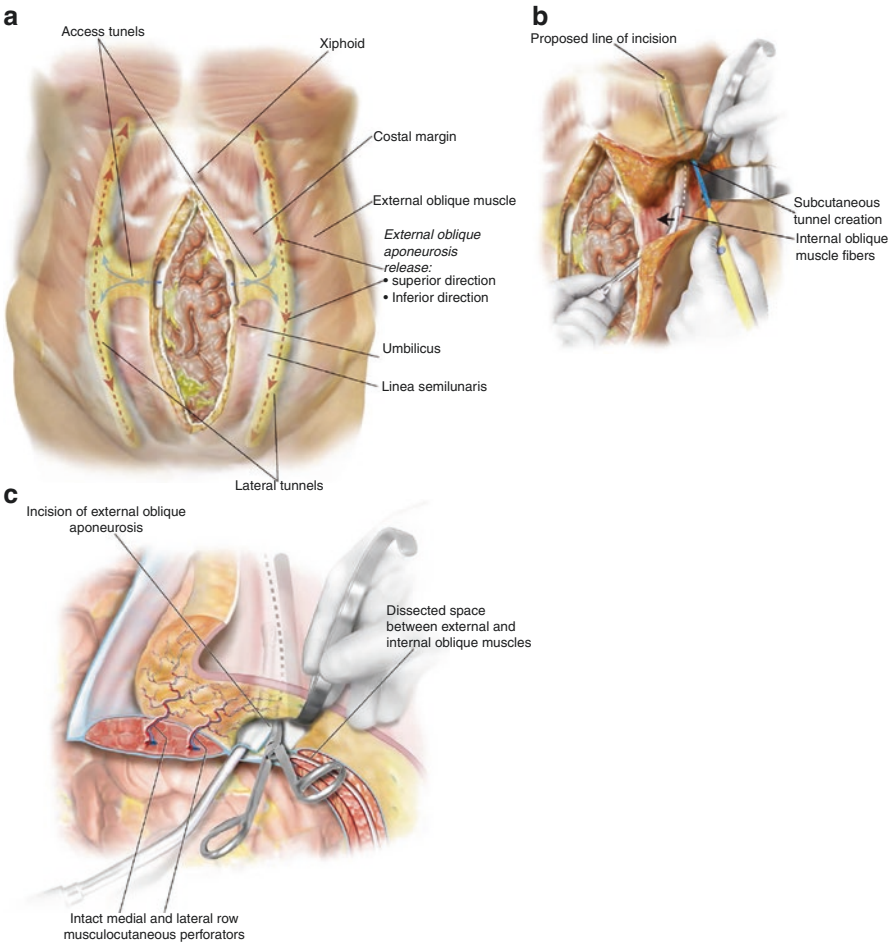

Fig. 17.3 Minimally invasive component separation (MICS) technique. (**a**) Access to the external oblique aponeurosis is achieved through a small tunnel from the midline to the supraumbilical external oblique aponeurosis. Vertical tunnels are created dorsal and ventral to the planned release site of the external oblique aponeurosis. Periumbilical perforators and the subcutaneous tissue overlying the anterior rectus sheath are left undisturbed. (**b**) The external oblique aponeurosis is then divided from the pubis to above the costal margin. The external oblique aponeurosis in the upper abdomen is released with electrocautery as muscle is transected at, and superior to, the costal margin. (**c**) Scissors are generally used to release the external oblique aponeurosis inferiorly. This MICS approach preserves the attachments of the subcutaneous tissue (including myocutaneous perforators) to the anterior rectus sheath throughout its course (Adapted with permission from Rosen MJ. Atlas of Abdominal Wall Reconstruction, Elsevier 2011)

drainage catheters are placed in each components separation donor site area, in the space between the rectus complex closure and mesh, and in the subcutaneous space. The remaining undermined skin flaps are sutured to the myofascia with vertical rows of interrupted resorbable 3-0 quilting sutures to reduce dead space and potential shear between the subcutaneous tissue and myofascia (Figs. 17.5, 17.6, 17.7, 17.8, 17.9, 17.10, 17.11, 17.12, 17.13, 17.14, and 17.15).

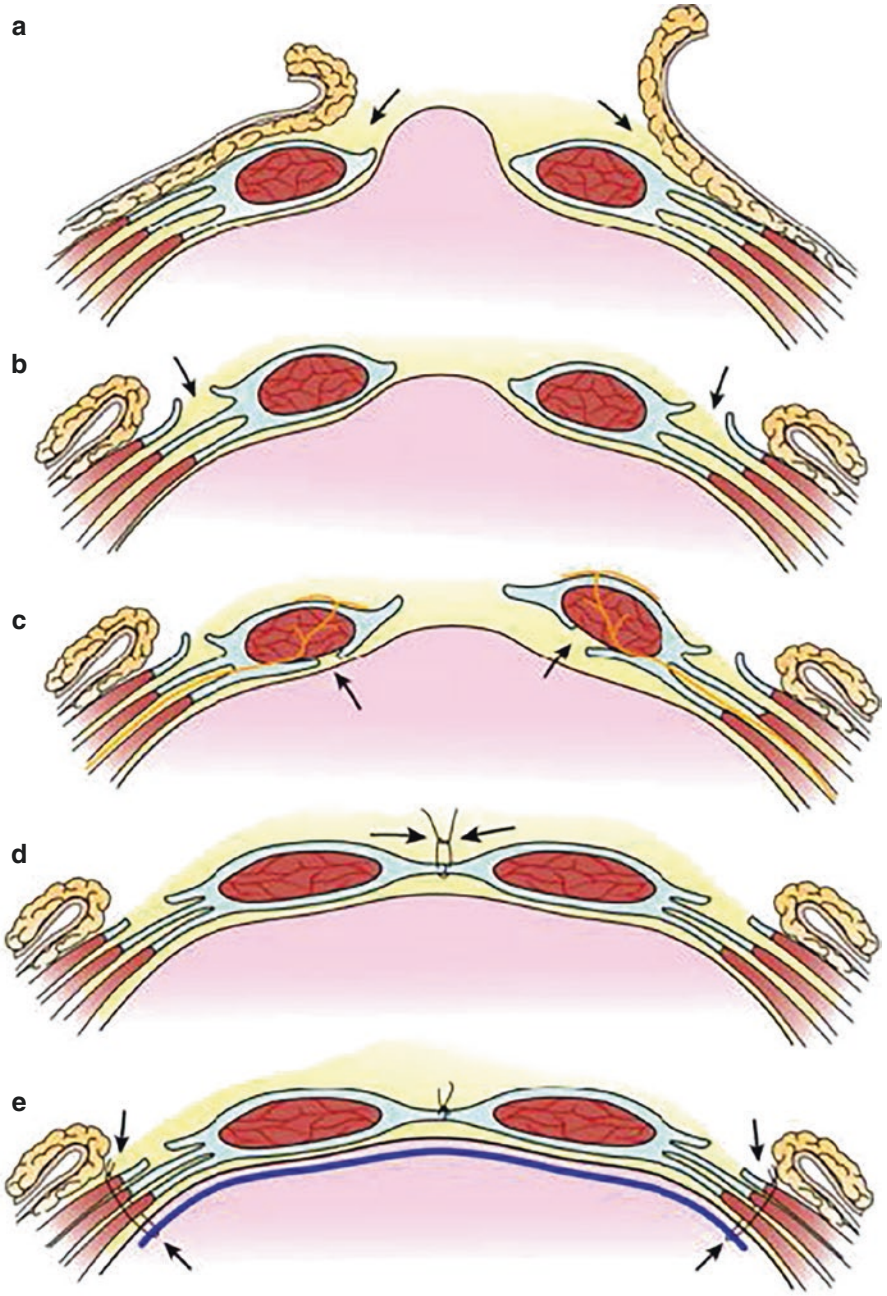

Fig. 17.4 Planes of dissection for component separation of the abdominal wall. Dissection begins with resection of the hernia sac, lysis of adhesions, and development of skin flaps past the linea semilunaris. (**a**) The external oblique aponeurosis is incised approximately 2 cm lateral to the linea semilunaris. (**b**) The posterior rectus sheath may also be incised for further advancement. (**c**) Complete fascial coaptation is achieved in the midline to avoid a bridged defect. (**d**) Fascial closure following ventral hernias frequently benefits from the addition of mesh reinforcement placed in an underlay position (**e**) or retrorectus position

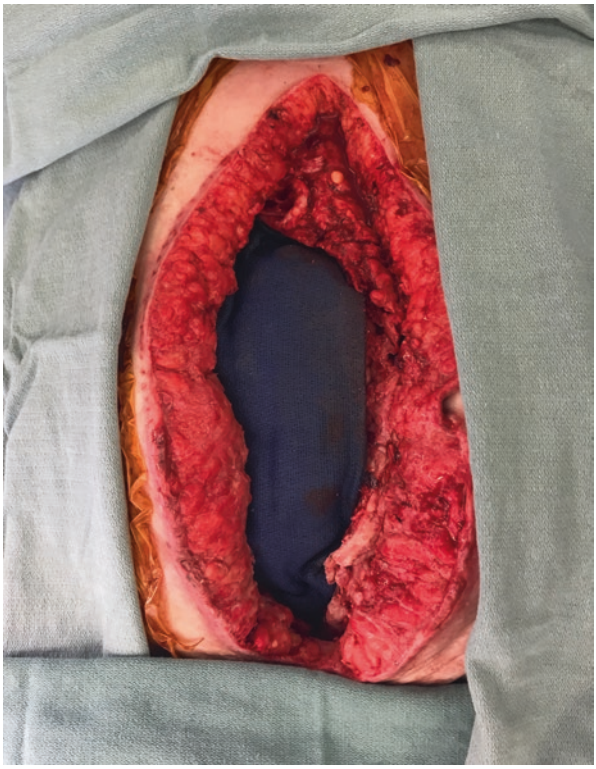

Fig. 17.5 Patient example of a minimally invasive component separation. Sixty-two-year-old male presented with a 10 cm midline ventral hernia

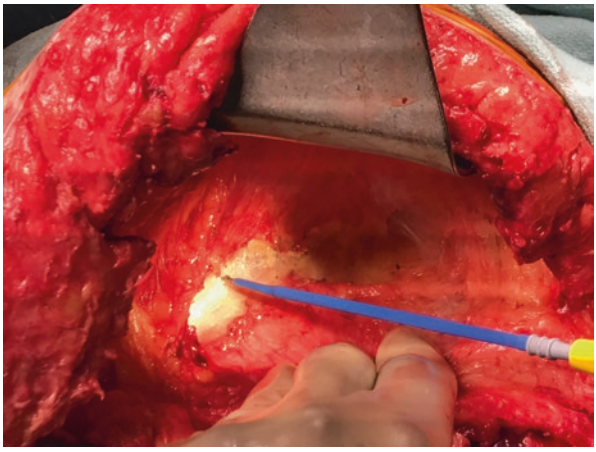

Fig. 17.6 Skin flaps are elevated off the anterior rectus fascia circumferentially around the defect leaving intact periumbilical perforators from the rectus abdominis complexes. Note that a subcutaneous tunnel is created at the costal margin with dissection laterally to the linea semilunaris

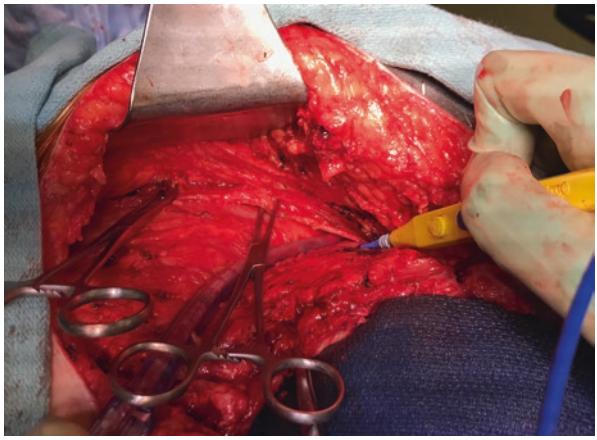

Fig. 17.7 Once the external oblique fascia is incised, the plane of dissection is easily visualized by using a Yankauer suction device. Release of the external oblique fascia should extend from above the costal margin down to the pelvis. Note in the figure that Alice clamps are attached to the cut edge of the external oblique fascia to demonstrate the components separation

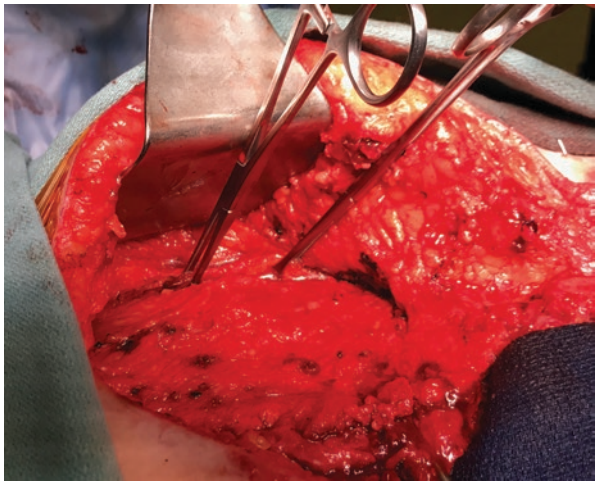

Fig. 17.8 Figure demonstrates complete release of the external oblique fascia. Note in the figure that Alice clamps are attached to the cut edge of the external oblique fascia to demonstrate the components separation

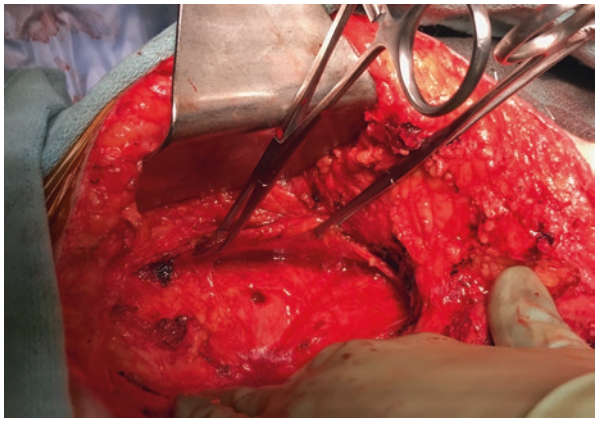

Fig. 17.9 Additional advancement of the rectus complexes to the midline can be achieved by dissection laterally between the external oblique and internal oblique muscles

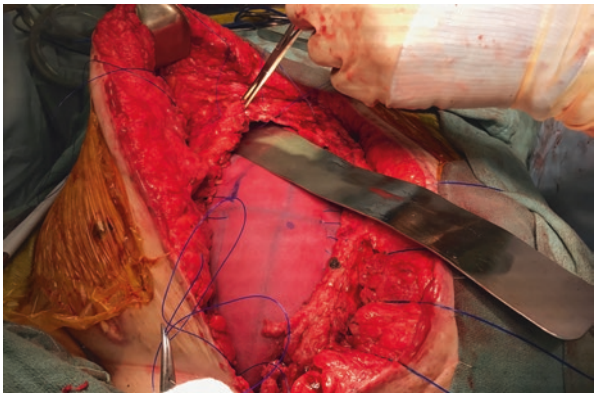

Fig. 17.10 Once component separations are performed, mesh reinforcement of the midline fascial closure is important for decreasing hernia recurrence rates. The figure demonstrates placement of mesh in an underlay position with transfixing sutures placed circumferentially

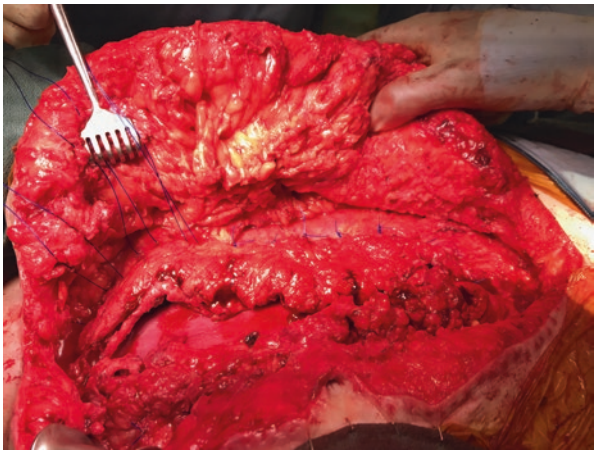

Fig. 17.11 Circumferential sutures are placed under tension allowing for a tensionless closure of the fascia in the midline

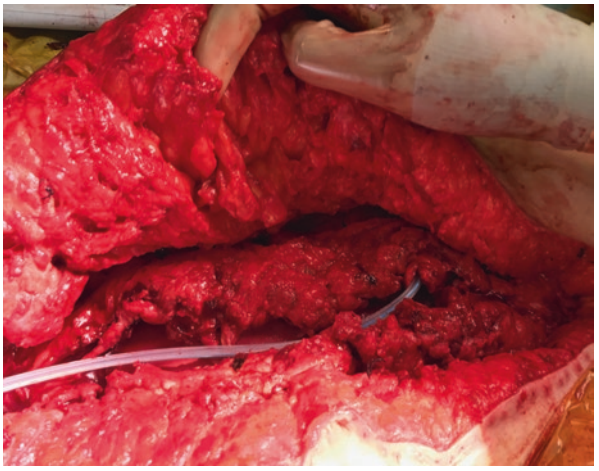

Fig. 17.12 Liberal use of drains as well as quilting sutures of the skin flaps obliterates dead space and helps prevent postoperative fluid collections

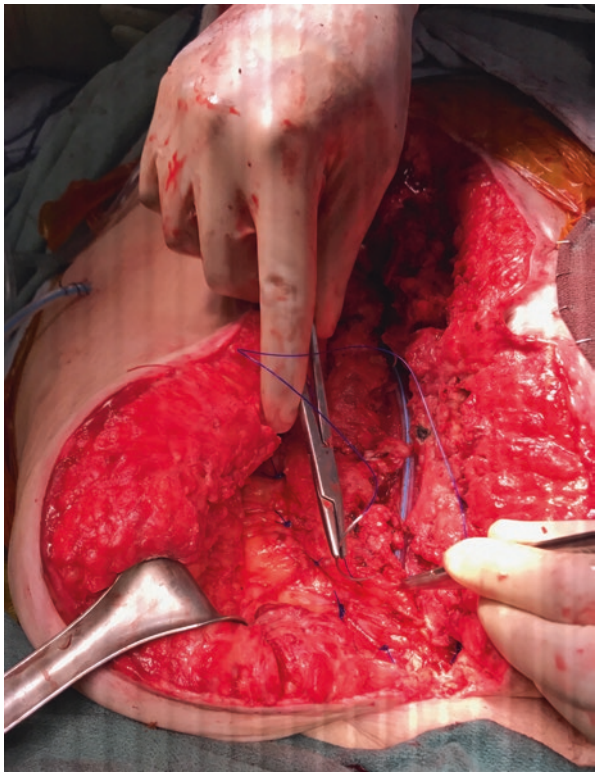

Fig. 17.13 Midline fascial closure is performed with figure of eight permanent sutures followed by a running permanent suture. Note despite the large original defect, midline closure of the fascia is now without tension following bilateral components separation and mesh reinforcement

Posterior Technique

A posterior components separation is based on the retromuscular Rives-Stoppa approach to ventral hernia repair (Fig. 17.16). Unlike the Ramirez components separation focusing on external oblique aponeurosis release, the posterior components separation focuses on transversus abdominis aponeurosis release. As previously mentioned, the transversus abdominis aponeurosis actually forms the posterior rectus sheath in the upper two-thirds of the abdomen. By incising this myofascial aponeurosis, the surgeon accesses the preperitoneal space. This provides substantial advancement of both the posterior fascial flap and the anterior myofascial compartment. The initial release is completed by incising the posterior rectus sheath approximately 1 cm lateral to the linea alba, and the posterior rectus sheath is separated from the overlying rectus muscle. The transversus abdominis muscle is incised just medial to the intercostal nerves, and the underlying transversalis fascia and peritoneum are identified. This myofascial release is extended the entire length of the posterior rectus sheath. The potential space between the transversus abdominis muscle and the peritoneum is developed as far laterally as necessary, even to the psoas muscle if needed. This plane can be extended superiorly to the costal margin, retrosternally above the xiphoid, and inferiorly into the space of Retzius. The

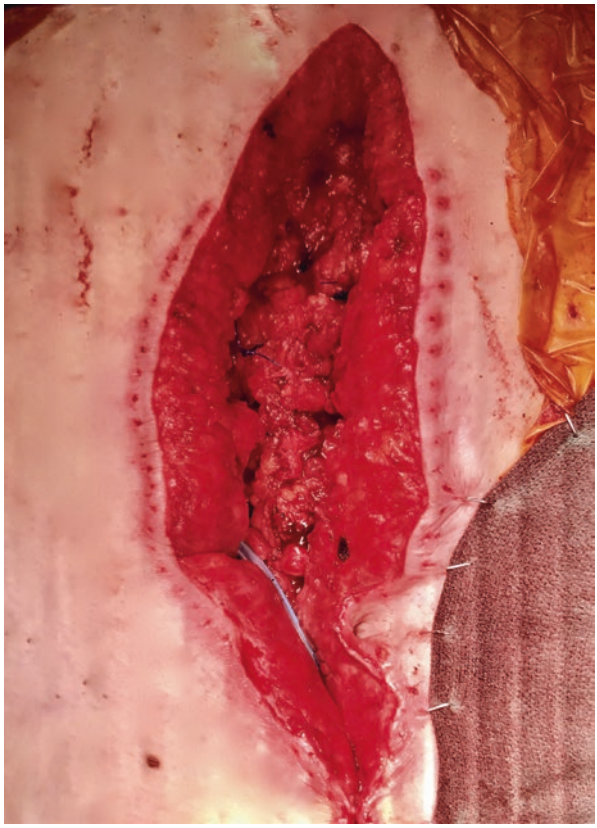

Fig. 17.14 Complete fascial closure is achieved to minimize hernia recurrence. Skin edges should be debrided back to healthy bleeding tissue prior to skin closure

posterior sheath is then closed, to completely exclude any mesh from the viscera. An adequately sized piece of mesh is then secured, similar to a standard retromuscular repair, but with greater overlap. The midline musculo-fascia is then reapproximated if possible.

Postoperative Management

In general, abdominal wall reconstruction patients have prolonged postoperative healing periods due to the dynamic function and mobility of the abdominal musculature. Based upon specific unique indications, each patient's postoperative care regimen should be individually tailored to allow for sufficient healing of the surgical site. Sequential compression devices and early ambulation should be utilized with low-molecular weight fractionated heparins administered postoperatively for DVT prophylaxis as indicated [22]. Perioperative antibiotics are indicated with violation of the gastrointestinal tract and should include broad coverage for anaerobic as well as Gram-negative bacteria. For ventral hernia, closed-suction drains are used liberally and are kept in place on average 1–2 weeks

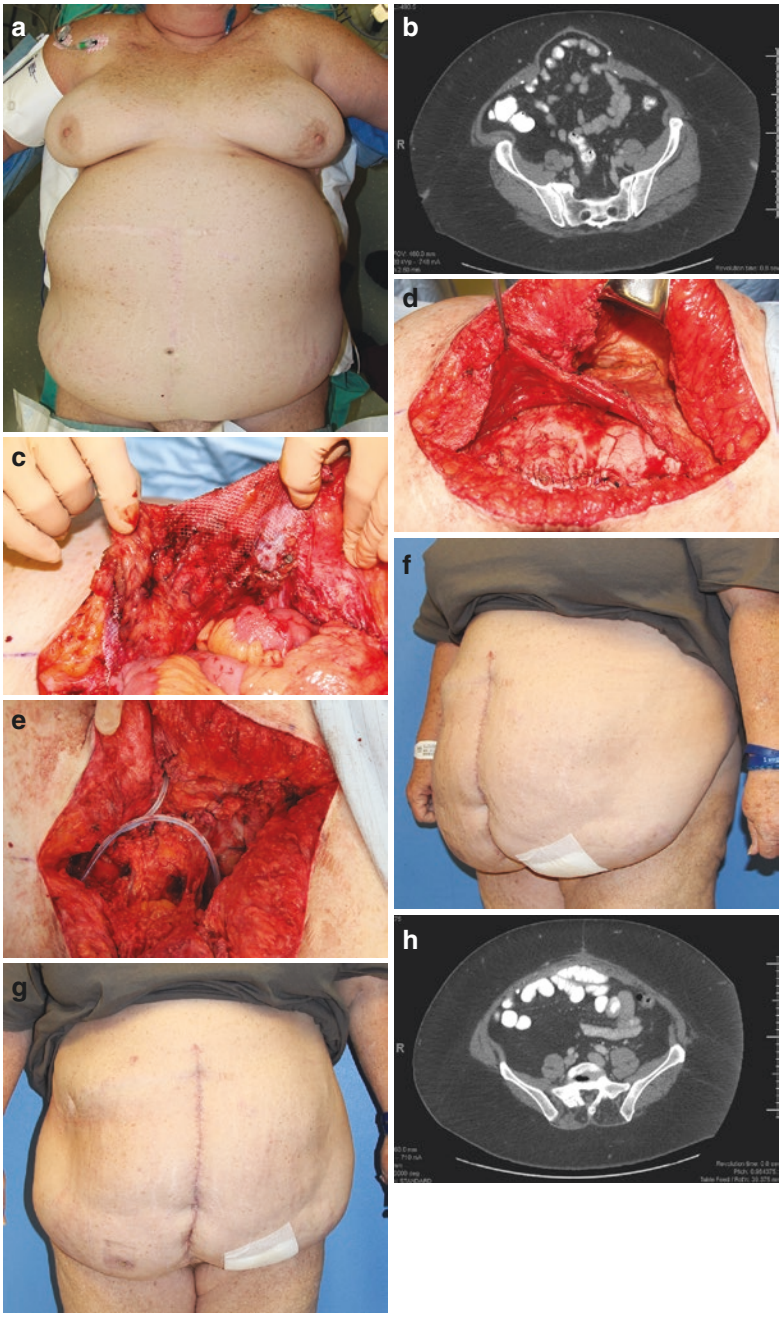

Fig. 17.15 Hernia repair. Patient is a 62-year-old female with a history of colon cancer, morbid obesity with BMI 46, and previous midline hernia repair with mesh reinforcement. She presents with a recurrent hernia 12 cm in greatest diameter. (**a**, **b**) Intraoperative evaluation demonstrates mesh failure. (**c**) Bilateral minimally invasive components separation was performed (**d**) which allowed for complete fascial coaptation (**e**). Postoperative evaluation is seen at 1 month (**f**, **g**) and by computerized tomography scan at 1 year (**h**)

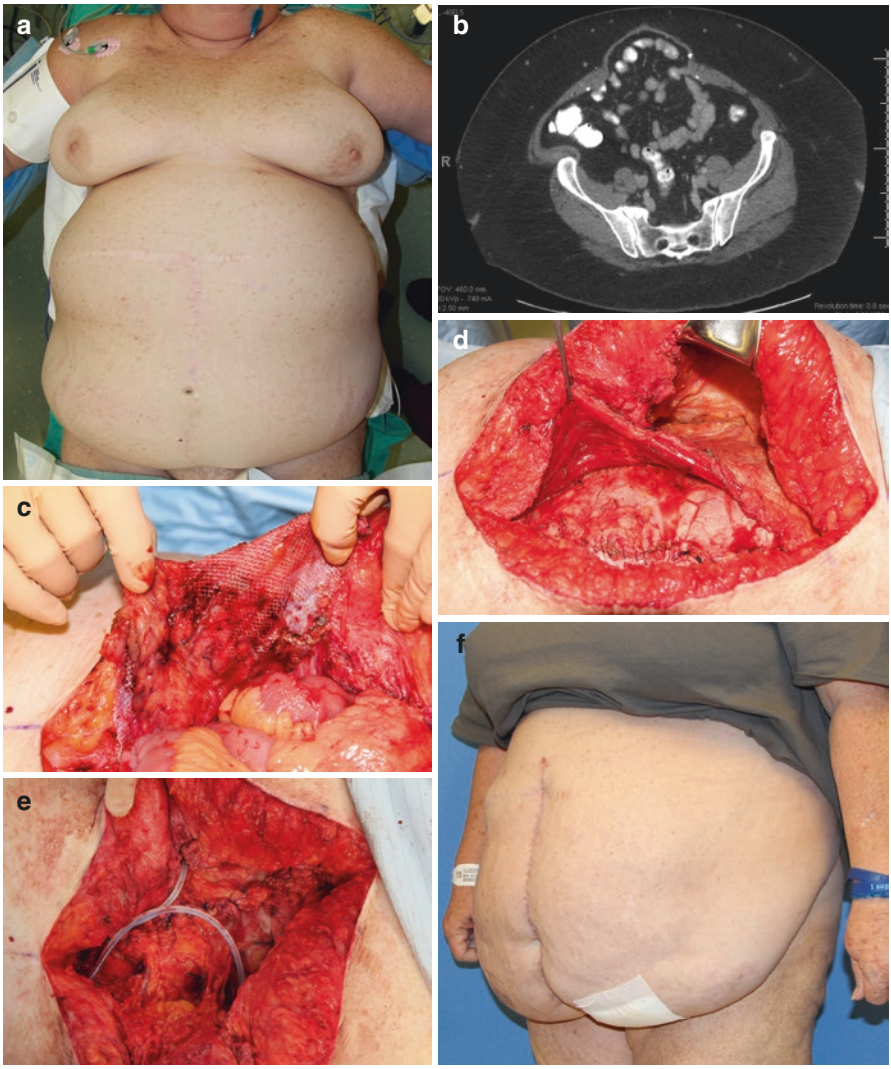

Fig. 17.16 Posterior component separation. (**a**) The initial release is completed by incising the posterior rectus sheath approximately 1 cm lateral to the linea alba, and the posterior rectus sheath is separated from the overlying rectus abdominis muscle. Dissection is carried to the lateral border of the rectus muscle, and the perforating intercostal nerves are identified, marking the linea semilunaris. (**b**) Next, the transversus abdominis muscle is incised just medial to the intercostal nerves, and the underlying transversalis fascia and peritoneum are identified. This myofascial release is extended the entire length of the posterior rectus sheath. The potential space between the transversus abdominis muscle and the peritoneum is developed as far laterally as necessary (Adapted with permission from Rosen MJ. Atlas of Abdominal Wall Reconstruction, Elsevier 2011)

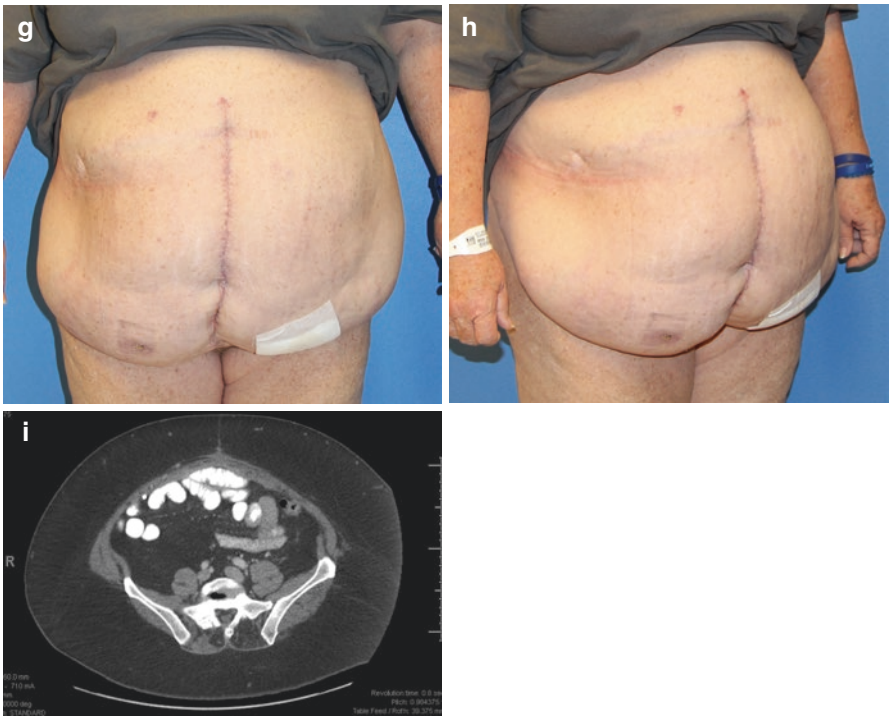

Fig. 17.16 (continued)

until less than 30 cm^3 per day. Abdominal wall reconstruction patients should refrain from strenuous activities and exercises that isolate the abdominal core for at least 6–12 weeks. Patients may gain comfort from the use of an abdominal binder for 3 months and then with any expected heavy physical activity thereafter. Routine follow-up includes a physical examination in an outpatient clinic, often performed weekly for 1 month after discharge, then every 3 months for 1 year, and then annually thereafter.

Complications

Infection

Surgical site infections are common after abdominal wall reconstruction. Categorization of the intraoperative level of wound contamination based on CDC criteria into clean, clean- contaminated, contaminated, and dirty wounds is important to appropriately stratify patients by risk of surgical site infection. The most common infectious organism is *S. aureus*, seen in up to 81% of infections; this suggests skin flora contamination during reconstruction [23]. However, Gram-negative

organisms, such as *Klebsiella* and *Proteus* spp., have been implicated in up to 17% of abdominal wall infections. Culture-directed antibiotics and operative debridement when indicated are the mainstay of treatment.

Seroma

Seroma formation can occur following abdominal wall reconstruction particularly in cases involving large undermined flaps, which create significant dead space. If symptomatic, seromas can be aspirated percutaneously or under ultrasound guidance. In most cases, small seromas will be reabsorbed over time. Resection of a previous hernia sac is important to prevent seroma formation. In open ventral hernia repair, drains are often placed in an attempt to obliterate the dead space caused by the hernia and tissue dissection [24]. Seroma formation is common after abdominal components separation and muscle flaps of the trunk owing to extensive tissue dissection, and drains may be necessary for up to 4–6 weeks. Intraoperative techniques, such as quilting sutures, fibrin sealant, and postoperative abdominal binders may help to prevent or reduce seroma formation.

Results

Estimated incidences of hernia recurrence have a wide range from 2 to 54%, depending on the type of repair (mesh 2–36% versus suture repair alone 25–54%), patient comorbidities, and surgical technique [12, 13, 25–27]. The number of prior attempts of hernia repair is predictive of the relative risk of recurrence. In a study of approximately 10,000 patients, 5-year reoperative rate was 23.8% after a primary repair, 35.3% following a secondary repair, and 38.7% after a tertiary repair [28, 29]. There are few comparative data to suggest the superiority of one myofascial advancement approach over another, and likely each has a role in abdominal wall reconstruction. Open components separation often allows tension-free closure of large defects, and recurrence rates as low as 20% have been reported with the use of open components separation and mesh reinforcement in large hernias. Recognizing the high recurrence rates with components separation alone, several authors have reported series of bioprosthetic or synthetic mesh reinforcement of these repairs, although to date, no randomized controlled trials have demonstrated lower hernia recurrence rates with a specific mesh type [30]. Comparative data have shown laparoscopic components separation to result in a lower rate of wound morbidity than open components separation. One series reported a significant reduction in wound morbidity with the periumbilical perforator-sparing technique compared with the standard open components separation technique (2% vs 20%; $p < 0.05$) [31]. A controlled study demonstrated that patients had significantly fewer wound-healing complications (32% vs 14%, $p = 0.026$) and skin dehiscences (28% vs 11%, $p = 0.01$) with MICS than with traditional open components separation [27]. These improved wound-healing outcomes are likely due to

preservation of the vascularity of the overlying skin flaps and reduction of paramedian dead space—the surgical principles underlying the MICS procedure. In a recent comparative review of open anterior components separation with posterior components separation for complex abdominal wall reconstruction, Krpata and colleagues reported similar fascial advancement but a 50% reduction in wound morbidity with the posterior approach when compared to an anterior components separation [32].

Conclusions

Ramirez and colleagues' description of the surgical technique of components separation (CS) facilitates medicalization of the rectus musculo-fascia and thus midline abdominal closure by releasing the external oblique aponeuroses. Components separation with myofascial advancement flaps is critically important and reliable method for obtaining primary fascial coaptation in large abdominal defects. Strength and integrity of the abdominal wall are preserved as well as muscle vascularity and innervation to provide a long-lasting repair with excellent functional outcomes.

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Technique: Transversus Abdominis Release

18

Luis A. Martin-del-Campo and Yuri W. Novitsky

Introduction

The goal of modern ventral hernia surgery is to restore the functionality of the abdominal wall. Therefore, tissue-based reconstruction with concurrent prosthetic reinforcement techniques has gained popularity in the past decades.

Approximately 50 years ago, Rives and Stoppa introduced retrorectus repairs [1, 2], while Wantz subsequently presented the concept of "giant reinforcement of the visceral sac" [3]. This technique has proven to be safe and effective for treating moderate-sized midline defects, but it has two significant drawbacks: limited myofascial advancement and a retromuscular plane for mesh placement that is limited by the linea semilunaris. Anterior component separation with external oblique release (see separate chapter) was initially described by Ramirez [4], but it is not our preferred approach given the need for creation of large skin flaps and its high rates of wound morbidity.

In order to attend to these limitations, posterior component separation with transversus abdominis muscle release (TAR) was developed in 2006 by Novitsky. Ever since the first presentation in 2009 and subsequent publication in 2012 [5], TAR has found an increasing role in addressing complex ventral hernia. The advantages of this technique include reapproximation of the linea alba with preservation of the neurovascular bundles to the rectus muscles and creation of a large sublay plane for prosthetic reinforcement without raising lipocutaneous flaps.

This chapter will discuss the anatomical principles, indications, technical aspects, and postoperative considerations of the TAR procedure.

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Anatomic Basis for TAR

The transversus abdominis (TA) muscle is the ideal target for posterior component separation due to its distinctive anatomy and function. Opposed to what has been the traditional anatomic description of the TA (Fig. 18.1), the muscular portion of the TA extends medially beyond the linea semilunaris in the upper third of the abdomen and inserts in the edge of the costal margin and xiphoid process. In the lower part of the abdomen, most of the TA medial to the linea semilunaris will be aponeurotic with almost no muscle fibers. This unique feature allows the surgeon to safely divide the TA and perform retromuscular dissection without injuring the rectus muscle neurovascular bundles.

The horizontal fibers of the TA help maintain intra-abdominal pressure and contribute to the tone of the lateral abdominal wall. Division of the TA releases some of the circumferential tension on the abdominal wall, but complete lateral retromuscular dissection after TA division is the key step that permits dissociation of the anterior fascia from the remaining posterior fascia. Our study in cadavers shows that the end result of these maneuvers is approximately 10 cm of myofascial advancement for the anterior sheath and just over 11 cm for the posterior layer. This advancement for both layers allows restoration of linea alba plus giant reinforcement of the visceral sac [6].

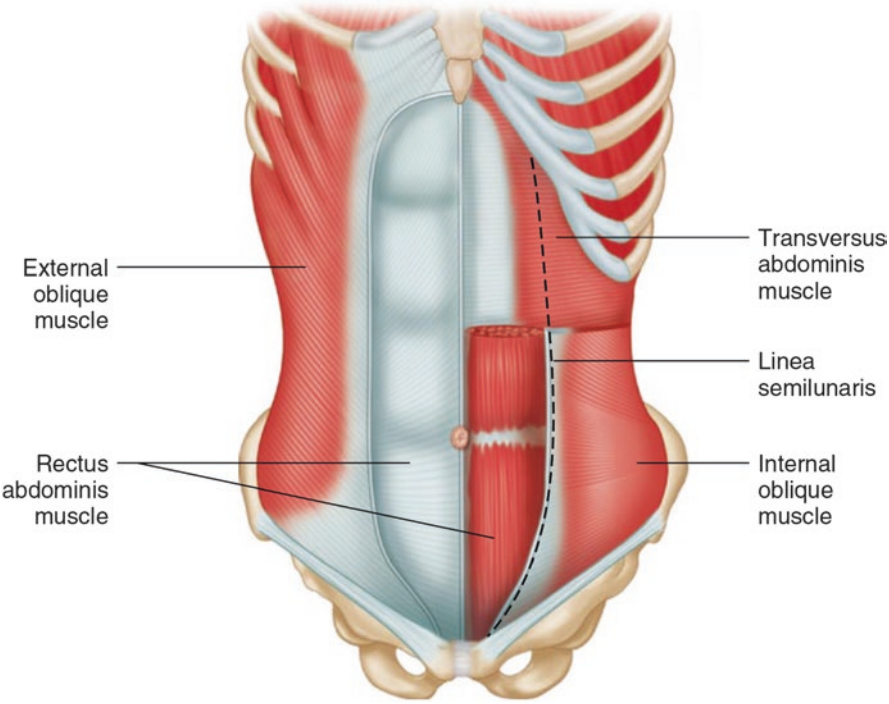

Fig. 18.1 Transversus abdominis muscular and aponeurotic extension medial to the semilunar line

Indications

The most common scenario for TAR is large midline defects (˃10 cm), but it has shown to be very useful in complex locations such as subcostal, subxiphoid, flank, parastomal, suprapubic, and donor site hernias after flap-based (TRAM) breast reconstruction [7, 8]. With the introduction of minimally invasive techniques for TAR [9], our current practice is to offer an open approach to patients with a predicted hostile abdomen and contaminated scenarios and those who require removal of mesh or large soft tissue excision and also for very large defects (>20 cm).

Although there are no absolute contraindications for TAR, patients with previous preperitoneal/retromuscular repair and those with history of severe necrotizing pancreatitis can be particularly challenging. TAR has been described as an option for recurrences after anterior component separation techniques [10], but it should not be performed simultaneously with anterior component separation as this would create lateral abdominal wall instability and bulging.

Preoperative Considerations

We require all patients to have non-contrast-enhanced abdomen and pelvis CT to identify and outline every abdominal wall defect, to define intra-abdominal anatomy, and to reveal occult intra-abdominal pathology. Preoperative optimization according to our enhanced recovery pathway for ventral hernia repair (Table 18.1) has proven to be invaluable to maximize surgical outcomes [11]. As long as the patient does not develop obstruction or other indication of emergent repair, elective cases are delayed until preoperative optimization goals are met.

Smoking cessation for at least 4 weeks is mandatory, and patients with recent tobacco use are tested before the operation. Diabetes control needs to be optimized (HbA1c ˂ 7.5%), and patients are selectively screened for obstructive sleep apnea. All patients undergo nasal swab screening for MRSA and routinely receive decolonization with mupirocin ointment the night before surgery.

Nutritional counseling includes preoperative weight loss for all obese patients, but in our practice a BMI of 45 kg/m^2 is considered as the upper limit for elective abdominal wall reconstruction. All patients are given arginine/ornithine and omega-3 supplementation drinks three times per day for 5 days before the day of operation. This strategy has been shown to improve healing and minimize wound complications.

Technical Aspects

The patient is placed in supine position. The abdomen is prepped from the nipples to mid-thigh and laterally to the posterior axillary lines.

Incision: Unless additional soft tissue resection is planned, most cases will be addressed through a midline laparotomy. After careful access to the abdominal

Table 18.1 Enhanced recovery after surgery pathway for ventral hernia repair

Preoperative	Weight loss counseling
	Diabetic control (HbA1C < 8%)
	Smoking cessation (≥4 week)
	OSA screening
	IMPACT preoperative nutrition shake
	MRSA screening
Perioperative	SQ Heparin 5000 × 1 dose + SCDs
	po Alvimopan 12 mg × 1 dose
	po Gabapentin 100–300 mg × 1 dose
	First-generation cephalosporin + vancomycin for positive MRSA screen
Intraoperative	
Pain control	Minimization of narcotics/paralytics
	Intraoperative TAP block: 20 mL liposomal bupivacaine diluted to 200 mL (100 mL per side)
Postoperative	
Pain control	IV Hydromorphone PCA: 0.2 mg q 6–10 min, no breakthrough dose; no basal rate; stopped on POD 2 once on clears
	po Oxycodone 5–10 mg q 4 h PRN started once off IV PCA
	po Acetaminophen 650 mg q 6 h scheduled started immediately post-op
	po Gabapentin 100–300 mg tid started on POD 1
	IV/po Diazepam 5 mg q 6 h PRN: 2.5 mg dose for patients >65 years old; hold for OSA patients, sedation, or any respiratory compromise
	po NSAIDs 600–800 mg po q 6–8 h PRN: hold for renal dysfunction; can use IV Toradol 15–30 mg q 6 h
Intestinal recovery	No routine nasogastric tube placement
	NPO except meds on operative day only
	Scheduled diet advancement: POD 1, limited clears (<250 mL/shift); POD 2, clear liquids ad lib; POD 3, regular diet
	po Alvimopan 12 mg bid until discharge or POD 7
Fluids	Fluid conservative strategy: LR at 100 mL/h on operative day; D5 ½NS at 75 mL/h on POD 1; heplock IVF on POD 2

cavity is obtained, complete lysis of adhesions from the anterior abdominal wall is obtained to protect the viscera during the release and to facilitate medialization of the posterior components. Meticulous dissection is required to avoid injury to the bowel and preserve the peritoneum as much as possible. Interloop intestinal adhesions are selectively lysed in patients with a history of obstructive symptoms. The falciform ligament is routinely freed in proximity to the liver to keep it in continuity with the posterior layers while allowing for placement of a towel that will protect the entire visceral contents extending from the hiatus to the pelvis and laterally to the gutters.

Retrorectus dissection: An incision is created in the posterior rectus sheath close to its medial edge. It is critical that the fibers of rectus abdominis are clearly visualized to avoid mistakenly entering the subcutaneous plane (Fig. 18.2). The retromuscular plane is then developed toward the linea semilunaris with constant traction on the anterior fascia using Kocher clamps or Richardson retractors under the rectus

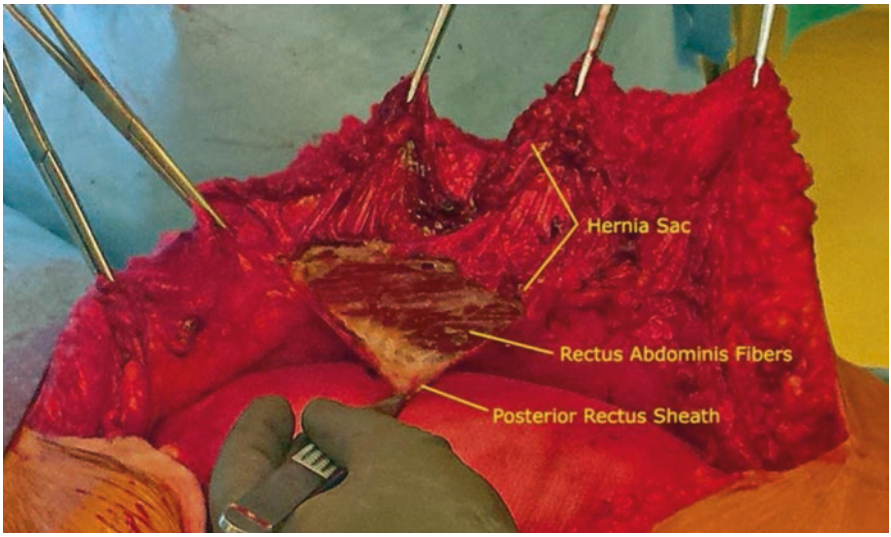

Fig. 18.2 Incision of the posterior rectus sheet in its medial-most portion. The correct location can be confirmed by visualizing fibers of the rectus muscle

muscle, combined with countertraction with multiple Allis clamps on the medial edge of the posterior layer. The plane can be dissected using blunt instruments in combination with monopolar energy to divide the fine areolar tissue and small perforating branches of the epigastric artery. The lateral limit of this mobilization is the perforators to the rectus muscle just medial to linea semilunaris. The retrorectus plane is extended cephalad toward the costal margin while preserving the attachments of the falciform ligament to the posterior rectus sheath, as they will be useful for closure of the posterior layers.

Caudally, the transition from the retromuscular plane within the rectus sheath into the pelvis involves the division of the medial attachments of the arcuate line of Douglas to the linea alba. Following that, the preperitoneal plane must be entered to allow dissection to the space of Retzius and exposure of the pubis symphysis and Cooper's ligaments. True access to the preperitoneal plane at this level will facilitate dissection and prevent injury to the epigastric vessels.

Division of the TA: Once the limits of the traditional Rives-Stoppa repair have been reached, the division of the transversus abdominis and subsequent posterior component separation are undertaken. Our preferred area to expose the TA is the upper abdomen, where the posterior rectus sheath will be incised just medially to the perforating neurovascular bundles to identify the underlying fibers of the TA. If this incision is created too medially, the muscle fibers may be difficult to visualize, and peritoneum may be cut. Similarly, if this step is done in the lower abdomen, the muscular portion of the TA is more lateralized in those areas and, as a result, more difficult to identify properly. The posterior rectus sheath is then incised in the cranial-caudal direction. The lateral aspect of the arcuate line is divided at its junction with the semilunar line.

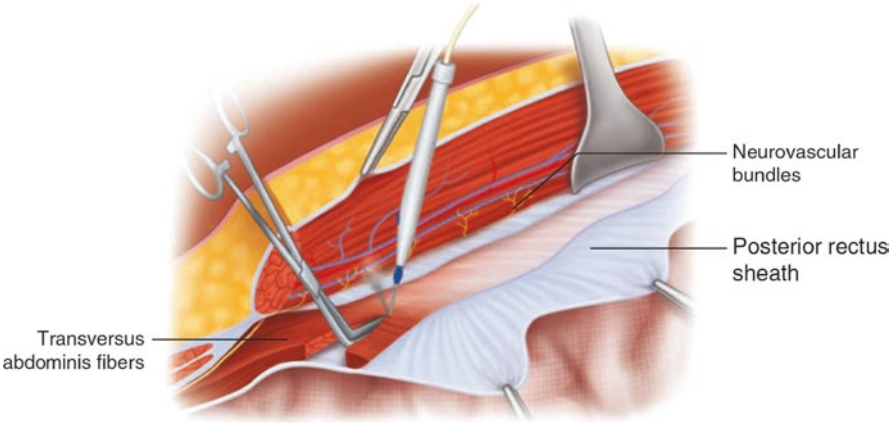

Fig. 18.3 Division of the transversus abdominis muscle fibers is performed medial to the neurovascular bundles to the rectus muscle

The division of the TA muscle itself is then undertaken (Fig. 18.3), ideally starting in the upper third of the abdomen where medial fibers of the transversus abdominis muscle are easiest to identify and separate from the underlying transversalis fascia. The use of a right-angled dissector helps to avoid penetrating the underlying transversalis fascia and peritoneum. This release allows entrance to the space between the transversalis fascia and the divided transversus abdominis muscle (pre-transversalis plane).

Lateral dissection: After division of the TA, the plane deep to it is developed in the medial to lateral direction. We usually accomplish this by providing traction on the TA with a right-angled dissector, countertraction in the posterior layer with Allis clamps and gentle use of the Kittner dissector. Bleeding at this point should alert to the possibility of erroneous entry into the intramuscular plane, and it should be noted that the correct retromuscular plane is posterior to the ribs. If fenestrations occur, they can be sutured with 2-0 Vicryl running or figure-of-eight sutures. This is done in the transverse direction to avoid tension on the suture lines.

The transition from the pre-transversalis/preperitoneal plane into the retroperitoneum is often defined by visualization of retroperitoneal fatty tissue. The lateral edge of the psoas muscle is used as safety landmark for the lateral extent of the retroperitoneal dissection. A transversus abdominis plane (TAP) block is performed during TAR by directly accessing the TAP plane through the cut edge of the transversus abdominis muscle to improve pain control, reduce narcotic use, and shorten hospital stay [12].

Inferior dissection: After exposure of Cooper's ligaments and pubis, the dissection is extended laterally across the entire myopectineal orifice. In women, the round ligament is divided routinely. In men, the spermatic cord is identified and separated from the peritoneum in a fashion similar to a laparoscopic inguinal hernia repair.

If inguinal or femoral hernias were identified, the dissection can be extended to expose at least 5 cm of the distal psoas muscle with subsequent prosthetic coverage of the myopectineal orifice. For this step, our preference is to use a separate preformed synthetic mesh with no fixation.

Superior dissection: Depending on the location of the hernia, the superior dissection may extend to the upper epigastrium or above the xiphoid process to the retrosternal space for hernias that extend superiorly. This step is easier after dissection is completed on both sides.

To prevent recurrent herniation off the superior edge of the dissection, the linea alba is maintained in continuity ventral to the mesh for at least 5 cm by dividing the insertion of the posterior rectus sheaths into the linea alba. This is accomplished by cutting the insertion of each posterior sheath in the cranial direction about 0.5 cm lateral to the linea alba with subsequent reconnection of the plane between posterior rectus sheath, preperitoneal space, and posterior rectus sheath. These planes can be easily connected using a cutting lineal stapler being careful not to staple the linea alba itself.

For the majority of mid and upper abdominal defects, cephalad dissection to the retrosternal space is critical to minimize superior/subxiphoid recurrences. First, the linea alba is divided to the xiphoid process, and then, posterior insertion of the posterior rectus sheath into the xiphoid process is also incised. This provides access to a fatty triangle that is extended cephalad in a substernal plane. Finally, the continuity of this space with the retromuscular dissection is created. The incision line at the lateral aspect of the posterior rectus sheath is extended to and slightly above the costal margin. This is followed by complete division of the uppermost fibers of the transversus abdominis muscle just off the lateral edge of the xiphoid, making sure not to create an iatrogenic Morgagni hernia by injuring diaphragm fibers. In order to provide adequate mesh overlap, the retromuscular plane can be extended to expose the upper aspect of the central tendon of the diaphragm.

Closure of posterior layers: This step is critical to avoid visceral contact with the mesh and to prevent intraparietal herniation. Reapproximation of posterior rectus sheaths is performed from the cephalad and caudal ends separately with running 2-0 Vicryl or PDS suture. In rare circumstances, this will not be possible and buttressing with omentum, Vicryl or biologic mesh can be done. The countable towel is removed shortly before completing the posterior layer closure. The intraperitoneal contents will be isolated afterward.

We routinely irrigate the visceral sac with approximately two liters of saline in all clean cases. Antibiotic pressurized pulse lavage significantly reduces the bioburden, and it is our preference in clean-contaminated and contaminated cases since it could potentially prevent prosthetic contamination [13].

Mesh placement: The mesh is placed in the retromuscular space based on the principle of "giant reinforcement of the visceral sac" (Fig. 18.4). For hernias that extend inferiorly, we secure the mesh to the Cooper's ligaments to ensure mesh overlap in the retropubic space. This is typically done with one interrupted suture on each of the Cooper's ligament, passing the tail through the mesh so that the knots will be tied at the dorsal surface of the mesh. Superiorly, the mesh could be secured

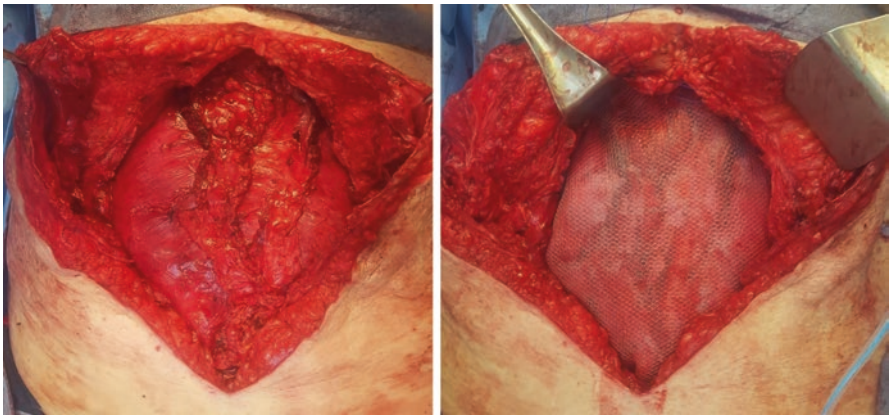

Fig. 18.4 Closure of the posterior layer and mesh implantation to obtain giant reinforcement of the visceral sac

with interrupted sutures around the xiphoid process and 4–5 cm off the edge of the mesh to provide with large superior overlap. We minimize/avoid lateral fixation, only using it selectively for lateral defects and cases where the linea alba cannot be completely reapproximated.

The vast majority of prosthetic reinforcements in our series are done using synthetic mesh [14]. Mid-weight, macroporous polypropylene is usually preferred; reserving heavy-weight polypropylene for cases where the linea alba cannot be reapproximated and for lateral defects. We strongly discourage the use of light-weight monofilament polyester for abdominal wall reconstruction due to the potential of recurrence from central mesh failure [15]. Our experience with biologic mesh has been somewhat disappointing [16], and a recent multicenter experience demonstrated biologic mesh to be an independent predictor of wound complications and recurrences in a comparative series with matched synthetic repairs [17].

Linea alba reconstruction: We routinely place closed suction drains over the mesh after open TAR. The combination of muscle releases and component separation performed in this operation will allow for medial advancement of the rectus abdominis.

Linea alba reapproximation is performed with running PDS suture, with occasional use of interrupted figure-of-eight. After resection of hernia sac, redundant soft tissue, and attenuated skin, closure of superficial layers is performed with selective use of subcutaneous drains.

Postoperative Care

A minority of patients might experience an increase of pulmonary plateau pressure above 6 mmHg and will need to stay intubated, at least overnight. Those patients with increase in plateau airway pressures >11 mmHg are kept paralyzed for 24 h

postoperatively. Abdominal compliance usually improves within 12–24 h postoperatively, and pulmonary physiology returns to baseline allowing for safe extubation [18].

All patients are kept NPO on postoperative day 1, and diet is advanced according to the patient's status and the enhanced recovery pathway schedule (Fig. 18.1). Alvimopan is given twice a day and is stopped after the first bowel movement. Patient-controlled analgesia is maintained for the first 1–2 days with adjunctive use of oral acetaminophen and gabapentin. Drains are usually kept in place until the output is <30–50 cm^3 per day. Most patients will wear an abdominal binder at least during the first week.

Outcomes

As experience with TAR is expanding, a wealth of outcome data is now available in the literature. In a nonrandomized study published in 2012 [19], 55 cases of TAR were compared to 56 traditional anterior component separation cases looking for differences in wound morbidity and repair durability. Hernia characteristics were similar between groups, but the mean operative time was significantly reduced in the TAR group (228 min vs 285 min). Midline reapproximation was equally feasible in both groups. Wound complications were significantly reduced when TAR was the procedure of choice (25.4% vs 48.2%, p 0.01), and this significance remained even after adjusting for differences in demographics between groups. There appeared to be a trend for lower hernia recurrence rate in the TAR group (3.6% vs 14.3%), but this was not statistically significant (p 0.09). This study was able to demonstrate one of the benefits TAR, since it allows preservation of the abdominal wall blood supply by avoiding creation of the skin flaps that are typically needed in the traditional anterior component separation.

The largest experience with TAR to date was published in 2016, when 428 consecutive repairs using synthetic mesh were reported [14]. The complex hernia population that was addressed by TAR in this study included a large proportion of obese patients (68%) with a mean BMI of 34.4 kg/m^2 (range 20–65). Patients would frequently present with comorbidities, DM (21%), COPD (12%), and active smoking status (7%), and usually had several previous abdominal surgeries (mean 3.9, range 1–19). The majority of patients in this study had a clean wound, but clean-contaminated and contaminated scenarios were also included (28% and 8%, respectively).

Although the mean postoperative stay in this study was 6.1 days, this has been successfully reduced to 4 days after implementation of the aforementioned enhanced recovery pathway for ventral hernia. Surgical site events were present in 18.7% of cases, and although overall surgical site infection incidence was 9.1%, it was only 6.7% for clean cases. Multivariate analysis revealed age, hernia width, and wound class III to be predictors for surgical site infection. No mesh explantation was required. The most common systemic complication after TAR was UTI (6.8%), followed by DVT/PE (6.3%) and pneumonia (1.2%).

After a mean follow-up of 31.5 months, the recurrence rate was 3.7%, most of which can be attributed to central mesh failure with polyester or to herniations

outside the edges of the prosthetic reinforcement (subxiphoid, suprapubic, lateral). Among those who recurred, repair was obtained either laparoscopically (IPOM) or with an onlay technique. The favorable wound morbidity observed in this study probably highlights the benefits of using rapidly integrated macroporous polypropylene mesh in a retromuscular space that provides bilaminar fascial coverage.

A particular challenging repair is often needed in kidney transplant recipients, in whom defect size, location, presence of an allograft, and multiple comorbidities and immunosuppression are all significant obstacles for a repair. We recently reported the safety and efficacy of TAR in this special population; 11 kidney transplant recipients who underwent incisional hernia repair using this technique were analyzed, most of whom had a previous attempted repair (73%) [7]. There were two cases of superficial surgical site infection that resolved with antibiotics. One patient developed skin necrosis that required debridement. After a mean follow-up of 12 months, only one patient developed a lateral recurrence, which during revisional surgery was found to be bulging and not a true hernia. Although a biologic mesh was used in two cases, this study again demonstrated how the use of a macroporous synthetic mesh in a sublay position can be safe and effective for such unique (immunosuppressed) patient population.

Repairing incisional hernias in patients with underlying inflammatory bowel disease can be problematic, since extensive surgical history and impaired healing are almost universal in this group of patients. Our retrospective analysis of 32 patients with IBS that underwent TAR for incisional hernias [20] found that 34% of patients developed a surgical site event, while 18.4% had a surgical site infection. Nevertheless, there were no intestinal complications, and after a mean follow-up of approximately 3 years, there were only three recurrences. Therefore, TAR displayed a favorable wound morbidity and durability profile in this series of complex hernias in difficult patients.

Experience with TAR has been replicated in other centers across the USA, where a series of 37 consecutive patients was recently published [21]. Similarly, patients often had defects with several previous abdominal procedures as well as attempted repairs. Almost 90% of the patients in this series had a clean wound, and the majority of these repairs was done using synthetic mesh (81.1%). Surgical site infection occurred in 5.4% of patients, and there was only one recurrence after a mean follow-up of 21 months. Similar results have been published in the UK [22], where a series of 12 patients has found anecdotical wound morbidity and no recurrences have been observed. Introduction of TAR has ignited changing practice patterns of hernia in many centers around the world. In Mexico, Espinosa de los Monteros et al. have progressively transitioned from anterior component separation to TAR for many of their complex ventral hernia repairs [23]. Similarly, promising reports from Russia [24] and Romania [25] suggest that the technique can be reproducible.

In order to address the concerns surrounding the potential impact that releasing the transversus abdominis would have in the abdominal wall physiology, we performed a CT-based analysis of the preoperative and postoperative morphology of the abdominal wall in 25 patients who underwent TAR and 25 who had a laparoscopic ventral hernia repair without defect closure (bridged repair) [26]. Development

of compensatory hypertrophy of the rectus abdominis and both external and internal obliques was observed only in the TAR group, reinforcing the importance of reconstruction of the linea alba. It is probably the combination of a functional midline restoration and the compensatory hypertrophy that has allowed for significant improvements in postoperative abdominal wall function, as demonstrated by dynamometric evaluation and quality-of-life indicators [27].

Conclusions

The transversus abdominis release technique has found an increasing role in addressing complex ventral hernia. TAR allows reconstruction of the linea alba and creation of a large sublay plane for prosthetic reinforcement without raising lipocutaneous flaps or injury to the neurovascular bundles.

Ever since its first description, data from the USA and many other countries have shown it to be a versatile, safe, and durable repair. Deep understanding of the surgical anatomy related to the abdominal wall and this procedure are paramount to prevent injury and offer a durable repair. Outcomes for elective cases can be maximized by adhering to perioperative optimization and managing patients according to our enhanced recovery pathway for ventral hernia.

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Robotic Transversus Abdominis Release: Tips and Tricks

19

Jeremy A. Warren and Alfredo M. Carbonell

Introduction

Robotic ventral hernia repair (rVHR) has experienced exponential growth in recent years. The benefits of three-dimensional, magnified visualization, articulating instruments that allow complex intracorporeal dissection and suturing, and improved surgeon ergonomics are appealing. Open retromuscular VHR as initially described by Rives [1] is widely considered the standard for hernia repair, with placement of mesh in a well-vascularized space behind the rectus muscle, isolated from the visceral cavity by closure of the posterior sheath. However, wound morbidity remains a significant deterrent to this approach, particularly in patients at higher risk for these complications. The robotic platform enables this complex myofascial dissection to be performed in a minimally invasive fashion, thus maximizing the benefits and minimizing the complications associated with standard laparoscopic or open repairs. Published literature to date on robotic transversus abdominis release (rTAR) demonstrates a reduced length of stay compared to both laparoscopic and open repair and some improvement in wound complications [2] [3, 4]. This is a complex technique that requires detailed understanding of abdominal wall anatomy and how to manipulate the various layers to ultimately mobilize the posterior layers and release tension on the anterior fascia for closure of the linea alba.

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Technique Overview

After entry into the abdominal cavity and establishing pneumoperitoneum, trocars are placed along the right lateral abdominal wall. Adhesiolysis is completed and the hernia reduced. Beginning on the contralateral side, the posterior rectus sheath is incised just lateral to the linea alba along the entire length of the hernia defect. The posterior rectus sheath is dissected away from the rectus muscle laterally to the semilunar line. Above and below the hernia defect, the preperitoneal space along the midline is taken down, leaving the linea alba intact. This allows additional incision of the posterior rectus sheath above and below the defect and allows mesh overlap superior and inferior to the defect.

The transversus abdominis release (TAR) is performed by incising the transversus abdominis (TA) muscle and aponeurosis within the lateral aspect of the posterior sheath to enter the preperitoneal plane, which is then developed laterally to approximately the midaxillary line. New trocars are placed in the contralateral abdominal wall into the preperitoneal space in mirror image to those placed initially. The hernia defect and dissected space are measured intracorporeally. Mesh is cut to size and placed into the retromuscular space, fixating it to the lateral abdominal wall below the nascent trocars. The robot is then undocked and redocked on the opposite side. Identical retromuscular and transversus abdominis dissection is completed, bringing the initially placed trocars into the preperitoneal plane. The posterior sheath is then closed with a running absorbable self-fixating suture for complete closure of the visceral sac. Mesh is retrieved from the lateral abdominal wall and deployed across the closed posterior sheath, affixing it to the opposite abdominal wall. The hernia defect is closed with a running, absorbable self-fixating suture to complete the repair.

Patient Selection

The published literature to date is inadequate to clearly define indications and contraindications for rTAR. However, many basic principles of laparoscopic ventral hernia repair (LVHR) patient selection still apply. Patients at higher risk for wound complications, including patients with diabetes, chronic obstructive pulmonary disease, or obesity likely benefit from this minimally invasive approach. Patients with poor skin condition, such as wide scars from prior wound complications or skin graft, are poor candidates for rTAR. Very large hernias, greater than 15 cm, should be approached cautiously, as larger defects are often difficult to close even with open VHR. This largely depends on the judgment and experience of the surgeon and the patients' abdominal wall compliance on physical exam. We have successfully used the rTAR approach for closure of defects up to 20 cm. Finally, patients with smaller hernias do not need significant myofascial release to reapproximate the defect. Defects less than 8 cm are typically repaired with some variation of rVHR, either a preperitoneal mesh placement or a single-dock approach that avoids TAR [3, 5–7].

Technique in Detail: Tips and Tricks

Patient Positioning, Trocar Placement, and Docking

Patient is placed supine with the bed flexed at the hip to open the angle between the costal margin and iliac crest. Arms are left out, as tucked arms tend to impair the anterior reach of the robotic arms. For da Vinci(R) Si system (Intuitive Surgical, Sunnyvale CA) users, it is helpful to turn the patients' feet approximately 45° to allow the robotic cart to be brought in from the patients left side more easily. This will likely vary depending on operating room configuration, and certainly if the da Vinci(R) Xi system (Intuitive Surgical, Sunnyvale CA) platform is used. We prefer an optical trocar placement in the right subcostal, anterior axillary line location, with initial trocar placement along the right lateral abdominal wall. Trocars are placed in the lateral abdominal wall, with the camera trocar placed midway between the costal margin and iliac crest near the midaxillary line. The working trocars are placed just off the costal margin superiorly and iliac crest inferiorly near the anterior axillary line. All trocars are long (180 mm), as this increases both the clearance from the patient and surgical table when working anteriorly and increasing the reach of the instruments when completing the contralateral dissection. When docking, the robotic arms should be brought downward parallel to the trocars in their resting position rather than distracting the trocars vertically to meet the robotic arms. This keeps the tip of the trocars away from the viscera to prevent bowel injury. Once docked, the instruments are "burped" up by clutching the robotic arm and elevating the trocar along with the abdominal wall. This maneuver allows the instruments to better reach the anterior abdominal wall.

The robotic cart is brought in on the patients' left side for docking to the trocars placed along the right side. We prefer to place the center column aligned with or just below the inferior-most working trocar. This accomplishes two things: First, this increases the space between the left arm and the robotic cart to allow placement of the left-sided trocars once the initial retromuscular dissection and TAR are completed and for passage of the mesh. Second, the elbows of the robotic arms tend to have greater clearance from each other in this position, resulting in fewer collisions. The camera is oriented with a 30°—upward view.

Positioning: Tips and Tricks (Fig. 19.1)
- Supine
- Arms out
- Bed flexed

Trocar Placement: Tips and Tricks (Fig. 19.2)
- Long (180 mm) trocars.
- Lateral: between anterior and midaxillary line.
- "Burp" trocars up by clutching robotic arm and elevating anteriorly.

Docking: Tips and Tricks (Fig. 19.3)
- Center column aligns with or below lowest trocar.
- Bring robotic arm downward to parallel, rather than trocar up to vertical for docking.

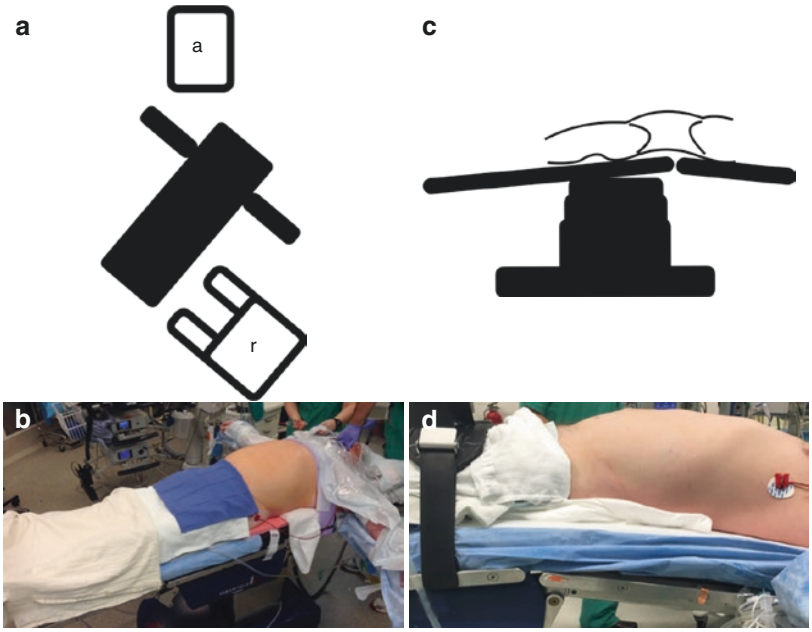


Fig. 19.1 Patient positioning tips and tricks. (**a**) Schematic of operating room setup. Bed is turned approximately 45°, keeping the head near anesthesia; *a* anesthesia cart, *r* robotic cart. (**b**) Operating room setup. (**c**) Schematic of bed position. (**d**) Bed and patient flexed to open the space between the iliac crest and costal margin

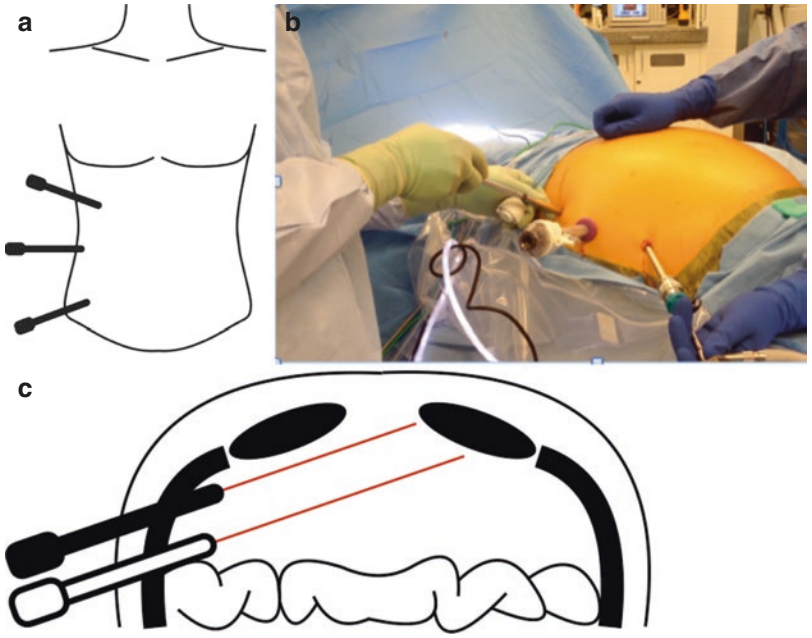


Fig. 19.2 Trocar placement tips and tricks. (**a**) Schematic of trocar placement. Trocars placed laterally between the anterior and midaxillary lines. (**b**) Lateral trocar placement. (**c**) Trocars are "burped" up to allow anterior reach of the robotic instruments (red lines)

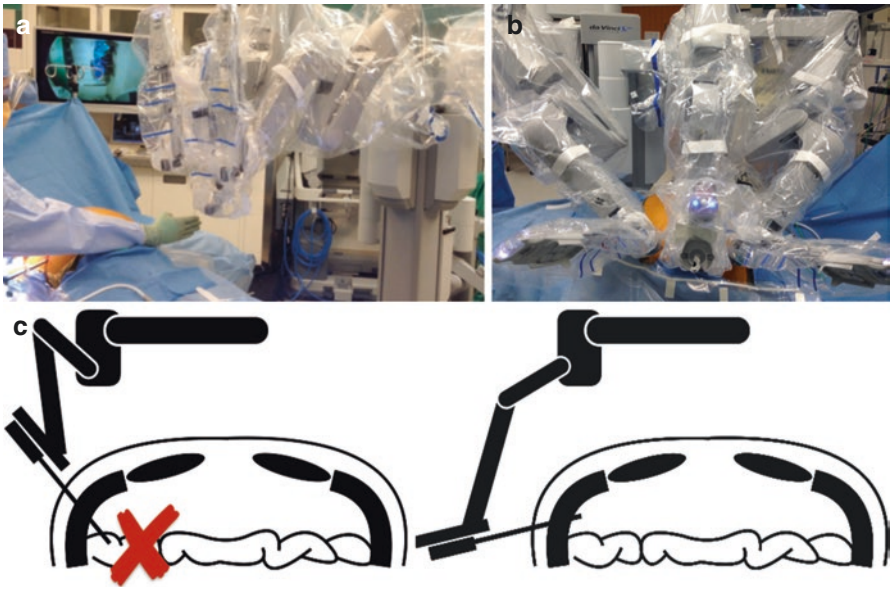


Fig. 19.3 Docking tips and tricks. (**a**) Positioning of the robotic cart. The center column is aligned at or below the lowest trocar. (**b**) Robot docked. (**c**) Schematic demonstrating docking technique. Robotic arms should be brought down to parallel when docking to avoid bowel injury

Retromuscular Dissection

The posterior rectus sheath is incised about 5 mm lateral to the linea alba, typically near the midpoint of the hernia defect. This incision is made longitudinally, exposing the rectus muscle, and extended to, but not yet beyond, the upper and lower limits of the hernia defect. The instruments can then be placed into the retromuscular space, bluntly separating the posterior sheath from the rectus muscle. It is important to maintain the line of incision just off the linea alba and prevent tapering the incision laterally, which would limit the width of posterior sheath available for closure. To avoid this, simply slide the instrument within the posterior sheath medially to the linea alba. The deflection of the instrument will clearly delineate the midline, allowing accurate incision of the posterior sheath. Below the arcuate line, only a thin layer of transversalis fascia attaches to the linea alba, which is taken down easily.

Blunt dissection is used to create the retromuscular space, with minimal need for cautery in most cases. Retraction of the posterior sheath in a medial and dorsal/posterior direction will ensure adequate tension—counter-tension to facilitate blunt separation of the fascia from muscle. Inferiorly, below the arcuate line, it is helpful to incise the transversalis fascia and remain in the preperitoneal plane. This ensures the dissection will remain below the epigastric vessels and is easily continued laterally. The lateral extent of the dissection is the linea semilunaris, where the oblique aponeuroses converge to create the anterior and posterior rectus sheath. This can be identified primarily by visualizing the intercostal neurovascular bundles that penetrate the posterior rectus sheath laterally to innervate the rectus muscle. These run a course in the interparietal plane between the internal oblique and transversus

abdominis muscles and are the critical landmark for initiating the TAR. The semilunar line itself is seen as a thicker, more dense condensation of fascia and will typically reflect the light of the camera more brightly than the surrounding tissue. Additionally, when retracting medially and posteriorly on the posterior rectus sheath at the semilunar line, vertical lines of tension are seen, and the rectus muscle can be observed reflecting downward.

Retromuscular Dissection: Tips and Tricks (Fig. 19.4)

- Identify rectus by visualization or cautery stimulation of muscle.
- Begin posterior sheath incision 5 mm lateral to linea alba.
- Retraction is *medial* and *posterior* on the posterior sheath. Pneumoperitoneum applies anterior retraction on the rectus for counter-tension.
- Blunt dissection.
- Pull instrument medially within the rectus sheath to consistently identify the linea alba and maintain the proper line of posterior sheath incision.
- Linea semilunaris is identified by visualizing intercostal neurovascular bundles, thick condensation of fascia, and a bright reflection from the fascia.

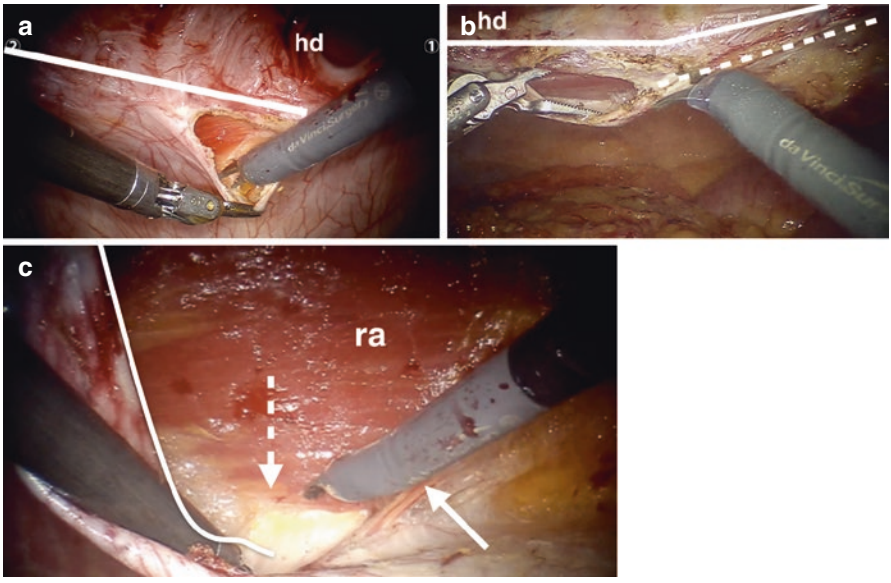


Fig. 19.4 Retromuscular dissection tips and tricks. (**a**) Initial posterior sheath incision; *solid line* linea alba, *hd* hernia defect. (**b**) Using the retracting hand to identify the linea alba and maintain appropriate line of dissection; *solid line* linea alba, *dashed line* line of incision along posterior sheath. (**c**) Extent of lateral retromuscular dissection; *solid line* cut posterior sheath, *solid arrow* segmental neurovascular bundle, *dashed arrow* semilunar line, *ra* rectus abdominis

Midline Dissection

Dissection of the midline superior and inferior to the hernia defect is also of critical importance. First, the retromuscular dissection is continued bluntly above and below the level of the hernia defect without dividing the posterior sheath and peritoneum initially. The posterior sheath joins with fibers from the anterior sheath to create the linea alba, which must remain intact above and below the hernia for a successful repair. There must also be adequate overlap of mesh in either direction to reinforce the defect closure, meaning the separate retromuscular compartments must be joined. This is accomplished by first incising the peritoneum horizontally and separating the peritoneum and preperitoneal fat away from the linea alba. Importantly, when performing this from a lateral docking position, the peritoneal incision runs a vertical course on the screen. Once this space is opened, the posterior rectus sheath can be clearly seen and incised. This leaves the peritoneum attached to the posterior sheath but creates a single space between the preperitoneal and retromuscular compartments. This should be extended at least 5 cm above and below the hernia defect. For hernias located in the epigastrium, dissection is continued into the subxiphoid space, and the retromuscular dissection continued to the costal margin. In the lower abdomen, the space of Retzius is opened, exposing Cooper's ligaments and the pubic symphysis.

Midline Dissection: Tips and Tricks (Fig. 19.5)

- The linea alba *must* remain intact above and below the hernia defect.
- The peritoneum along the midline should remain intact and attached to the posterior sheath on each side above and below the hernia defect.
- The line of incision of the peritoneum is nearly vertical on the screen but anatomically transverse.
- Superiorly, this may extend into the subxiphoid space.
- Inferiorly, this may extend into the space of Retzius.

Transversus Abdominis Release

After completion of the retromuscular dissection, the camera is turned to a 30° downward view for TAR. The TAR involves dividing the musculofascial TA complex from within the posterior rectus sheath to enter the preperitoneal plane, facilitating both mobilization of the anterior fascia and broad mesh overlap. As noted above, the critical landmark for initiating the TAR is the intercostal neurovascular bundles. These run between the internal oblique and transversus abdominis muscles, penetrating the posterior lamina of the internal oblique fascia just medial to the semilunar line and entering the lateral aspect of the rectus muscle. Incision is made just medial to the nerves in a downward direction, opening the posterior lamina of the internal oblique fascia. In the upper abdomen, the TA is now plainly visible and is divided. In the upper

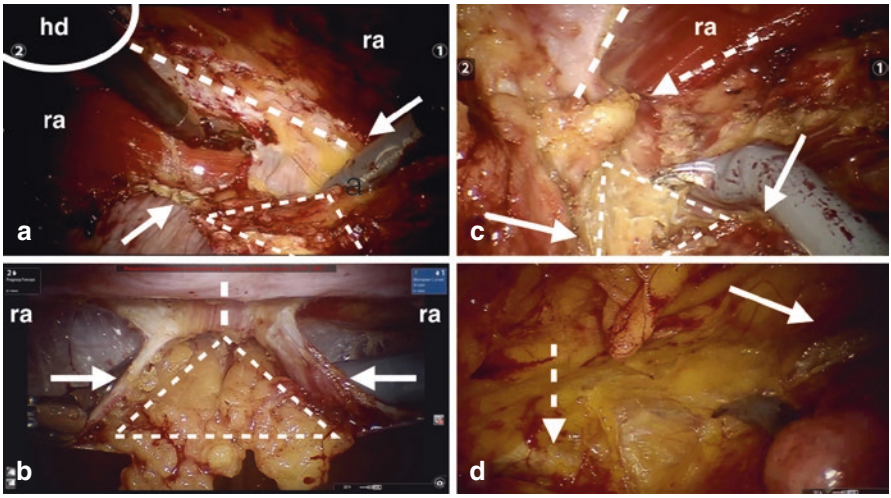


Fig. 19.5 Midline dissection tips and tricks. (**a**) Lateral view of midline dissection cephalad to hernia defect; *solid line/hd* hernia defect, *dashed line* linea alba, *dashed triangle* peritoneum and preperitoneal fat remains attached to posterior sheath and separated away from linea alba, *ra* rectus abdominis. (**b**) Midline view of dissection; *solid arrows* posterior sheath attached to linea alba, *dashed line* linea alba, *dashed triangle* intact peritoneum. (**c**) Subxiphoid space; *dashed line* linea alba, *dashed arrow* xiphoid process, *dashed triangle* intact peritoneum, *solid arrow* posterior sheath (cut). (**d**) Space of Retzius; *dashed arrow* Cooper's ligament, *solid arrow* inferior epigastric vessels

abdomen, the TA extends medially well beyond the semilunar line. As one progresses caudad, the muscle belly becomes increasingly more lateral, leaving only its aponeurotic portion within the posterior rectus sheath. For this reason, we recommend beginning the TAR in the upper abdomen where the TA is easily identified. It is also helpful to score the posterior sheath along the planned line of incision with a wide camera view before bringing the camera closer for the finer dissection. This avoids extending the dissection too lateral, where the semilunar line could be damaged, or too medial, where the peritoneum tends to be thinner and more difficult to dissect. Once the TA is divided, one of two spaces can be entered. Immediately below the TA lies the transversalis fascia. Just below the transversalis fascia is the peritoneum. There are minimal filmy attachments between the peritoneum and transversalis fascia, making separation of this plane possible with only blunt dissection. However, the peritoneum can be quite thin and sometimes difficult to maintain its integrity. Alternatively, the pretransversalis plane can be developed, leaving both peritoneum and transversalis fascia down. Dissection in the pretransversalis plane is slightly more tedious, as the TA is more adherent to the transversalis fascia.

As the TAR progresses inferiorly, the TA layer becomes increasingly aponeurotic, leaving four definable layers: the posterior lamina of the internal oblique, TA aponeurosis, transversalis fascia, and peritoneum. It can be difficult to identify and separate these layers at times. As dissection progresses laterally, if muscle fibers are noted deep to the plane of dissection at any point, then the aponeurosis of the TA was not incised, and the dissection is interparietal (between TA and internal oblique) rather than preperitoneal or pretransversalis. Below the arcuate line, dissection beyond the semilunar

line is easily accomplished with blunt dissection. Care must be taken to avoid the vas deferens and spermatic vessels here. Though we typically advise initiating the TAR more cephalad where the muscle belly is plainly identified, beginning below the arcuate line is also a reliable starting point. The lateral extent of the TAR is typically near the midaxillary line. Typically, once the posterior flap is noted to be lying flat across the viscera, there is no need for further dissection.

TAR Tips and Tricks (Fig. 19.6)

- Dissection begins *medial* to the intercostal neurovascular bundles.
- Recommend beginning in the upper abdomen, where the TA muscle makes up a significant portion of the posterior sheath. This serves as a reliable landmark to enter the correct preperitoneal plane.

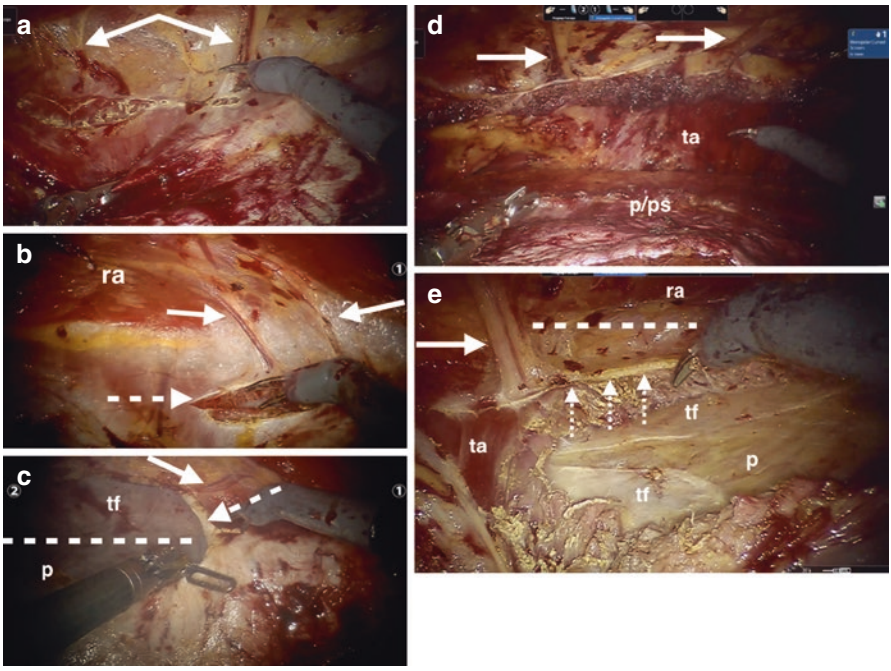


Fig. 19.6 TAR tips and tricks. (**a**) Scoring the planned line of incision through the posterior sheath and TA. Line of incision is *medial* to the neurovascular bundles (*solid* arrows). (**b**) TAR performed by incising posterior lamina of internal oblique and TA muscle (*dashed arrow) medial* to the neurovascular bundles (*solid arrows*); *ra* rectus abdominis. (**c**) Continuation of the TAR *medial* to the neurovascular bundles (*solid arrow*) through the aponeurotic portion of the TA (*dashed arrow*); *dashed line* junction of peritoneum (*p*) and transversalis fascia (*tf*). (**d**) Completed TAR. The posterior sheath and peritoneum (*p/ps*) lie flat across the viscera, and the TA fibers are seen along the lateral abdominal wall (*ta*); *solid arrows* intact neurovascular bundles. (**e**) Demonstrating the four layers of the posterior rectus sheath; *dashed arrows* posterior lamina of the internal oblique, *ta* transversus abdominis muscle, *tf* transversalis fascia, *p* peritoneum, *solid arrow* neurovascular bundle, *dashed line* semilunar line, *ra* rectus abdominis

- There are *four* layers that make up the posterior sheath: Posterior lamella of the internal oblique, TA muscle or aponeurosis, transversalis fascia, and peritoneum.
- Below the arcuate line, only transversalis fascia and peritoneum are present.
- It is helpful to score the fascia along the planned line of incision to keep proper orientation and avoid extending the dissection too lateral, where the semilunar line could be damaged, or too medial, where the peritoneum tends to be thinner and more difficult to dissect.
- Pretransversalis or preperitoneal planes are appropriate.
- If muscle fibers are seen deep to the plane of dissection at any point, you are in the wrong layer.
- Medial and downward retraction.
- Avoid grasping peritoneum if possible to minimize risk of tearing.
- Extend laterally until the posterior flap lays flat across the viscera.
- Close any defects in the posterior sheath created during dissection.

Contralateral Port Placement, Measuring and Mesh Placement

Once the retromuscular and TAR dissections are completed, three new trocars are placed in the left lateral abdomen in mirror image to the initially placed trocars. These are placed under direct visualization directly into the dissected preperitoneal space. Once in place, a metric ruler is passed, the camera is reoriented to 30° up, and the hernia defect height and width is measured. The vertical length of the dissection is measured at the midline, which should be at least 5 cm above and below the hernia defect. Additional dissection can easily be done at this time if necessary. This will be the vertical dimension of the mesh. To determine the horizontal dimension, the distance from the left lateral abdominal wall to the left edge of the hernia defect is measured. This is best accomplished by laying the ruler down across the posterior sheath and then placing a spinal needle through the left edge of the hernia defect perpendicular to the abdominal wall and down to the level of the ruler and posterior sheath. Measuring along the curve of the abdominal wall will significantly overestimate the width of mesh needed, as will measuring from the midpoint of the hernia defect, as this will later be closed. The distance measured is equal to half of the mesh width required.

Once the appropriate measurements are made, the appropriate mesh is selected. We recommend using a bare, mid-weight, large-pore polypropylene mesh. This is cut to the appropriate size to fill the dissected space. The mesh is marked with a permanent marker horizontally at the midpoint of the mesh and then rolled along its vertical axis, leaving 3–4 cm unrolled that will be used to secure the mesh to the lateral abdominal wall. The rolled mesh is then secured loosely to itself with an absorbable suture, preferably dyed for ease of later identification, placed 2–3 cm off the midpoint of the mesh.

The mesh is brought into the dissected space, oriented properly, and the tail is fixed to the left lateral abdominal wall lateral to the new trocars. We prefer absorbable suture fixation at two or three points to ensure proper alignment of the mesh when is deployed later in the case.

Contralateral Port Placement Tips and Tricks (Fig. 19.7)

- Mirror image to initially placed trocars.
- Place directly into preperitoneal space.

Measuring Tips and Tricks (Fig. 19.8)

- Measure along the midline above and below the hernia defect to ensure adequate overlap (at least 5 cm).

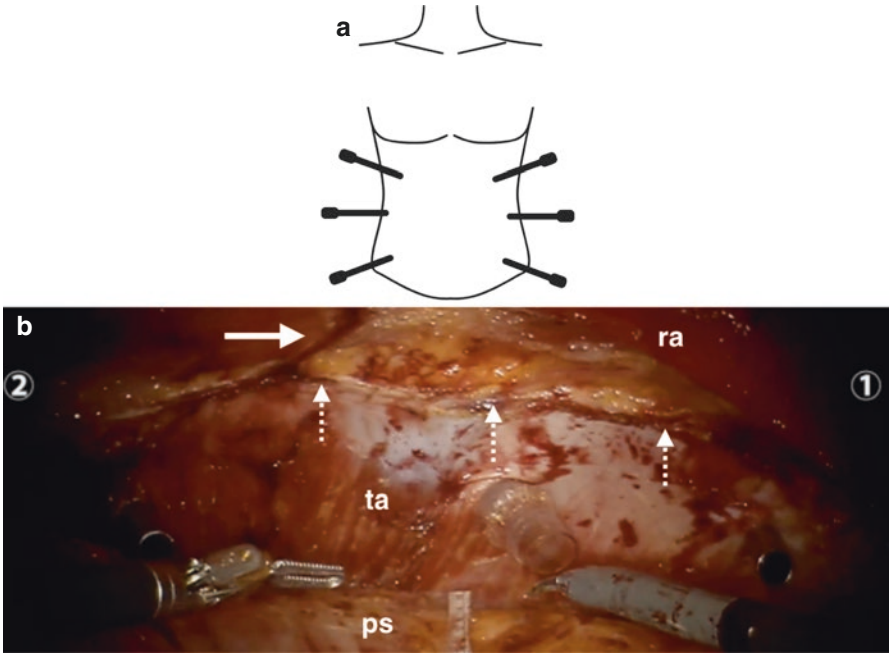


Fig. 19.7 Contralateral port placement tips and tricks. (**a**) Contralateral ports are placed in mirror image to the initial trocars. (**b**) Operative view of contralateral ports; *ra* rectus abdominis, *solid arrow* neurovascular bundles, *dashed arrows* cut edge of TA, *ta* transversus abdominis muscle, *ps* posterior sheath/peritoneal flap

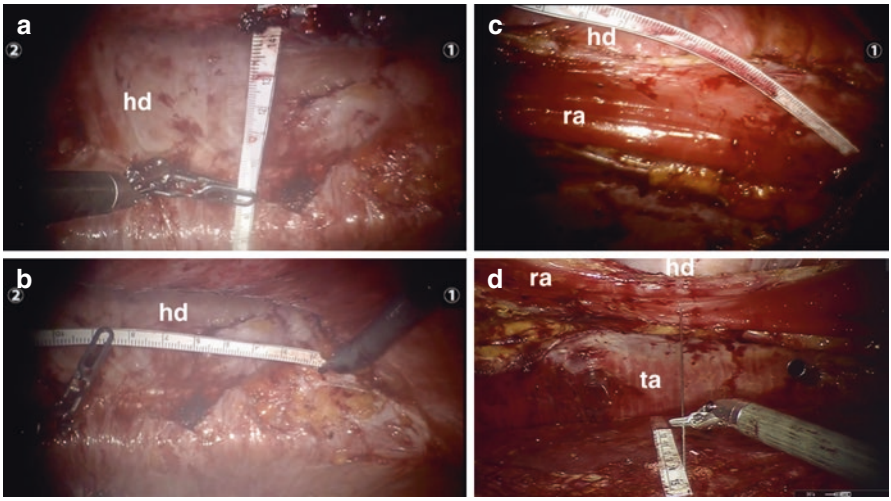


Fig. 19.8 Measuring tips and tricks. (**a**) Metric ruler used to measure the hernia (hd) width. (**b**) Measuring the hernia height. (**c**) Measuring the vertical dimension of the dissected space, ensuring at least 5 cm overlap above and below the hernia defect. This will be the vertical length of the mesh. *ra* rectus abdominis. (**d**) Measuring the horizontal dimension of the dissected space. A spinal needle is passed through the edge of the hernia defect perpendicular to the ruler, which lays flat across the posterior sheath. This will be *half* the width of the mesh needed. *ta* transversus abdominis

- Measure the width of the mesh by placing the ruler down on the dissected posterior sheath, and place a spinal needle vertically through the contralateral edge of the hernia defect.
- Remember, the hernia defect will be closed, so measure from the edge, not the middle.
- Measuring along the abdominal wall will overestimate the size of mesh needed due to the effect of pneumoperitoneum.
- Measured width is half the final width of mesh needed.

Mesh Placement Tips and Tricks (Fig. 19.9)

- Cut the mesh to the size measured.
- Roll the mesh in a single scroll fashion along the vertical axis.
- Leave a 3–4 cm tail for fixation to the lateral abdominal wall and for easier retrieval of the mesh later.
- Secure mesh to itself with a dyed, loosely tied suture.
- Secure mesh lateral to the newly placed trocars.

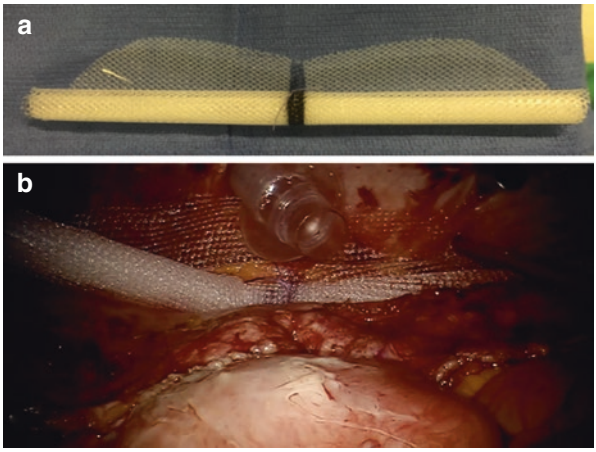


Fig. 19.9 Mesh placement tips and tricks. (**a**) Mesh is rolled in a single scroll fashion, leaving a 3–4 cm tail and marking along the midpoint of the vertical axis to ensure proper orientation when deploying. Secure with a single absorbable suture. (**b**) Mesh is placed lateral to the newly placed trocars and secured to the abdominal wall

Double Dock, Contralateral Dissection

At this point, the robot is undocked from the right side and redocked on the left. For Si users, this involves turning the patients' feet 90° (45° in the opposite direction of initial setup) in order to bring the robotic cart in on the patients' right side. Turning in this manner keeps the head of the bed with anesthesia, minimizing risk to the airway. For Xi users, this step is unnecessary and the arms can simply be rotated on the boom. In either case, once the robot is redocked, dissection is performed on the right side in the same manner as on the left. There are a few points of difference that should be noted. First, the midline dissection can be readily extended at this point if needed. Any remaining peritoneum along the midline is actually easier to visualize now, as a portion of it has already been dissected down with the left posterior rectus sheath. The incision of the posterior sheath above and below the defect should be extended on the right side to the same level as on the left. Once completed, this should leave a segment of peritoneum extending from the linea alba toward the hernia defect and still attached to the posterior sheath on each side.

Secondly, the initially placed right lateral trocars will be brought back into the TAR plane as the dissection extends laterally. As the dissection approaches the trocars, a bedside assistant should stand the trocars up vertically to keep from elevating the peritoneum and obscuring the plane. Once the dissection reaches the trocar as it passes through the peritoneum, it is simply redirected into the preperitoneal space and dissection continues beyond the trocar as far as necessary.

Double Dock Tips and Tricks (Figs. 19.10 and 19.11)

- Keep the head of patient with anesthesia and swing feet 90^0.
- Initially placed trocars should be brought into the dissected space.

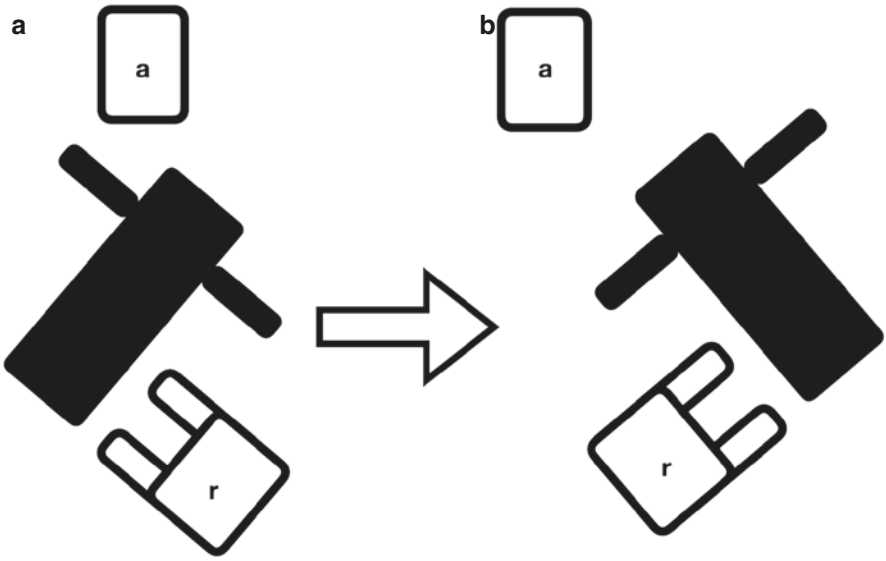


Fig. 19.10 Double-docking tips and tricks. (**a**) Initial patient positioning. (**b**) New patient positioning. The foot of the operating table is turned approximately 90°, leaving the patient's head near anesthesia cart (*a*), and robotic cart (*r*) is brought around to the other side of the patient for docking

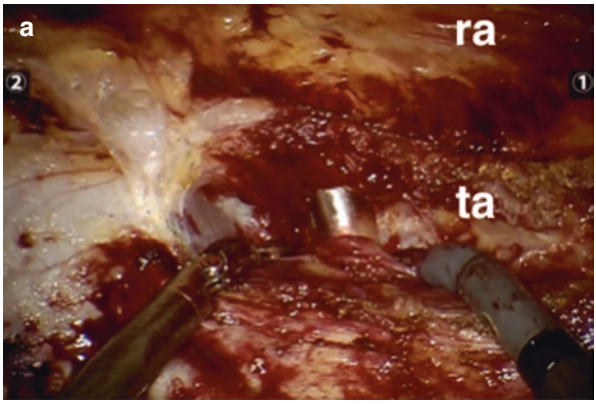


Fig. 19.11 Contralateral dissection tips and tricks. (**a**) Initially placed trocars will be encountered during TAR; *ra* rectus abdominis, *ta* transversus abdominis. (**b**) Trocars are pulled back and brought into the newly dissected space. (**c**) Elevating the trocar against the abdominal wall allows dissection to easily progress beyond the trocar

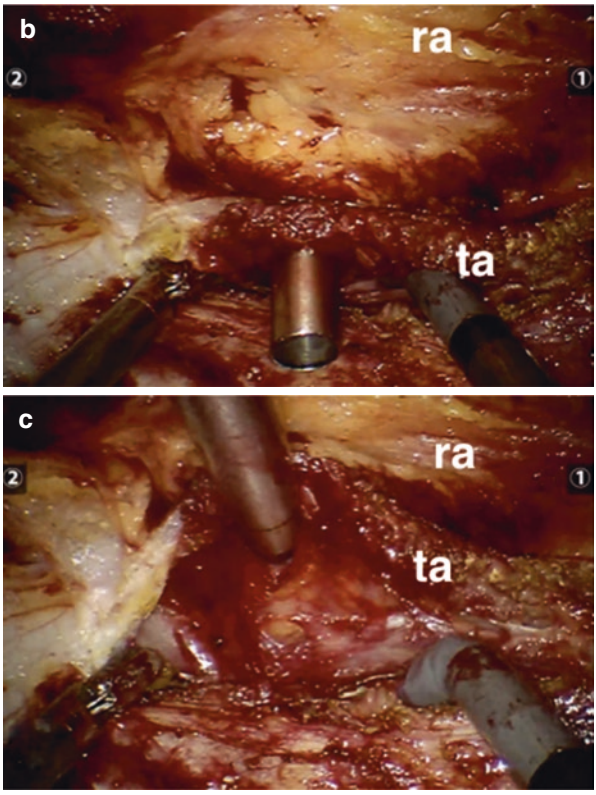


Fig. 19.11 (continued)

- Stand trocars vertically, pull back, the readvance through the peritoneal defect into the preperitoneal space.
- Close peritoneal defects from initial trocars.

Posterior Sheath Closure, Mesh Deployment, and Defect Closure

Now that the dissection is completed, the posterior rectus sheath is closed. We prefer an absorbable, self-fixating 2-0 suture sewn in a running fashion. Any significant (>1 cm) defects in the posterior sheath or peritoneum should be closed using absorbable suture. Once the posterior sheath is closed, the mesh, which is now lying under the trocars currently in use, is retrieved by pulling back the scrolled portion and breaking or cutting the suture holding it in place. The mesh is then rolled across the closed posterior sheath and affixed in similar fashion to the right lateral abdominal wall. If the mesh is found to be too long for the dissected space, it can be easily

trimmed and excess removed. Should it be too short, proceed with closure of the defect, which will likely then allow the mesh to reach.

The hernia defect is now closed. We prefer a self-fixating, absorbable suture in a running fashion. Stratafix™ Symmetric (Ethicon) is preferred, as this is currently the only self-fixating suture given a fascial closure indication and, in our experience, performs much better for closure of larger hernia defects. Multiple bites of the hernia sac are included with the fascial closure to imbricate the tissue and decrease the dead space. It can be difficult to identify the fascial edge on the ipsilateral side. The muscle can sometimes simply be pushed aside to view the fascia for closure. If still not plainly visible, the needle can be passed above the rectus and engage the overlying tissue, which can be visualized by deflection of the muscle, and then pulled medially; the needle will bring the fascial edge into view for closure. Finally, if unsure if the fascia is included in the suture, grasping both ends of the needle while engaged through the tissue and pulling medially will ensure that an adequate fascial bite was taken; if the bite includes only muscle, it will pull through easily.

In order to maintain the loop of the suture and avoid tangling, retrieve the needle and immediately begin the next throw, leaving the needle through the fascia only, and then proceed to pull the suture through. It is helpful to pull downward on the suture with one hand and sweep laterally with the other to more rapidly pull the suture through. Then complete the throw and begin the next. Once the defect is closed, the abdomen is desufflated and trocars removed. Trocar site fascia is not closed, as mesh covers each trocar site.

Posterior Sheath Closure Tips and Tricks (Fig. 19.12)

- 2-0 absorbable self-fixating suture.
- Close any defects made in the posterior sheath or peritoneum.
- Closure does not need to extend as far as the dissection along the midline—only as far as the level of peritoneum remaining attached to the posterior sheath.

Mesh Deployment Tips and Tricks (Fig. 19.13)

- Mesh is located below and lateral to the trocars you are currently working from.
- The 3–4 cm tail left after scrolling the mesh facilitates mesh retrieval.
- If the mesh fails to fully reach the contralateral abdominal wall, close the anterior defect and then reassess.

Defect Closure Tips and Tricks (Fig. 19.14)

- Absorbable, self-fixating suture. Recommend Stratafix™ Symmetric for larger defects, as this is currently the only available self-fixating suture with indication for fascial closure.

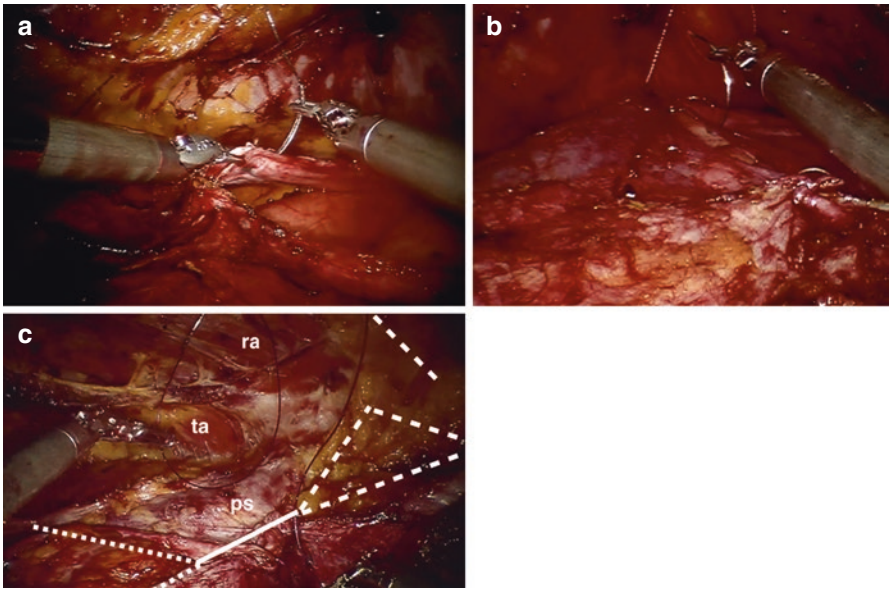


Fig. 19.12 Posterior sheath closure tips and tricks. (**a**) The cut edges are easily identified and lie below the robotic instruments over the viscera. Closure proceeds using a self-fixating absorbable suture. (**b**) Any defects made during TAR, including initial trocar sites, are closed with absorbable suture. (**c**) Posterior sheath closure begins (and ends) at the level where the peritoneum was left intact (*dashed triangle*) above and below the hernia defect; *dashed line* linea alba, *solid line* closed portion of posterior sheath, *dotted lines* cut edge of posterior sheath to be closed, *ra* rectus abdominis, *ta* transversus abdominis, *ps* posterior sheath

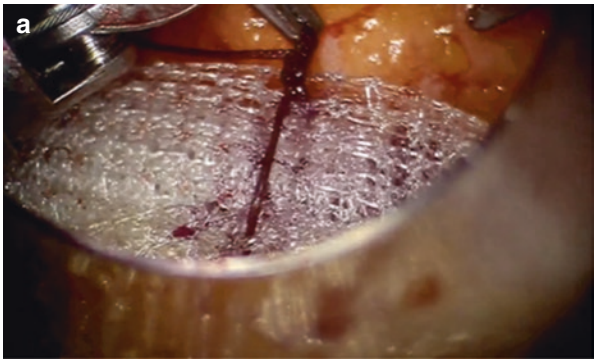
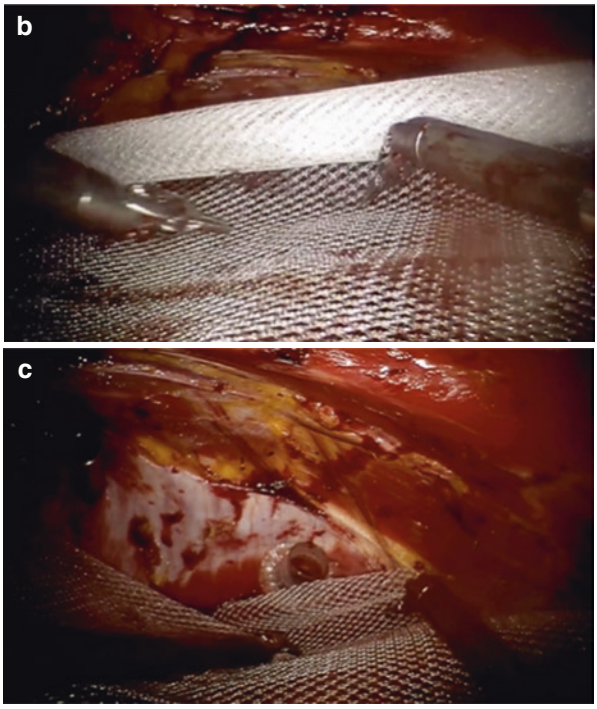


Fig. 19.13 Mesh deployment tips and tricks. (**a**) Mesh is located below the robotic instruments and camera. First, identify the stay suture keeping the mesh scrolled. (**b**) Unroll the mesh across the closed posterior sheath. (**c**) Mesh should reach just beyond the contralateral trocars to the abdominal wall

Fig. 19.13 (continued)



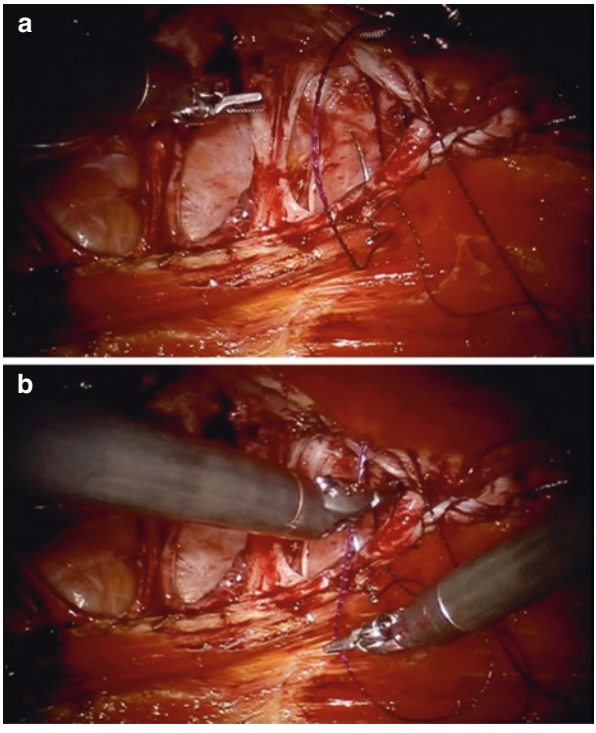
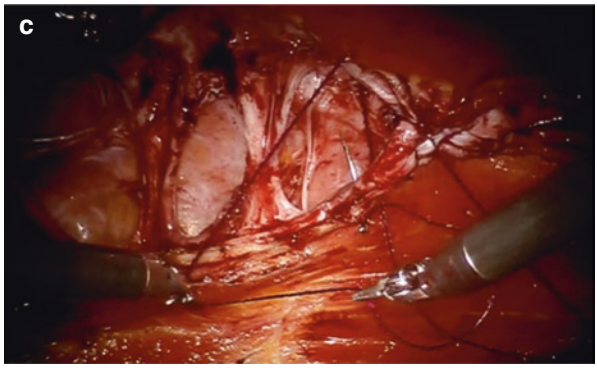


Fig. 19.14 Defect closure tips and tricks. (**a**) Self-fixating, absorbable suture used for closure. In order to control the loop of the suture, make the initial needle throw before pulling the suture through. To more rapidly advance the suture, first pull downward with one hand (**b**), and then sweep laterally with the other (**c**)

Fig. 19.14 (continued)



- Make sure to clearly identify the fascia when closing.
- Begin the next throw before pulling the suture through to control the loop and prevent tangling.
- Pull suture downward with one hand and sweep laterally with the second to progress suture more quickly.
- Include bites of the hernia sac to imbricate the tissue and decrease the dead space.
- Decrease pneumoperitoneum.

Outcomes of rTAR

To date, three studies have been published on this technique. The first reported outcomes of robotic RM repair with or without TAR compared to standard laparoscopy [3]. The operative time was significantly longer for rVHR, and there was a significantly higher rate of surgical site occurrences (SSO), primarily seroma, following robotic repair. Despite the significant difference in complexity and the extent of musculofascial dissection with rVHR, the median length of stay was still reduced compared to standard LVHR. In the largest report of robotic RM VHR to date, open RM repair was compared to robot VHR using a propensity score matched cohort from the AHSQC [2]. Robotic VHR resulted in a shorter median length of stay. Fewer surgical site infections (SSI) were also noted, though this did not reach statistical significance. Finally, the most recent published study compares open to robotic TAR, again demonstrating a significantly shorter length of stay. This study similarly reported a decreased rate of SSI, but was not statistically significant. Table 19.1 summarizes the current literature on rTAR.

Table 19.1 Summary of rTAR outcomes in the published literature

Author (year)	*n*	Comparison group	rTAR SSI (%)	Comparison group SSI (%)	rTAR LOS (days)	Comparison group LOS (days)
Warren (2016)	53	LVHR ($n = 103$)	2(3.7%)	1(1%)	1*	2*
Carbonell (2017)	111	ORVHR ($n = 222$)	9 (4%)	2 (2%)	2*	3*
Martin-del-Campo (2017)	38	OTAR ($n = 76$)	0 (0%)	5 (6.6%)	1.3*	6*

rTAR robotic transversus abdominis release, *SSI* surgical site infection, *LOS* length of stay, *LVHR* laparoscopic ventral hernia repair, *ORVHR* open retromuscular ventral hernia repair, *OTAR* open transversus abdominis release

Future of rVHR

Robotic retromuscular VHR with or without TAR affords the ability to reestablish the functional anatomy of the abdominal wall, reinforcing the closure with mesh in an extraperitoneal sublay position. The optimal patient selection for this technique or its variants has yet to be fully determined. The extensive dissection of a TAR is clearly unnecessary for small hernias, and the promising early results may or may not hold true for significantly larger defects in high-risk patients. Ongoing clinical trials hope to address this issue (clinicaltrials.gov, NCT03007758). Several variations on the above technique have also been used, including a single-dock method that begins at the lateral aspect of the ipsilateral rectus sheath and then extends across the midline [3], placing trocars in the upper or lower abdomen in a single-dock approach [6, 8], or an extended totally extraperitoneal (eTEP) approach [9]. While early published results of rVHR are quite promising, continuous and critical evaluation of this technology in hernia repair is needed to gain better understanding of optimal patient selection, approach, and patient outcomes.

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Ventral Abdominal Hernia Repair: MIS Extraperitoneal Repair Techniques: eTEP Rives, MILOS/EMILOS, and Onlay MIS Repair

20

Flavio Malcher Martins de Oliveira, Leandro Totti Cavazzola, Adam S. Weltz, and Igor Belyansky

Introduction

Minimally invasive surgery (MIS) ventral hernia repairs were first described by Le Blanc in 1993 with the laparoscopic approach and an intraperitoneal onlay mesh (IPOM) implant. The use of IPOM was never the gold standard in open ventral hernia repairs because of the fear of placing uncoated mesh materials in direct contact with abdominal viscera [1]. The development of laparoscopic techniques included several modifications such as the use of new coated meshes, new fixation devices, and, perhaps most importantly, changes in surgical technique. These technical changes included the abandonment of the traditional onlay and retromuscular/preperitoneal options. The intraperitoneal era had begun. Laparoscopic techniques have proven themselves in the last 20 years as safe and effective treatments for ventral hernias, despite increased rates of intra-abdominal complications [2].

The adoption of laparoscopic repairs plateaued at approximately 20% of all ventral hernia repairs, despite their noted benefits. Several reasons have been postulated, such as increased cost (fixation devices) and difficult learning curve.

Advances in MIS ventral hernia repair, such as the robotic platform, have enhanced the ability to operate on the abdominal wall through fully articulated

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instruments and improved optics and visualization. Surgeons quickly began performing MIS repairs without IPOM, returning to traditional techniques such as onlay and sublay. After robotic surgery ushered this trend, several MIS surgeons without robotic access began performing these techniques using traditional laparoscopic/endoscopic instruments. In this chapter, we will explore several of these extraperitoneal techniques.

eTEP

Preoperative Planning and Considerations

All potential minimally invasive abdominal wall reconstruction candidates must undergo a comprehensive workup to ensure they are appropriately selected for surgery. This includes a comprehensive past medical and surgical history, physical exam, and laboratory testing with emphasis placed on screening for absolute and relative contraindications to the eTEP approach (Table 20.1). An up-to-date computed tomography study of the abdomen and pelvis is recommended for effective preoperative planning [3]. All major comorbidities must be addressed by means of a multidisciplinary approach before proceeding to the operating room. Preoperative antibiotics should be properly selected and dosed according to hospital protocol [3, 4]. We recommend routine administration of subcutaneous heparin for DVT prophylaxis in our patient population, beginning prior to the induction of anesthesia and administered throughout the typical duration of the procedure [5, 6].

Operating Room Setup and Patient Positioning

After induction of general anesthesia, all patients are positioned supine with arms tucked to the side. A Foley catheter is placed to decompress the bladder. The operating table is flexed with the legs extending downward at a minimum of 30° to afford the surgeon greater instrument range of motion (Fig. 20.1). Failure to sufficiently flex the operating table will result in hand collisions with the patient's body during dissection.

The enhanced-view totally extraperitoneal (eTEP) access approach was previously described for laparoscopic inguinal hernia repair by Daes in 2012 [7]. This approach introduced the notion that the extraperitoneal domain is a limitless space

Table 20.1 Absolute and relative contraindications to eTEP approach

Relative	Absolute
Previous incision extending from xiphoid process to the pubic bone	Active mesh infection
Loss of domain	Presence of fistula
Dystrophic or ulcerated skin	
Extensive intra-abdominal adhesions	

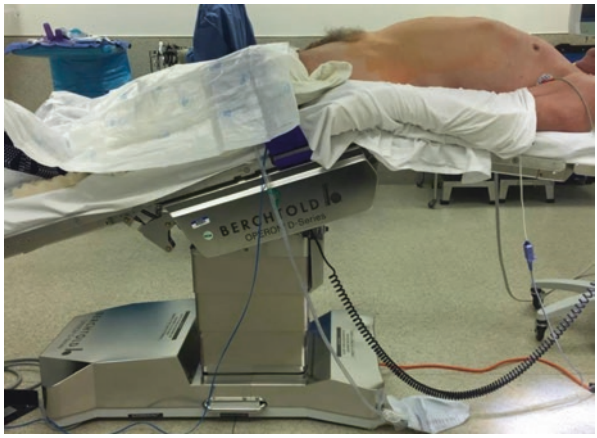

Fig. 20.1 Positioning of the patient for laparoscopic eTEP. Patient is in Trendelenburg position with hips extended. Bed flexion is best avoided

once the confluence of arcuate line and semilunar line is taken down. This technique relies on proper anatomic identification and dissection in the naturally occurring retromuscular spaces. Typically, dissection is initiated in one of the retrorectus spaces and then crossed over to the contralateral side, thus joining the two spaces into one large operative field. Since Daes' initial description, we have adopted this technique for ventral and incisional hernia repair [7, 8].

Positioning of the surgeon, monitor, and trocars are dependent on the location of the hernia defect and decision where to cross the midline. Monitors are placed at the head of the bed with trocar sites on the lower abdomen when addressing an upper midline hernia defect and inverted in instances of lower midline hernia defects.

Upper Midline Defect

Figure 20.2 demonstrates the port position for upper midline defects. The first incision is made 2 cm bellow a horizontal line drawn through umbilicus just medial to the right linea semilunaris. The anterior rectus sheath is identified and incised sharply. Single site balloon dissector is used to develop the right retrorectus space in cephalad and caudal directions. It is critical to avoid over-inflation which may rupture the linea semilunaris and consequently injure the rectus abdominis muscle. In addition, special care should be given to appreciating the inferior epigastric vessels that travel parallel and medial to the linea semilunaris in the vicinity of the #1 port. Once the space of Retzius is developed, ports #2 and #3 are placed under direct vision in the lower abdomen. The site of port #3 can also be used to pass the balloon space-maker in a cephalad direction to develop the left retrorectus space. Thus, even before any initiation of sharp dissection, the retromuscular space surrounding the hernia defect is completely dissected bluntly with the balloon space-maker.

We prefer to perform the crossover below the level of the umbilicus, developing preperitoneal and retromuscular spaces that have not been previously violated. A 30° scope is placed through port #3 after which we proceed with division of the

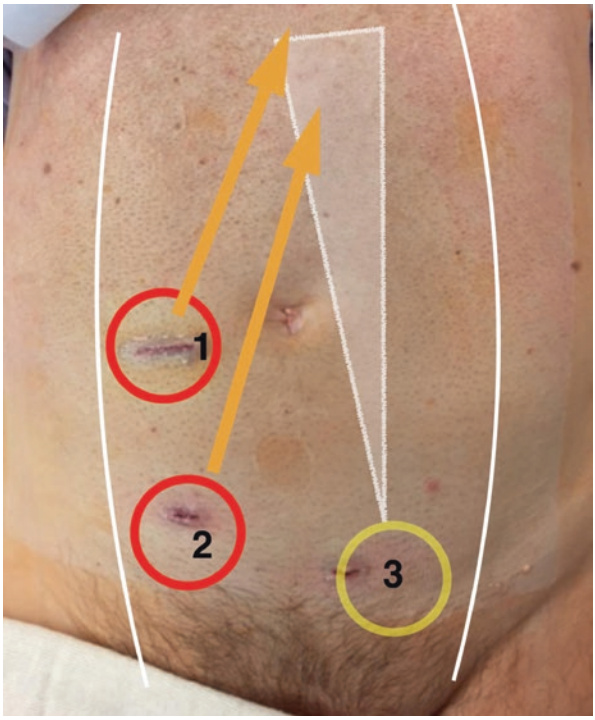

Fig. 20.2 Port positioning for upper midline defects. The balloon dissector is placed in port #1. Ports #2 and #3 are positioned under direct vision. The arrows show the working instruments with the camera vision demonstrated by the white triangle

medial contributions of the posterior rectus sheath to the linea alba bilaterally from caudal to cephalad direction. In the middle we try to preserve the preperitoneal contributions to the posterior layer which are made up of the falciform and umbilical ligaments. In such a fashion, the division of posterior rectus sheath and preservation of falciform ligament and umbilical ligaments allow us to join the right and the left retrorectus spaces together with the midline preperitoneal space (Fig. 20.3).

Following the dissection in these planes, we then anticipate to encounter the neck of the hernia sac. In an incisional hernia, these layers surrounding the neck of the sack can be thoroughly fused together and difficult to differentiate. An attempt may be made in some cases to reduce the entirety of the sac by separating it from its distal attachments; however this is not often attempted. We frequently give consideration to sharply opening the peritoneal layer just proximal to the neck of the sac to reduce visceral contents under direct visualization and perform limited adhesiolysis (Fig. 20.4). Any defects in the posterior layer can be fixed with running suture. Once the hernia contents are reduced, retromuscular dissection commences with release of the medial aspect of the posterior rectus sheath and concludes just below the level of the xiphoid process.

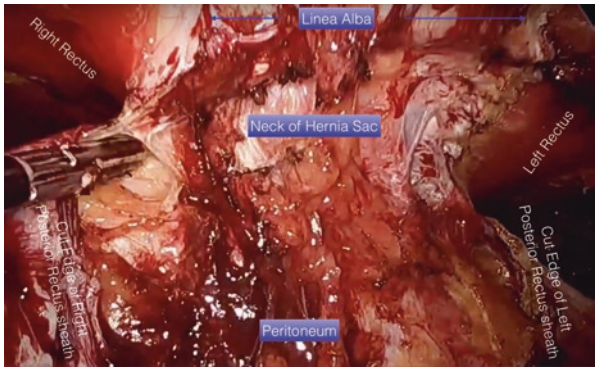

Fig. 20.3 View of the retrorectus space. After crossing over and dissection, the retrorectus spaces on both sides are combined into one large retrorectus space. This falciform ligament can be seen below

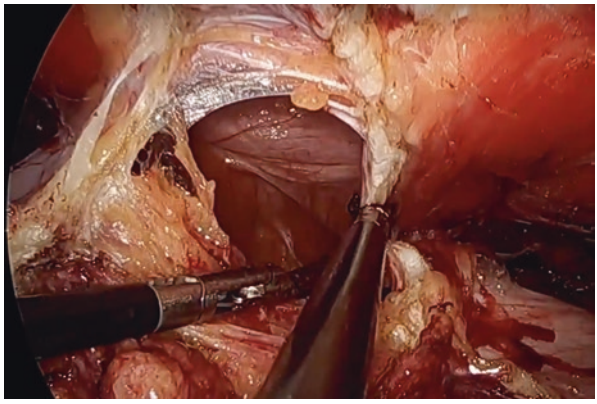

Fig. 20.4 Sharp opening of the peritoneal layer proximal to the neck of the hernia sac, allowing for reducing visceral contents under direct visualization and limited adhesiolysis

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 20.5 demonstrates the typical port position that we chose to use for this approach. Balloon dissector is used at port position #1 to develop the left retrorectus space, followed by direct visualization for placement of port #2 into the developed space with an optional port #3. Blunt dissection in the left retrorectus space is performed in a caudal direction and the pubis is identified. As the upper midline has not previously been violated above the level of umbilicus, the medial aspect of the left posterior rectus sheath is incised and the preperitoneal space entered just superficial to falciform ligament (Fig. 20.6). The right posterior rectus sheath is identified and its medial aspect incised and released in a cephalad to caudal direction followed by blunt dissection in the right retrorectus space (Fig. 20.7). Port #4 is then placed under direct vision through the upper aspect of right rectus abdominis muscle which is then used as the camera port. The retrorectus dissection is carried out in the caudal direction completing bilateral release of the posterior rectus sheathes. When encountering the hernia sac, we try to

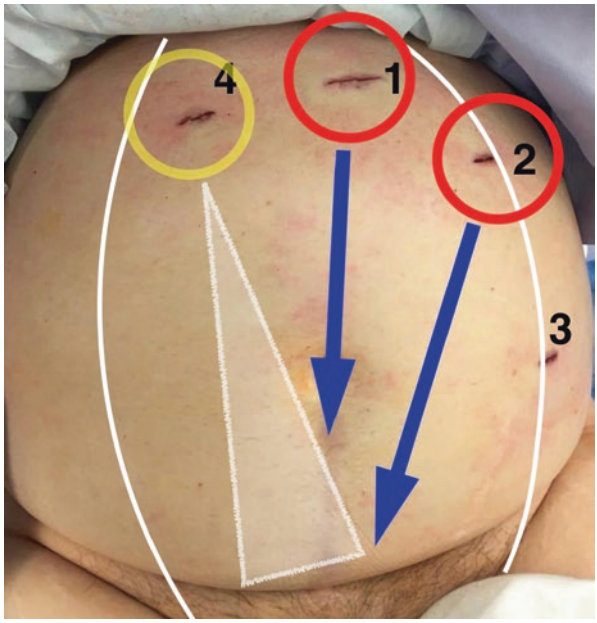

Fig. 20.5 Port placement for a right-handed surgeon addressing a lower midline defects. We initiate the dissection in the upper portion of left retrorectus space. Balloon dissector is used at port position #1 to develop the left retrorectus space, followed by direct visualization for placement of port #2 into the developed space with an optional port #3. Port #4 is used as a camera port

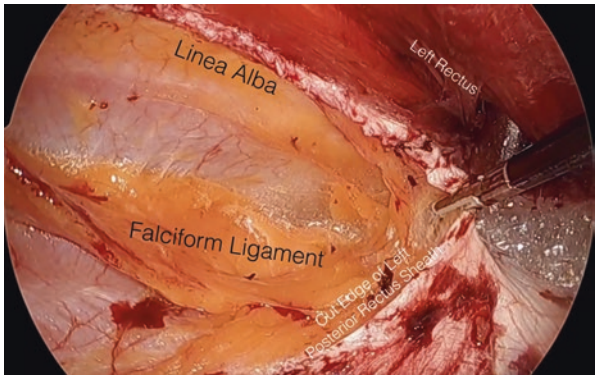

Fig. 20.6 Medial aspect of the left posterior rectus sheath is incised and the preperitoneal space entered just superficial to falciform ligament

sharply dissect the distal attachments, thus mobilizing it downward. Alternatively, the sac can be sharply entered and laparoscopic adhesiolysis performed as needed.

Transversus Abdominis Release (TAR)

For more complex defects that require large mesh placement, the TAR procedure is added [9, 10]. We have found that incorporation of TAR is beneficial in cases with wide (>10 cm) defects, narrow (<5 cm) retrorectus spaces, or when dealing

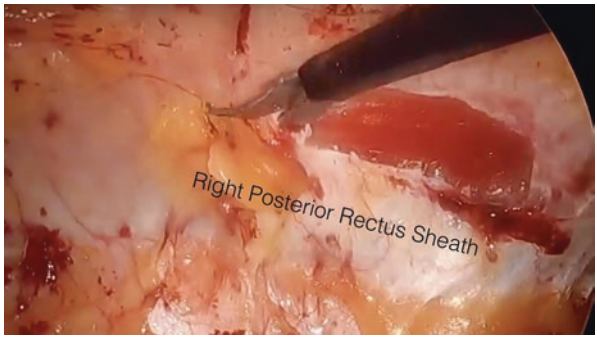

Fig. 20.7 The right posterior rectus sheath is identified and its medial aspect incised and then released in a cephalad to caudal direction followed by blunt dissection in the right retrorectus space

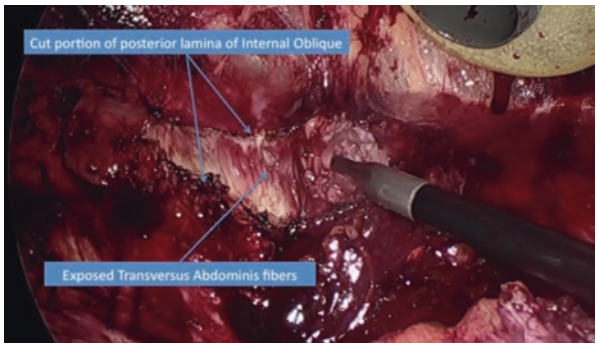

Fig. 20.8 The cut edge of PRS is retracted medially revealing the posterior lamina of the internal oblique muscle, a thin layer of connective tissue covering. Once identified and incised with hook electrocautery, the transversus abdominis muscle fibers can be appreciated

with a poorly compliant abdominal wall. Any defects in the posterior layer are closed with 2-0 absorbable suture. The abdominal wall defect is primarily closed using 0 barbed suture in running fashion, while pneumoperitoneum is dropped to 8 mmHg.

For defects wider than 10 cm, primary fascial closure can rarely be achieved under physiologic tension unless additional component separation in the form of TAR is added to the procedure. The edge of the cut posterior rectus sheath (PRS) on one side is retracted medially, and a thin, almost transparent layer of connective tissue that covers the transversus fibers is identified as the posterior lamina of the internal oblique muscle and incised with hook electrocautery, thus exposing the transversus abdominis muscle fibers (Fig. 20.8). Care must be taken to stay medial to the perforating nerves and vessels at the linea semilunaris to maintain functional segmental innervation to the rectus (Fig. 20.9). Hook cautery is used to elevate and transect the exposed transversus fibers, revealing the glistening transversalis fascia underneath. This is continued from cephalad to caudad until the transversalis fascia is seen as a glistening line extending the entire craniocaudal length of the abdominal wall. Blunt dissection is now used to develop the plane just deeper to the transversus muscle fibers and superficial to the transversalis fascia resulting in a retromuscular preperitoneal plane, thereby achieving TAR (Fig. 20.10). The plane can be extended in the lateral direction as far as

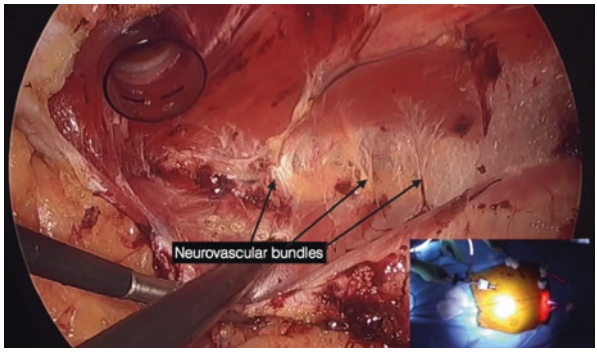

Fig. 20.9 When incising the lateral edge of the PRS sheath to expose the transversus abdominis, care must be taken to prevent injury to the neurovascular bundles near the linea semilunaris

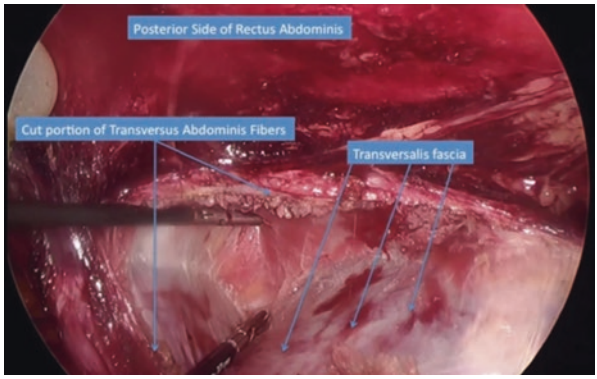

Fig. 20.10 The transversalis fascia is separated from the transversus abdominis by blunt dissection achieving TAR

the midaxillary line. A unilateral TAR can achieve as much as 7 cm of medial fascial mobilization at the level of the umbilicus. Bilateral TAR can be performed as needed.

Closure

Posterior layer: The edges of the PRS are sutured together in the midline with 2-0 absorbable or barbed suture starting near the xiphoid process running caudally. Starting at the dome of the bladder, the surgeon and assistant switch positions, and suture is run cranially, meeting in the middle where the two sutures are tied together.

Anterior layer: Pneumoperitoneum is dropped to 8–10 mmHg to decrease the tension placed on the anterior layer closure. The defect being closed is at the top of the monitor and is sutured "upside down" with back-handed needle driving. A 0 barbed suture is used for this closure due to technical ease of use afforded in this situation. If a large subcutaneous sac is present, one or more bites of the sac are included in the suture line for plication in order to reduce the likelihood of developing a postoperative seroma (Fig. 20.11). With the previously performed posterior

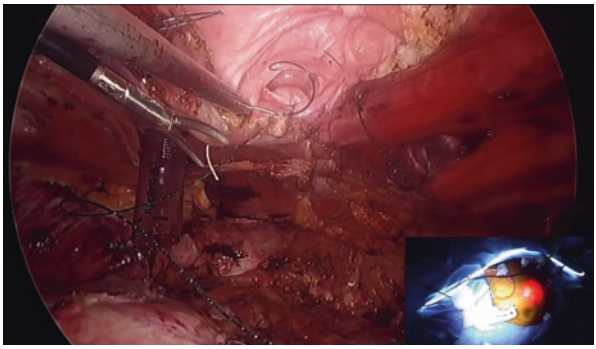

Fig. 20.11 Closure of the anterior layer. A 0 barbed suture is used in a back-handed fashion with an "upside down" view to take bites of the edges of the defect while including the sac (if a large subcutaneous portion is present) in between to reduce the chance of postoperative seroma

CS, the defect edges should come together in a tension-free fashion. The defect is closed with v-lock suture, completed with four or five throws run in a backward fashion.

Mesh Placement

Once both anterior and posterior fascial layers are closed, the mesh is deployed in the retromuscular sublay position. The developed retromuscular space is measured for appropriate mesh size selection. Our preference is medium-weight macroporous polypropylene mesh which is deployed through our 12-mm trocar (Fig. 20.12). There is no need for antiadhesion barriers as there now exists an autologous barrier between the mesh and viscera, a significant advantage of the sublay position. Mesh placement in the retromuscular space has allowed for the discontinuation of aggressive penetrating fixation techniques with transfascial sutures, transitioning first to fibrin glue and, more recently, to complete cessation of mesh fixation as our data illustrates penetrating fixation is associated with higher incidence of chronic pain without the added benefit of lowered rates of recurrence. Pneumoperitoneum is released under direct vision, assuring the mesh is lying flat and wrinkle-free between the posterior and anterior layers.

Formerly, we once placed drains just superficial to the mesh in all hernia repair cases. We are now more selective with drain placement and do not utilize it for most patients. To date we have not observed an increase in wound morbidity as a result.

Transabdominal Approach

Alternatively, traditional laparoscopic transabdominal approach can be used. Standard laparoscopic entry to the peritoneal cavity can be achieved and adhesions taken down. The PRS is then incised just lateral to the defect or the linea alba. Dissection can proceed from there as we described in l-TAR originally, prior to our adoption of the eTEP access approach [11]. This lateral approach comes with higher degree of difficulty on the midline suturing for closure.

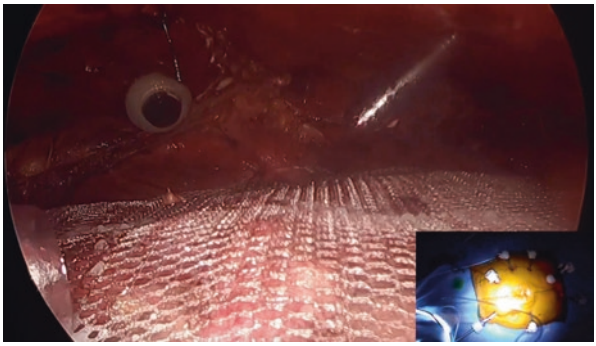

Fig. 20.12 Placement of a medium-weight macroporous polypropylene mesh deployed through the 12-mm trocar. There is no need for antiadhesion barriers as there now exists an autologous barrier between the mesh and viscera

Postoperative Management

Patients are transferred from the PACU for admission to the wards or alternatively discharged to home as determined by the complexity of the surgery and other patient factors. Those that underwent an eTEP access Rives-Stoppa repair (retrorectus mesh placement) are typically discharged home the day of surgery. Diet is advanced as tolerated, and patients are encouraged to ambulate early and often as possible to prevent postoperative ileus or thromboembolism. The average length of stay at our center following eTEP access TAR procedures is approximately 1–2 days. Prolonged postoperative ileus, although uncommon, is the primary cause for increased length of hospital stay.

Patients are discharged from the hospital once they are sufficiently ambulating, tolerating oral intake, have a return of bowel function, and tolerating pain control without the need for intravenous medications. Typically, patients are seen 4 weeks following surgery for their first postoperative clinic visit; however, visits are scheduled sooner (typically at 1 week) if they are discharged with a drain in place.

MILOS and EMILOS Approaches

Since the space to be dissected is the same of eTEP, the contraindications are the same for the MILOS approach.

MILOS stands for mini and less open sublay and uses the hernia itself to get access to the preperitoneal space with a 2–6-cm skin incision directly over the center of the hernia defect, followed by exposure of the hernia sac (this can be widened for large incisional hernias), as described by Reinpold [12]. The hernia sac can be opened at this time to inspect the abdominal cavity, and this can be followed by open or laparoscopic adhesiolysis if necessary. The abdominal wall is lifted with retractors. After transhernial mini-open dissection of an extraperitoneal space of at least 8 cm in diameter and closing of the peritoneal cavity, one can continue the procedure as total extra peritoneal gas endoscopy (TEP of the abdominal wall) using either standard trocars or a transhernial single port. Here the medial aspect of the posterior rectus sheath is opened under direct vision in both sides of the

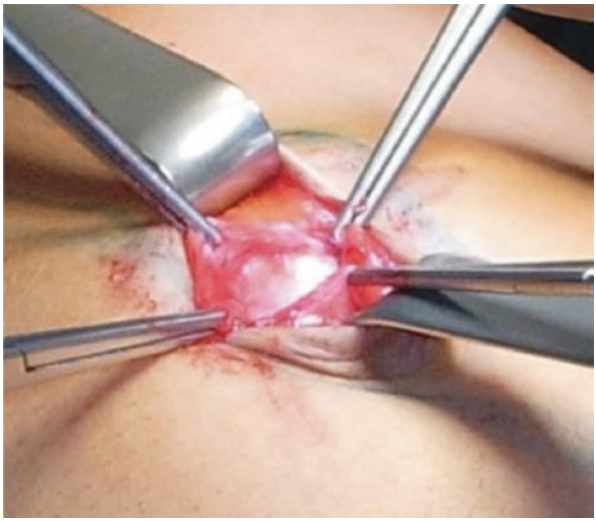

Fig. 20.13 MILOS technique—Transhernial exploration with exposition of the hernia defect [13]

abdominal wall, enabling a large retromuscular pocket that can receive the mesh. This can be achieved using regular surgical and/or laparoscopic instruments. A special laparoscopic light source with a working channel in his middle designed to allow the use of regular laparoscopic instruments to dissect this space, normally without the use of a laparoscopic camera port is suggested [12, 13]. This device is called EndoTORCH Light Tube® (Richard Wolf GmbH, Knittlingen, Germany). Very large synthetic meshes can be implanted if the size of the hernia requires it. A total sublay repair of the abdominal wall can be achieved with excellent results according to recent publications [12, 13] (Figs. 20.13, 20.14, 20.15, 20.16, 20.17, and 20.18).

The endoscopic mini/less open sublay (EMILOS) technique consists of a modification described by Reinpold where the dissection of the retromuscular space is performed in an endoscopic fashion, using regular laparoscopic instruments and carbon dioxide insufflation (or, e.g., using a single port) [14]. The procedure is the same as for MILOS operation until the transhernial exploration is done [13, 14]. After that the endoscopic part (which stands for the E in EMILOS) of the MILOS operation starts with the incision of the posterior sheath of the rectus muscle on one side. The rims of the opened fascia are marked with holding sutures. A sponge forceps is placed into the rectus sheath and directed toward the pubis, in a caudal direction. In the original description, a balloon dissector is positioned down and inflated, creating a space for safe introduction of the camera port. Carbon dioxide is started at this point, allowing gas to gain the preperitoneal space (sutures at the entrance to the rectus sheath are fixed to the port to avoid leak). In the original description, a port is placed in this space and the 10-mm port is removed.

At this point, the opposite side of the posterior sheath of the rectus muscle is incised. These incisions on both sides are continued caudally and cranially as far as it is convenient in relation to the small skin incision. During this step, the

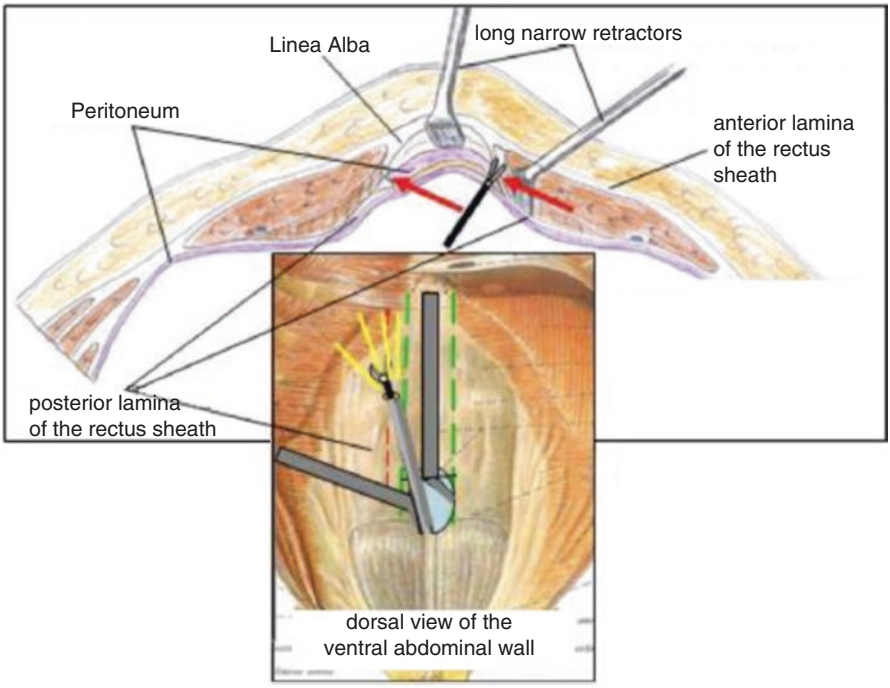

Fig. 20.14 MILOS technique—Lifting of the abdominal wall with retractors and dissection of the preperitoneal space. Incision of the medial aspect of the posterior rectus sheath bilaterally to gain access to retromuscular space [12]

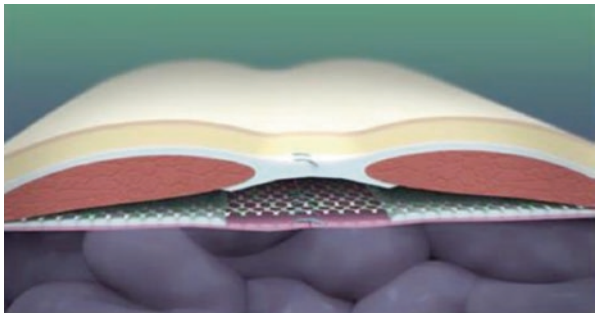

Fig. 20.15 MILOS technique—Retromuscular final positioning of the mesh, allowing a big overlap [12]

abdominal wall is elevated by retractors, always taking care to preserve the linea alba. Blunt detachment of the posterior sheath of the rectus muscle using the curved sponge forceps as far as it is possible is accomplished, accompanied by tight closure of the skin incision. The camera is positioned in the lower trocar facing up and the carbon dioxide insufflation restarted, which allows endoscopic visualization of the retromuscular space with the surgeon standing between the legs and the video tower behind the head of the patient. Dissection cephalad is achieved after

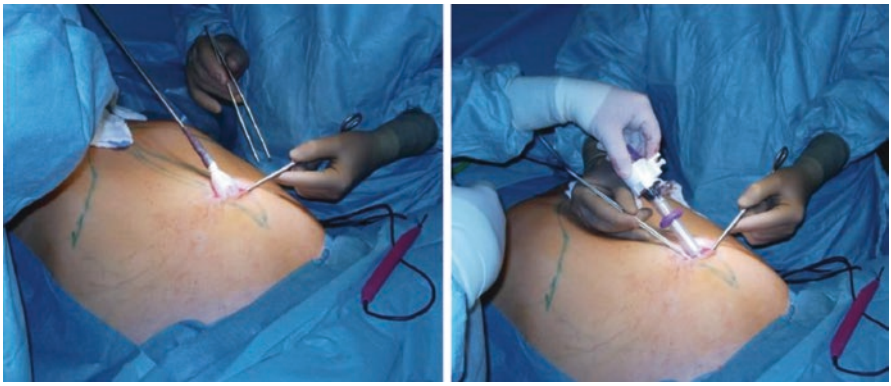

Fig. 20.16 EMILOS technique—Positioning of a suprapubic trocar after creating the preperitoneal space downward to the pubis [14]

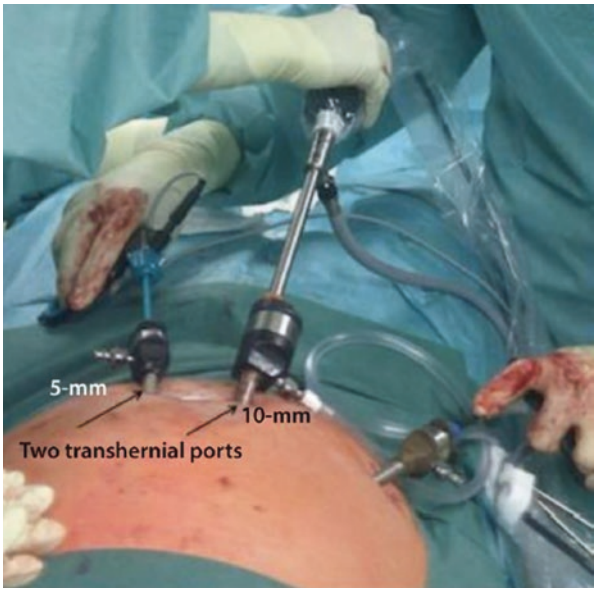

Fig. 20.17 EMILOS technique—Trocar positioning with the surgeon between patient legs and dissecting cephalad. Two port positioned in the hernia defect in this picture [12]

introducing 5-mm working trocars on each side laterally to the midline in the medio-clavicular line and about 3–5 cm above of the umbilicus under direct view. In a comfortable position, the surgeon can continue the incision of the posterior rectus sheath cranially up to the costal margin and the xiphoid. The space behind the costal margin as well as behind the sternum (fatty triangle) is easily dissected and opened for later mesh placement. It is always important to remember to preserve the linea alba; otherwise one will be working on the subcutaneous space. Detachment of the fascia from the rectus muscle while carefully preserving the vessels and the nerves perforating the fascia laterally is easily performed.

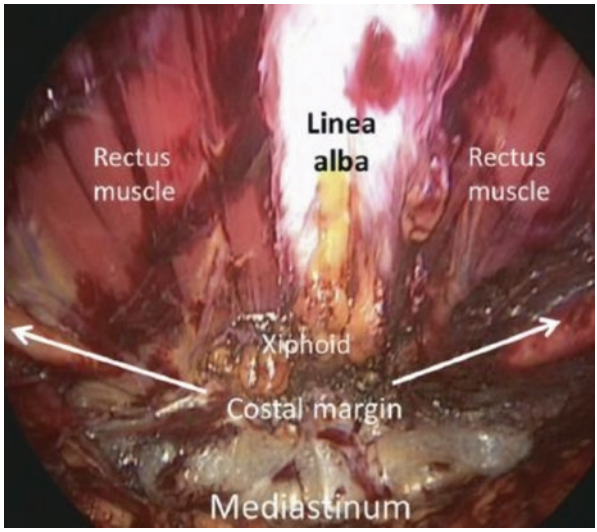

Fig. 20.18 EMILOS technique—Endoscopic view of the cephalad aspect of the dissection [14]

Introducing a 10-mm optic trocar about 5–7 cm superior to the working trocars under view through the rectus muscle will allow continuation of the incision of the posterior rectus sheath downward to the arcuate line. The space of Retzius will be opened, and the dissection may be proceeded down to the pubic bone and below of the inferior suprapubic trocar.

A large mesh can be positioned in the enormous preperitoneal space prepared with the dissection described above. Drains are introduced via the 5-mm working trocars. The skin is reopened, the hernia defect is closed with a nonabsorbable running suture in small bite technique, but the posterior rectus sheath is left open. The wound is closed and dressed, and an abdominal binder is placed [13, 14].

Onlay MIS Repair: Subcutaneous Onlay Laparoscopic Approach (SCOLA) and Endoscopic-Assisted Linea Alba Reconstruction (ELAR)

This technique has previous anecdotal descriptions and consists of performing a "subcutaneoscopic" dissection and is directed specially to small umbilical and epigastric hernias with concomitant rectus muscle diastasis [15]. Recently, a large series with description of the technique and results was published [16]. In this subset of patients, if one only corrects the hernia, the patient might still complain of the abdominal bulge of the rectus diastasis and will result in a higher recurrence rate [15, 16]. Only correcting the diastasis in an onlay fashion will result in a large scar, which is unacceptable from a cosmetic standpoint, especially since there's no true hernia (and its consequences) in the diastasis part of the operation.

Patient Positioning and Trocar Placement

The patient is positioned supine with the left arm tucked at the side and the right arm abducted. Another alternative is to open the patient's legs. The endoscopic equipment is positioned to the left of the patient. The access route consists of a half loop on the left around the umbilicus, extending 2–3 cm cranially in the midline (Fig. 20.19). Dissection of the umbilical hernia (if present) is performed as usual, and the anterior layer of the rectus sheath is exposed on both sides from the xiphoid process and extends several centimeters below the umbilicus. The anterior layer of the rectus sheath is freed from subcutaneous tissue by diathermy on both sides in a width of around 4–5 cm. The original description uses regular surgical instruments, but one can use laparoscopic instruments and carbon dioxide insufflation if desired. When using regular instruments, the surgeon has a direct view of the surgical area via the skin incision but needs the light source to that effect, while the two assistants watch the monitor of the video endoscopic equipment positioned to the right of the patient. A more ergonomic approach (SCOLA) is to be positioned in between the legs, with three ports positioned in the suprapubic area, 6 cm apart each other (Fig. 20.20). A robotic approach can be performed as well, with docking from the left shoulder after the suprapubic port access.

SC Space Creation and Midline Plication

The surgeon starts the subcutaneous dissection from bottom up, until he or she reaches the subxiphoid area, going through the entire midline and associated hernias, creating a 15-cm wide space (Fig. 20.21). At this point, the surgeon can decide if only an approximation of the linea alba is necessary or if an incision needs to be made around 2 cm from the medial margin of the rectus sheath to reinforce linea alba or to allow approximation without tension (described as endoscopic-assisted linea alba reconstruction—ELAR [15, 16]). If not, the plication can be done with barbed sutures to facilitate after measuring the space and mesh size required

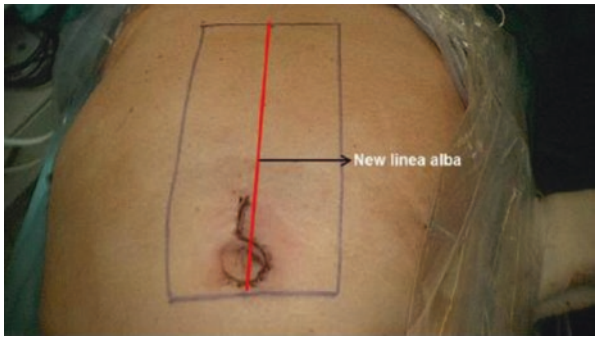

Fig. 20.19 ELAR—Size of the mesh (in blue line) and extent of skin incision [15]

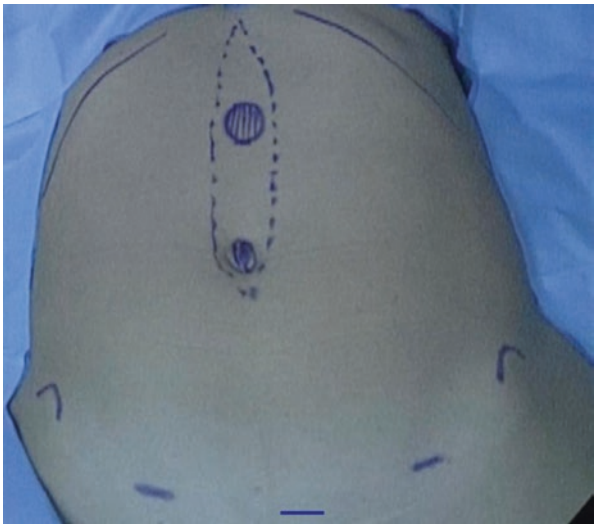

Fig. 20.20 SCOLA—Alternative access from the suprapubic area. Three-low-port incision for a patient with a recurrent umbilical hernia, an epigastric hernia, and a diastasis (shown as marked)

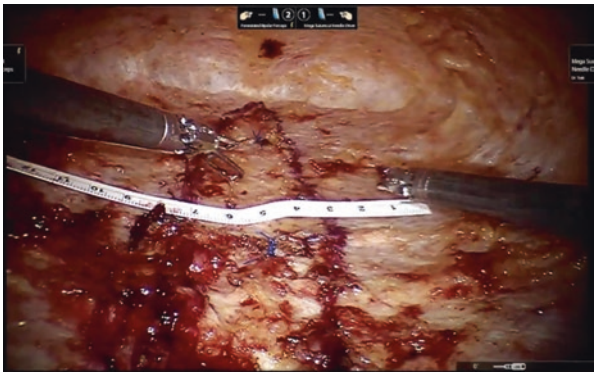

Fig. 20.21 SCOLA—Measurement of the defect and diastasis, after the rise of the entire SC flap and defect closure (Prolene sutures)

(Figs. 20.22, 20.23, and 20.24). If done, this incision runs bilaterally from the xiphoid process to the subumbilical area, thus exposing the bellies of both rectus muscles, and the two medial segments of the anterior layer of the rectus sheath are sutured together using continuous, nonabsorbable loop sutures (Fig. 20.25). Inward plication of the rectus abdominis diastasis is effected, and a new linea alba is formed once suturing is complete. With that, both rectus muscles are restored to their position at the midline adjacent to the reconstructed linea alba.

Mesh Placement

Next step is the placement of a polypropylene mesh. Medium-weight macroporous meshes are preferred due to the proximity to the skin. The mesh is tailored to size. Only then is the mesh sutured to the anterior layer of the dissected rectus sheath

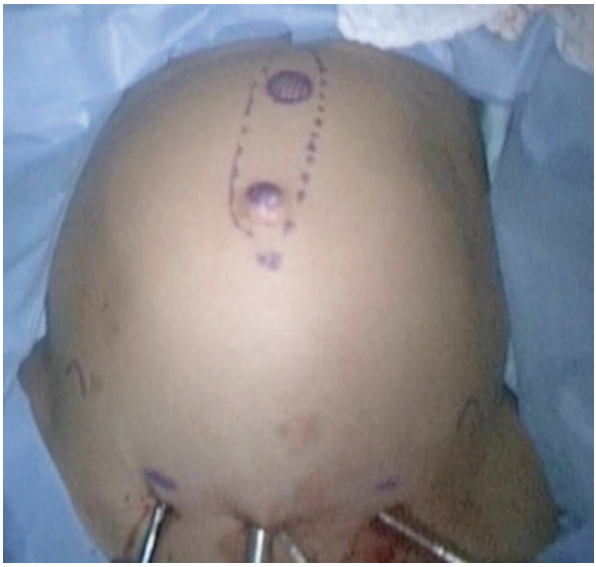

Fig. 20.22 SCOLA—Intra-op picture with the three trocars in place and entire subcutaneous dissected/raised from the fascia

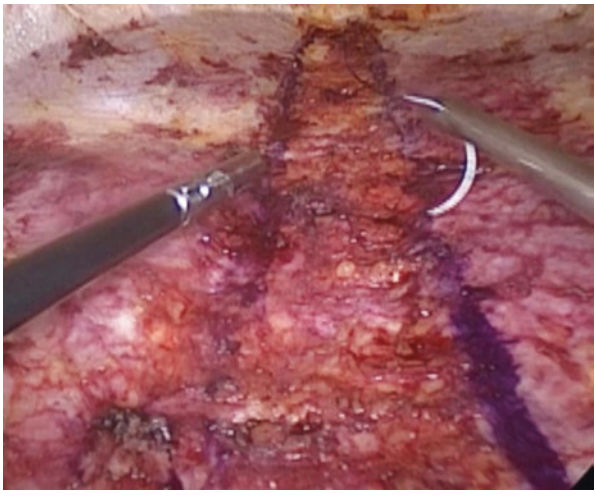

Fig. 20.23 SCOLA—Midline plication

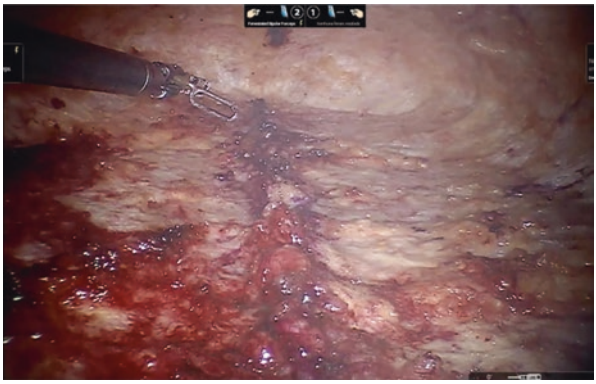

Fig. 20.24 SCOLA—Final aspect after midline plication and defect closure

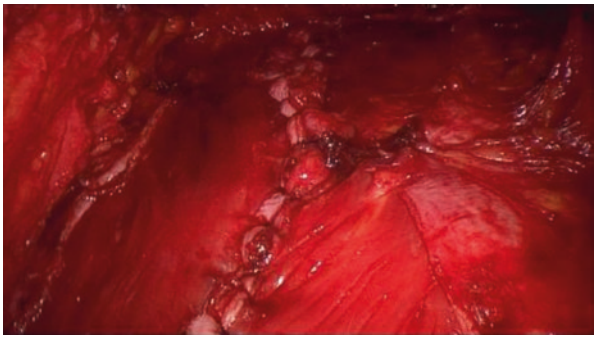

Fig. 20.25 ELAR—New formed linea alba after suturing the medial portions of the two rectus sheaths at the midline [15]

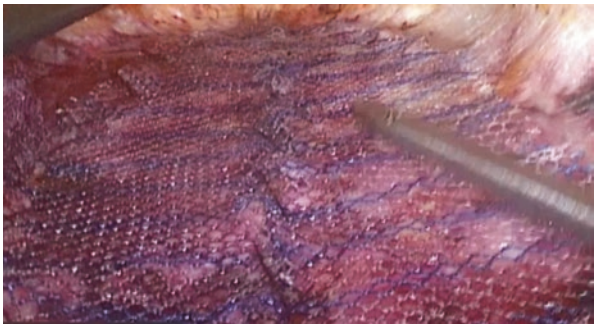

Fig. 20.26 SCOLA—Final aspect after laparoscopic mesh fixation with running sutures

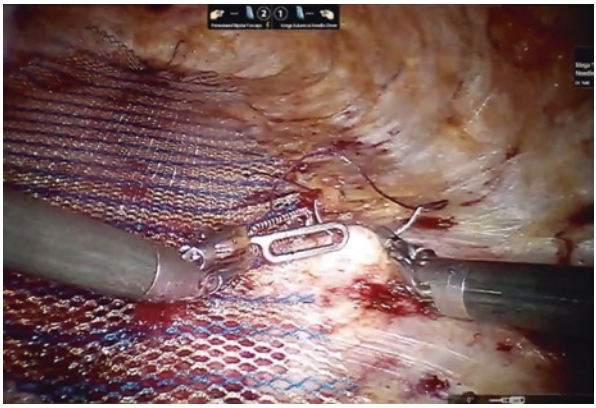

Fig. 20.27 SCOLA—Robotic suturing of the mesh

using continuous nonabsorbable suturing material (Figs. 20.26 and 20.27). Drains are placed, the subcutaneous tissue is sutured, and the skin is closed in a regular fashion. Patients are advised to use an abdominal binder for 6 weeks after the operation [16].

Conclusion

MIS for ventral hernias have been changing for the last few years, with a clear trend to reproduce traditional open techniques and avoiding IPOM meshes. As what happens with the open techniques, there is no one gold standard, but each different approach described in this chapter has its own indications and contraindications. The role of the surgeons is to analyze and decide the best technique for each patient.

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Component Separation: Outcomes and Complications

21

Maurice Y. Nahabedian

Introduction

The primary goal of abdominal wall reconstruction in the setting of a midline ventral hernia is to achieve primary fascial closure and maintain abdominal function. The transverse diameter of the abdominal wall defect is a critical factor that often determines the reconstructive approach. For midline defects less than 5 cm in diameter, midline fascial closure is often possible without undue tension and can be performed with or without mesh reinforcement; however, mesh reinforcement is typically used and recommended. For defects that range from 5 to 10 cm in diameter, additional maneuvers such as relaxing incision of the external oblique fascia are often necessary and usually require mesh reinforcement. However, for defects that exceed 10 cm in diameter, more aggressive maneuvers are often required to achieve midline closure.

The introduction of the anterior component separation operation has facilitated our ability to close complex defects of the anterior abdominal wall. This classic operation was first described by Ramirez et al. in 1990 and has revolutionized hernia repair [1]. Prior to component separation, midline approximation of complex ventral hernias was difficult and often not possible. The premise for this operation is to separate the muscle groups that constituted the anterior abdominal wall to facilitate the midline excursion of the rectus abdominis muscle. This can be performed unilaterally and bilaterally depending on the width of the hernia defect. Early studies demonstrated that the mobility of the unilateral rectus abdominis myofascial complex was approximately 4 cm above the umbilicus, 8 cm at the level of the umbilicus, and 3 cm below the level of the umbilicus [2]. The primary benefit of this approach is that it is considered a functional repair because the muscle groups are mobilized without compromising the vascularity or innervation.

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With the evolution of hernia repair techniques, the use of mesh to further support the repair has demonstrated success. The benefits of using a surgical mesh have been demonstrated in the classic study by Luijendijk who found that primary fascial closure with and without mesh reinforcement resulted in a recurrence rate of 24% and 43%, respectively, at 3-year follow-up [3]. Ten-year follow-up of the same cohort demonstrated a recurrence rate of 32% and 63%, respectively [4]. Although the initial description of component separation by Ramirez did not utilize mesh, current techniques of component separation are usually performed using a mesh for reinforcement. This mesh can be biologic, synthetic, or resorbable and can be placed in various layers that include onlay, underlay, retrorectus, as well as fascial interposition/bridge. The anterior component separation can also be performed as a minimally invasive technique or laparoscopically. Another recently described method is the "sandwich" technique whereby a classic component separation is performed followed by bilaminar mesh reinforcement as an underlay/retrorectus and onlay [5]. This chapter will include a description of the various types of component separation repairs with an emphasis on outcomes and complications.

Anatomy

A thorough knowledge of the anterior abdominal wall anatomy is critical in order to perform the component separation technique. The primary components include the skin, subcutaneous fat, anterior rectus sheath, paired rectus abdominis muscles, paired external, internal, and transverse oblique muscles, external oblique fascia, and the posterior rectus sheath. There are four paired muscles that provide function to the anterior abdominal wall. The origin, insertion, vascularity, innervations, and function are listed in Table 21.1.

It is important to recognize that the vascularity and innervation to the abdominal muscles are segmental. The rectus abdominis muscle is a type 3 and 4 muscle according to the Mathes and Nahai classification because it has two dominant pedicles (inferior and superior epigastric vessels as well as segmental vascularity via the intercostal vessels). The intercostal arteries, veins, and nerves enter the rectus abdominis at the junction of the lateral and central third and are spaced every 5–6 cm along the length of the muscle. Within the rectus abdominis muscle, the dominant inferior and superior vessels can course via one, two, or three dominant pathways. The intercostal arteries, veins, and nerves that supply the oblique musculature lay between the external and transversus oblique muscles. The plane between the external and internal oblique muscles is a loose areolar plane without blood vessels or nerves.

The midline confluence of the anterior and posterior rectus sheath is the linea alba. Lateral to the rectus abdominis and medial to the oblique muscles is the linea semilunaris which is the confluence of the external, internal, and transversus fascia. The tendinous inscriptions along the rectus abdominis muscles are zones of confluence between the muscle and the anterior rectus sheath to prevent bowstringing. The vascularity at the tendinous inscription can be altered and known as choke vessels that are of lesser caliber than the primary source vessel.

Table 21.1 The vascularity, innervation, origin, and insertion of the four paired abdominal muscles are provided

Muscle	Origin	Insertion	Vascularity	Innervation	Function
Rectus abdominis	Pubic symphysis	Costal margin 5–7, xyphoid	Deep and superior epigastric	Thoracoacromial nerves	Trunk flexion
External oblique	Lower 8 ribs	Linea alba, ASIS, pubic crest	Intercostal and subcostal	Intercostal 7–11, subcostal, ilioinguinal	Trunk flexion and lateral bending
Internal oblique	Thoracolumbar fascia	Linea alba, pubic crest, lower 3 ribs	Intercostal and subcostal	Intercostal 7–11, subcostal, ilioinguinal	Trunk flexion and lateral bending
Transversus abdominis	Lower 6 ribs, thoracolumbar fascia	Linea alba, pubic crest	Intercostal and subcostal	Intercostal 7–11, subcostal, ilioinguinal	Abdominal compression

The vascularity of the skin and fat of the anterior abdominal wall is another important consideration. The arteries and veins that nourish the skin and subcutaneous layers of the abdomen include perforating branches of the superior and inferior epigastric vessels as well as perforating branches from the intercostal and subcostal systems. The superficial inferior epigastric vessels provide perfusion to the lower anterior abdominal wall, while the deep epigastric, intercostal, and subcostal perforators provide perfusion to the mid- and lateral abdominal wall. The majority of dominant perforators emanate from the periumbilical region and typically range in diameter from 1 to 3 mm. Previous work has demonstrated that a 1.5 mm perforator can adequately perfuse approximately 750 g of tissue (unpublished data). The importance of these perforators is that they are preserved when performing a perforator sparing component separation or a minimally invasive component separation.

Etiology and Indications

The etiology of the ventral midline hernia is multifactorial. Factors that contribute to the formation include suture pull-through, increased intra-abdominal pressure, and patient comorbidities such as obesity, poorly controlled diabetes mellitus, malnutrition, tobacco use, as well as inadequate soft tissue support to withstand the forces of hernia formation [6]. Physiologically, as the midline repair along the linea alba becomes disrupted or attenuated, the contraction of the rectus abdominis and oblique muscles causes widening of the midline defect resulting in a hernia. The indications for performing component separation include a wide midline defect where primary fascial closure is not possible, patients at high risk of recurrence, and in patients that have had prior repair of a hernia >5 cm [7, 8].

The use of preoperative abdominal computerized tomography to determine the feasibility of anterior component separation has been studied [9, 10]. In a review of 54 patients that had CT imaging prior to component separation, it was demonstrated that when the transverse diameter and defect area were greater than 19.8 cm and 420 cm^2,

respectively, a bridged repair was likely, whereas when the transverse diameter and defect area were less than 10.4 cm and 184 cm^2, respectively, primary fascial closure was readily achieved ($P = 0.0002$ and 0.006, respectively) [9]. Pannus thickness and circumference as well as the estimated intra-abdominal area and volume were similar in both groups. Blair demonstrated that preoperative CT scan was useful for planning and patient education [10]. Increasing defect width and abdominal wall thickness were associated with an increased need for component separation.

The use of perfusion angiography using indocyanine green (ICG) is also useful for perfusion assessment following component separation with or without panniculectomy. In a review of 17 patients following abdominal wall reconstruction, wound-healing complications occurred in 5/12 (42%) patients in the non-ICG cohort vs. 1/5 (20%) of the ICG cohorts [11]. Figure 21.1 illustrated the hypoperfusion following panniculectomy with the relative perfusion gradients noted. Figure 21.2 demonstrated the postoperative ischemic changes of the abdomen that directly correlated with the perfusion scan.

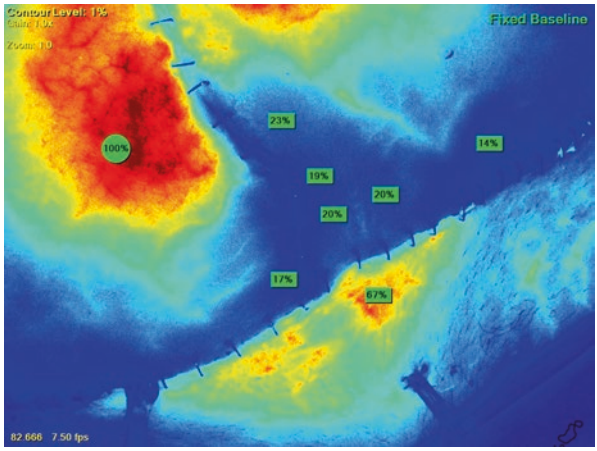

Fig. 21.1 Color-enhanced fluorescent angiography demonstrating an area of hypoperfusion on the left lower abdominal wall

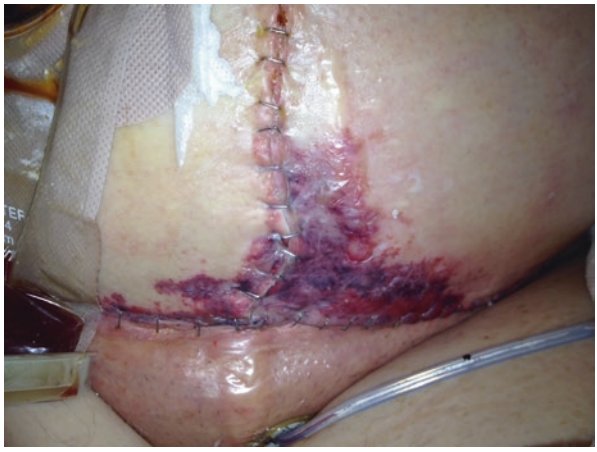

Fig. 21.2 Postoperative ischemic tissue that correlates with the intraoperative angiography

Techniques

The technique of anterior component separation has been previously described in the literature [12, 13]. The salient aspects of the operation will be reviewed. Prior to performing the component separation, a thorough lysis of adhesions and all bowel work is completed. Upon completion, the adipocutaneous skin flaps are widely undermined usually to the level of the anterior axillary line. Perforator preservation is strongly recommended when undermining to preserve the vascularity of the adipocutaneous tissue and minimize the likelihood of soft tissue necrosis and delayed healing [14–16] (Fig. 21.3). The hernia defect, anterior rectus sheath, linea semilunaris, and external oblique fascia are in clear view. Component separation can be performed unilaterally or bilaterally. In the original description by Ramirez, the separation of parts allowing mobilization of the anterior muscle groups occurs via two routes [1]. The first is by release of the posterior rectus sheath from the rectus abdominis muscle preserving the inferior epigastric artery and vein coursing through the muscle. The posterior sheath is incised throughout its length that permits 2–3 cm of mobilization of the rectus abdominis muscle toward the midline. The second and more effective release point is the external oblique fascia and muscle. The external oblique fascia and muscle is incised 1 cm lateral to the linea semilunaris. The avascular plane between the external and internal oblique muscles is entered and undermined toward the anterior axillary line. Following this release the rectus abdominis musculofascial complex is pulled medially to achieve primary fascial approximation. When mobility is hindered superiorly or inferiorly, the origin of the rectus abdominis muscle on the costal margin and pubic bone can be released to achieve additional excursion. The use of a biologic or synthetic mesh is usually considered following component separation to reinforce the repair and to reduce the likelihood of recurrence [3]. These mesh materials can be positioned in a variety of locations that include underlay, retrorectus, onlay, and interposition [17]. The goal of anterior component separation is to achieve primary fascial closure. When not possible, bridging

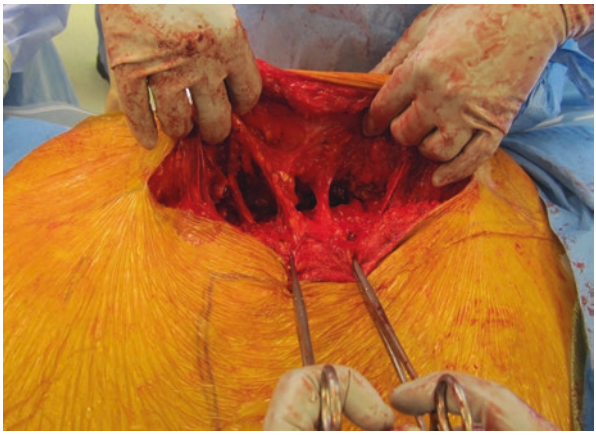

Fig. 21.3 Perforator sparing component separation illustrating the individual perforators perfusing the adipocutaneous tissue

techniques with interpositional mesh are usually required. Figures 21.4, 21.5, 21.6, 21.7, 21.8, and 21.9 illustrate a patient having bilateral anterior component separation with biologic mesh underlay. In patients at high risk for delayed healing, an incisional negative-pressure wound therapy device can be applied (Fig. 21.10).

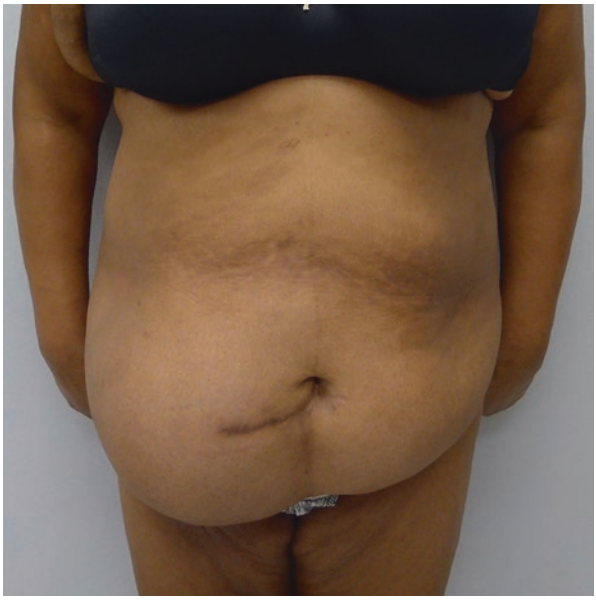

Fig. 21.4 Preoperative image of a patient with a recurrent right/ventral incisional hernia

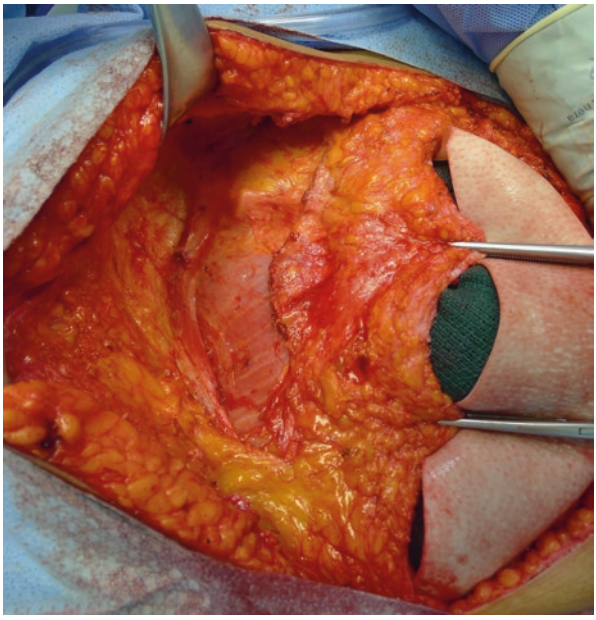

Fig. 21.5 The right component separation is complete

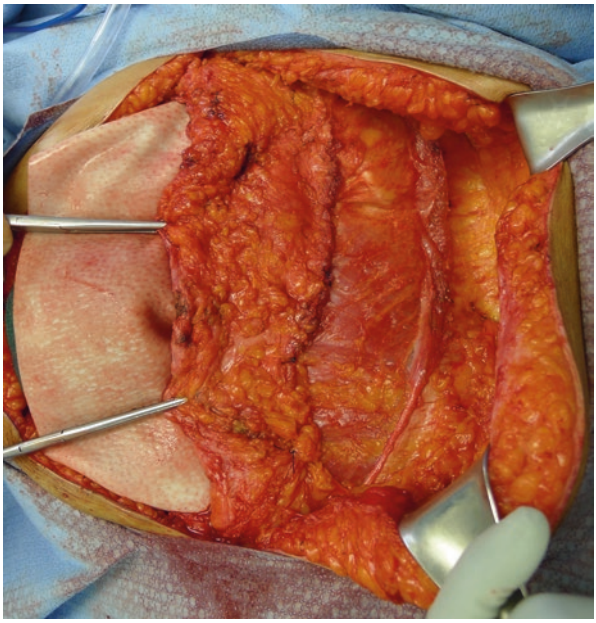

Fig. 21.6 The left component separation is complete

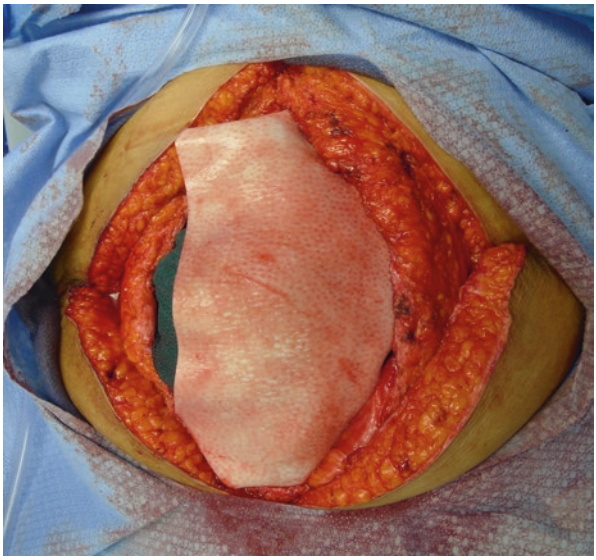

Fig. 21.7 Underlay biologic mesh is placed for reinforcement

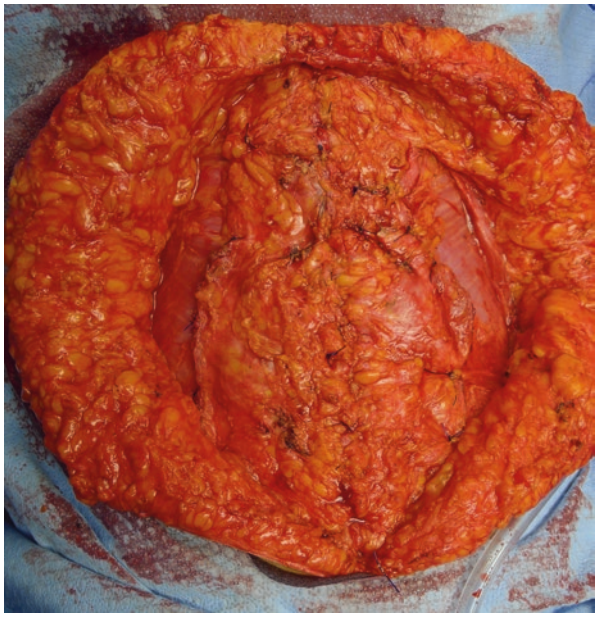

Fig. 21.8 Midline fascial approximation is achieved

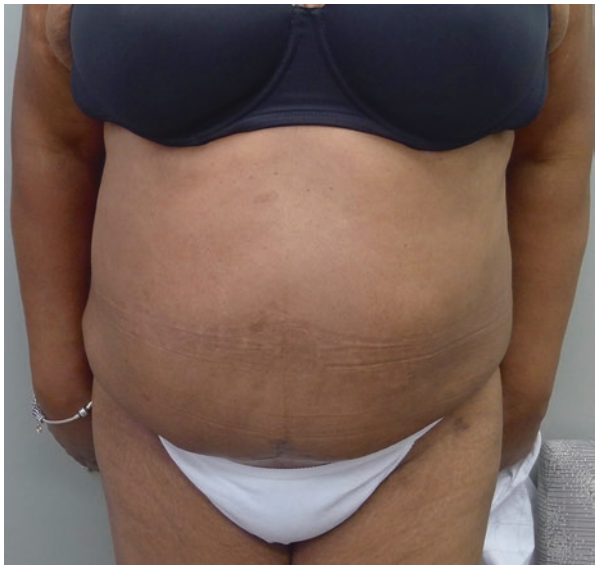

Fig. 21.9 Postoperative image demonstrating no hernia and improved contour at 9 months

Other modifications of the anterior component separation technique have been described that provide additional reinforcement to the midline repair [5, 18] or further improve the vascularity to the adipocutaneous layer [14, 15]. Following the classic anterior component separation technique with an underlay mesh, the incised edges of the external oblique fascia are left as is. A modification, known as the

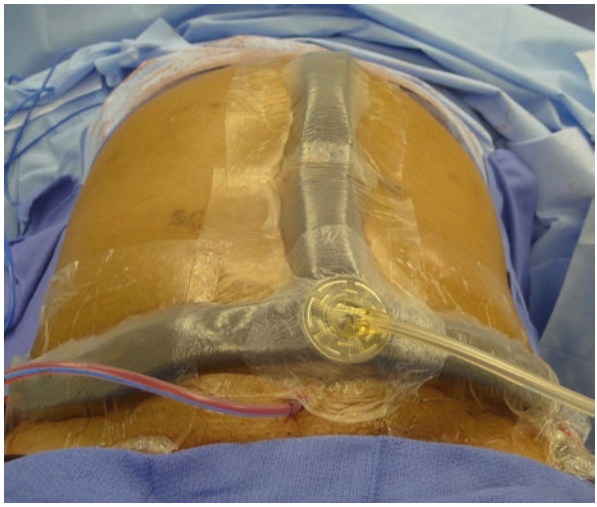

Fig. 21.10 Incisional negative-pressure wound therapy can be placed to improve wound healing

"sandwich" technique, can be performed whereby the incised edges of the external oblique fascia and muscle are bridged with an onlay mesh that can be synthetic or biologic in nature [18]. This bilaminar repair will tend to minimize the lateral forces that can attenuate or disrupt the midline closure as well as provide additional lateral support to minimize the occurrence of a lateral bulge.

Minimally invasive component separation (MICS) is another recent advancement that preserves the perforating vessels to the anterior abdominal wall [14, 15]. The purpose of MICS is to optimize perfusion to the adipocutaneous layer of the abdominal wall and minimize the incidence of wound-healing complications such as necrosis and dehiscence. The technique involves the creation of 3 cm wide horizontal subcutaneous tunnels that extend from the linea alba to the linea semilunaris at the level of the costal margin. This is followed by the creation of a 3 cm vertical tunnel that extends from the costal margin to the pubic bone. The perforating vessels at the periumbilical level are undisturbed. The external oblique fascia and muscle is then incised throughout the length of the vertical tunnel lateral the linea semilunaris. A blunt Yankauer suction handle is then inserted into the plane between the external and internal oblique muscle. Following mobilization of the rectus abdominis myofascial complex and placement of an underlay mesh, the midline defect is re-approximated with nonabsorbable sutures.

Outcomes

Outcomes following anterior component separation will vary based on the specific details and variables of each repair. These include whether or not a mesh was used for reinforcement and where the mesh was placed. The nature of the mesh, biologic or synthetic, can also affect certain outcome measures. Table 21.2 is a compilation

Table 21.2 Recurrence, surgical site infection (SSI), and surgical site occurrences (SSO) are tabulated in these studies evaluating outcomes following component separation *without* mesh reinforcement

Author	Year	Number	Mesh	Recurrence	SSI	SSO	FU (months)
Ramirez [1]	1990	11	None	0	0	0	4–42
Girotto [19]	1999	33	None	6.10%	8 (24.1%)	Enterocutaneous fistula [1]	21
Shestak [2]	2000	22	None	5%	2 (9.1%)	Seroma [1], death [1]	52
De Vries [23]	2003	43	None	12/38 (32%)	6 (13.9%)	17 (39.5%) hematoma [5], seroma [2] skin necrosis [2],	15.6
Ko [6]	2009	158	None	36 (22.8%)	(see SSO)	25.3% (MI, PE, death, infection, seroma, skin necrosis)	9.6

of various studies in which a component separation repair was performed without mesh for reinforcement. Table 21.3 is a compilation of studies in which a component separation was performed with mesh reinforcement. This section will focus on specific outcome measures that include recurrence, reoperation, and quality of life issues.

Girotto reviewed the Johns Hopkins experience following three cohorts of patients that included primary fascial closure without component separation ($n = 110$), component separation and fascial closure with onlay mesh ($n = 96$), and component separation with interposition graft ($n = 78$) [19, 20]. Recurrence rate for the smaller defects that were closed with primary fascial closure group without component separation was 15%, whereas the recurrence for the two cohorts combined requiring component separation was 26% (43/164). Component separation with and without primary fascial closure demonstrated recurrence rates of 22% and 29%, respectively. The risk of recurrence was independent of patient age, gender, perioperative steroid use, wound infection, defect size, and preoperative enterocutaneous fistula. However, prior hernia repair with the use of a mesh was predictive of recurrence (odds ratio = 2.2, $p = 0.01$). Increasing the complexity of the repair was also associated with an increased risk of recurrence (odds ratio = 1.5, $p = 0.04$). Patient satisfaction scores were obtained in 108 patients demonstrating improvements in abdominal appearance, postoperative emotional state, abdominal strain, ability to lift objects and lift themselves from a chair and bed, and exercise.

Ko and Dumanian performed primary component separation on 200 patients demonstrating a recurrence rate of 21.5% [6]. Of these 200 patients, 158 (79.0%) had primary component separation without mesh, and 42 (21.0%) had primary component separation with underlay mesh. Of the underlay mesh cohort, 6 (3.0%) had polypropylene mesh, 18 (9.0%) had human acellular cadaveric dermis, and 18 (9.0%) had soft polypropylene mesh. Comparison based on reinforcement material

Table 21.3 Recurrence, surgical site infection (SSI), and surgical site occurrences (SSO) are tabulated in these studies evaluating outcomes following component separation *with* mesh reinforcement

Author	Year	Number	Mesh	Recurrence	SSI	SSO	FU (months)
Ko [6]	2009	18	Human	33.30%	(See SSO)	22.2% (MI, PE, death, infection, seroma, skin necrosis)	14.7
Ko [6]	2009	24	Polypropylene	4.10%	(See SSO)	16.7 (MI, PE, death, infection, seroma, skin necrosis)	5.4
Morris [5]	2013	51	Porcine + polypropylene	3.90%	1 (1.9%)	SSO – 39% (partial mesh excision 7, skin necrosis, death)	20.6
Gallud [18]	2017	351	Polypropylene, DynaMesh	8.20%	7.20%	Seroma 35.1%, hematoma 9.1%, skin necrosis 8.8%, SBO 1.5%	31.6
Garvey [22]	2017	191	Porcine 57.1%, bovine 31.4%, human 11%	13.60%	8.40%	25.1%: Bulge 6.3%, dehiscence 16.8%, hematoma 2.1%, seroma 3.7%	52.9

demonstrated a recurrence rate of 0 with a polypropylene mesh compared to 33% with human acellular dermal matrix. The recurrence rate using soft polypropylene mesh was significantly less compared with the other groups ($P = 0.04$). The failure of human dermis as a reinforcement material is notable in these complex cases due to the inherent elasticity of the human dermis [21]. Obesity was associated with a significant increase on hernia recurrence (odds ratio = 1.06, $P = 0.003$) [6]. Previous hernia repair by another surgeon approached significance with an odds ratio of 1.87 ($P = 0.08$). Factors that were not associated with an increased risk of recurrence included hernia width, diabetes mellitus, tobacco use, and contamination.

In a more recent review, Garvey studied 191 patients having component separation with a median follow-up of 52.9 months (range 36–104 months) [22]. Hernia recurrence was documented in 26/191 (13.6%). The cumulative recurrence rates were 11.5% at 3 years and 14.6% at 5 years demonstrating relatively stable repairs over time. Interestingly, at 7 years, the hernia recurrence rate remains stable at

14.6%. Factors associated with hernia recurrence included a lack of primary fascial closure, bridged repair, incisional dehiscence, and the use of a human ADM. Performing a component separation was associated with less recurrence compared to no component separation. The authors found that when the analysis was adjusted to exclude patients with a bridged repair or those that had human ADM, the cumulative hernia recurrence rate was 6.4% at 3 years and 8.3% at 5 years. The authors noted no difference in recurrence following component separation with either a porcine or bovine acellular dermal matrix.

In another recent review, Torregrosa-Gallud evaluated 351 patients with complex ventral hernias with over 10-year follow-up that were managed with a modified component separation [18]. The primary modification was the application of an onlay synthetic mesh in addition to the underlay biologic mesh aka sandwich repair. Other modifications included preoperative botulinum toxin and progressive pneumoperitoneum in patients with giant hernias in whom the volume ratio between the incisional hernia (VIH) and the abdominal cavity (VAC) was 20%. The recurrence rate following this modified component separation was 8.2% (29/351). The mean follow-up was 32 months (range 24–60 months). Twenty-four (83%) of the patients that had a recurrence had a secondary repair that included a posterior component separation (n = 11), preperitoneal repair (n = 9), and primary suture repair with onlay polypropylene mesh (n = 4).

Morris reviewed a series of 51 patients that had abdominal wall reconstruction utilizing component separation with bilaminar mesh reinforcement [5]. Hernia recurrence was observed in 3.9% of patients (2/51), and surgical site occurrence occurred in 39% (20/51). Of the two patients that developed a recurrence, one sustained a mesh infection 2 months postoperatively and required complete mesh excision that resulted in recurrence. The second patient also sustained a mesh infection and failed negative-pressure wound therapy developing a recurrence.

Complications

Complications following anterior component separation include surgical site infections and other occurrences that include seroma, hematoma, delayed healing, death, pulmonary emboli, enterocutaneous fistula, myocardial infarction, and others.

In the Ko and Dumanian study evaluating 200 patients following component separation, major complications were documented in 48 patients (24.0%) and included hematoma, infection requiring incision and drainage, reoperation, as well as myocardial infarction, pulmonary embolus, and death [6]. Minor complications were documented in 38 patients (19.0%) and included cellulitis, seroma, and delayed healing. The type of mesh used did not correlate with postoperative morbidity. Factors associated with major complications included contamination at time of surgery (odds ratio = 2.26, p = 0,04) as well as a preoperative enterocutaneous fistula (odds ratio = 3.67, P = 0.02). Factors associated with minor complications included obesity (odds ratio = 1.06, P = 0.01) and diabetes mellitus (odds ratio = 2.38, P = 0.04). Figures 21.11 and 21.12 illustrate a patient with delayed healing managed with a vacuum-assisted closure device.

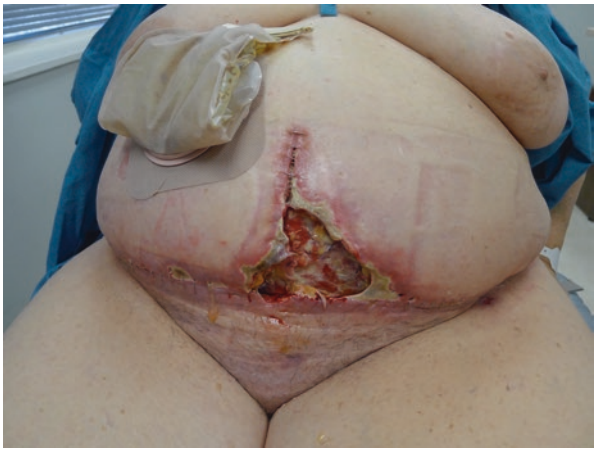

Fig. 21.11 Complex wound following simultaneous component separation and panniculectomy

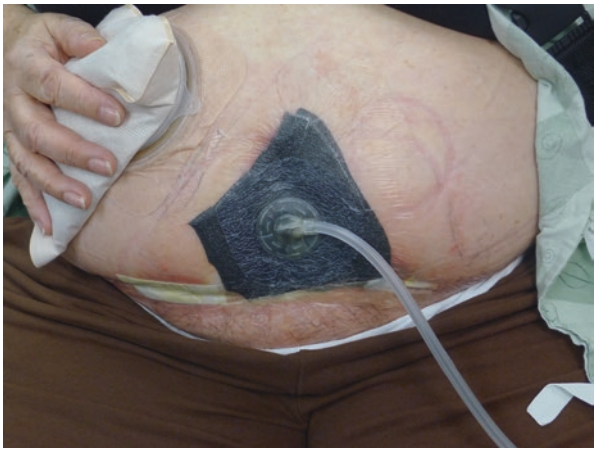

Fig. 21.12 Vacuum-assisted closure application to facilitate wound healing

In the Garvey study evaluating 512 patients following anterior component separation of which 191 had greater than 3-year follow-up, the overall incidence of adverse events was 38.7% (74/191) [22]. Surgical site occurrences related to the abdominal wall occurred in 25.1% (48/191). Factors associated with the development of a surgical site occurrence were analyzed using a multivariable logistic regression model and demonstrated that BMI > 30 (odds ratio = 4.4, $p < 0.01$) and at least 1 medical comorbid condition (odds ratio = 4.5 $p < 0.02$), and defect width > 15 cm (odds ratio = 2.1, $p < 0.01$) were all significant, independent predictors.

In the Torregrosa-Gallud study evaluating 351 patients following anterior component separation using a synthetic mesh over 10 years, major complications included bowel evisceration ($n = 3$, 0.9%), small bowel fistula ($n = 4$, 1.1%), and mesh infection ($n = 11$, 3.1%) [18]. Reoperation and total or partial mesh excision was required in 6 patients that had mesh infection. Salvage of the infected mesh was possible in 5/11 patients (45%) using conservative measures and antibiotics. Minor

surgical site occurrences included seroma (35.1%), hematoma (9.1%), skin necrosis (8.8%), and wound infection (7.2%). Medical complications occurred in 20 patients (5.6%) and included a prolonged postoperative ileus (n = 9, 2.5%), pneumonia (n = 5, 1.4%), and urinary tract infection (n = 3, 0.9%) patients. Anterior compartment syndrome occurred in two patients with a bladder pressure of 31 mmHg. One patient with anterior compartment syndrome died due to multisystem organ failure and the other required a biologic interposition graft.

Ghali and Butler studied 57 patients following MICS and 50 patients following open component separation with a mean follow-up of 15.2 months [15]. The mean fascial defect size was larger in the MICS cohort compared to the open component separation cohort (405.4 cm^2 vs. 273.8 cm^2, $p = 0.002$). It was demonstrated that the incidence of dehiscence (11% vs. 28%; $p = 0.011$), wound-healing complications (14% vs. 32%; $p = 0.026$), abdominal wall laxity/bulge (4% vs. 14%; $p = 0.056$), and hernia recurrence (4% vs. 8%; $p = 0.3$) was lower in the MICS cohort compared to the open component separation cohort.

Conclusion

Component separation is a useful technique for complex abdominal wall reconstruction. The use of mesh is an effective means of minimizing recurrence. Mesh placement can be as an underlay, onlay, interposition (bridge), or bilaminar. Primary fascial closure is recommended to minimize the risk of recurrence. Risk factors for recurrence include but not limited to prior hernia repair, obesity, and prior mesh repair. Risk factors for surgical site occurrence include but not limited to obesity, poorly controlled patient comorbidities, tobacco use, and poor tissue perfusion.

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Botulinum Toxin in Abdominal Wall Hernia Repair

22

Talar Tejirian and Louise Yeung

Introduction

Despite being one of the most potent biologic toxins, botulinum neurotoxin has been found to have a broad degree of versatility in clinical applications. Initial ideas for therapeutic use emerged as early as 1817, when the toxin was first extracted from infected sausage and found to cause paralysis of skeletal muscle. The causative agent, *Clostridium botulinum*, was not elucidated until 1895 and was given its name due to its association with sausage (*botulus*, sausage in Latin) [1]. From these humble beginnings, botulinum toxin now has a vast array of clinical uses in the fields of neurology, ophthalmology, gastroenterology, urology, orthopedics, dermatology, pain management, plastic surgery, and, increasingly, general and hernia surgery.

Background and Pharmacology

Botulinum toxin products are made up of a botulinum neurotoxin component in addition to various nontoxic complexing proteins. The pharmacological structure of botulinum is made up of an interconnected heavy and light amino chain acid with a disulfide bridge [2].

Botulinum binds with high affinity to cholinergic nerve terminals, specifically to the glycoprotein structures, temporarily interrupting the transmission through the

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synapse and inhibiting the release of acetylcholine from the presynaptic terminal. Botulinum toxin also has the ability to block the cholinergic autonomic innervation of various glands and smooth muscles. Studies have also shown the effect of botulinum toxin on pain transmitters. Effects of botulinum blockade have been described for substance P, glutamate, calcitonin gene-related peptide, and noradrenaline [2].

The toxin first starts taking effect within 2–3 days, with maximal effect at around 2 weeks. The overall effect will start declining at around the 2.5-month mark, with fair consistency. Despite repeat or prolonged usage, no habituation effects are usually seen. However, antigens may be formed against botulinum toxin given that they consist of foreign protein. These antibodies may induce therapy failure by blocking the effects of the toxin. Only antibodies against the botulinum toxin itself (rather than those against the complexing proteins) will block the biologic activity and so are referred to as neutralizing antibodies. Risk factors for antibody-induced therapy failure include single dose and interjection interval, but do not include cumulative dose, treatment time, and patient age. Current studies show a frequency of immunogenicity of only 1–5% [3], less than previously thought; thus studies are emerging that support more frequent (<12 weeks) or higher doses without as much fear of inducing treatment failure [4, 5].

The safety profile for botulinum toxin is fairly good, as the toxin binds with high affinity to the cholinergic nerve terminal. Local effects and unintended diffusion into adjacent sites may cause weakness in and around the target area [6]. It is possible for small amounts to be distributed throughout the body via systemic circulation. This is usually only clinically apparent when extremely large amounts of botulinum toxin are used and is detected as increased jitter in muscles distant from the injection site [2]. Other systemic adverse effects are rare but include allergic reactions, generalized weakness, and influenza-like symptoms. Caution should be exercised in patients with existing pareses such as myasthenia gravis, Lambert-Eaton syndrome, amyotrophic lateral sclerosis, or other myopathies or motor neuropathies [7].

While there are seven serotypes of botulinum toxin, only types A and B are approved for medical uses. Four commercial botulinum toxin preparations are approved and available in the United States and European countries. Onabotulinumtoxin A (trade name Botox®, Allergan Inc., Irvine, CA), abobotulinumtoxin A (trade name Dysport®, Ipsen Ltd., Slough, UK), incobotulinumtoxin A (trade name Xeomin®, Merz Pharmaceuticals, Frankfurt, Germany), and rimabotulinumtoxin B (trade name Myobloc® or NeuroBloc®, US World Meds, Louisville, KY) have varying shelf lives between 24 and 36 months. Botox®, Dysport®, and Xeomin® act by cleaving synaptosomal-associated protein 25 on the A serotype, whereas Myobloc® or NeuroBloc® cleaves the vesicle-associated membrane protein on the B serotype. Additional preparations available elsewhere internationally include Prosigne (Lanzhou Biological Products, China, Lanzhou, Gansu, China), Meditoxin or Neuronox (Medy-Tox, Seoul, Korea), and Botulax (letibotulinumtoxin A; Hugel Inc., Chuncheon, Korea).

Applications in Hernia Surgery

Hernia surgery is a rapidly developing subfield within the specialties of general and plastic surgery. With the advent of laparoscopic and robotic technologies, as well as advances made in biomedical technology and mesh development, evolving techniques are allowing surgeons to tackle more challenging and larger, more complex hernias than ever before, while still striving for excellent long-term outcomes.

Large hernias, whether primary or incisional in origin, pose a difficult challenge for repair. Up to 20% of patients undergoing laparotomy may develop an incisional hernia [8], with rates as high as 35% for those patients needing emergency procedures [9]. Additionally, factors such as obesity, diabetes, wound infection, immunosuppression, malignancy, smoking, and previous laparotomy will increase the risk of hernia development [10]. Simply performing a bridging repair, or closing an abdominal defect under too much tension, has a high rate of failure. Each previous failed hernia repair places a patient at increasingly higher risk of recurrence as the quality of the tissue declines from repeated dissection, mesh explantation, and fascial debridement and retraction [11]. The recurrence rate of incisional hernia was reported as 24% after first repair, increasing to 35% after second and 39% after third attempted repair [12]. Hernia repair can be further complicated if the patient has "loss of domain." While there is no explicit definition or precise measurement method for this, a generally accepted definition is where 50% of the abdominal viscera reside outside the abdominal cavity [13]. The upper size limit of hernias that can be repaired takes many factors into consideration apart from absolute size, including the location of the hernia, orientation and number of defects, amount and compressibility of intra-abdominal contents, and the quality and compliance of the abdominal wall. If closure of the abdominal fascia is successfully accomplished, additional risks remain. These include abdominal compartment syndrome if intra-abdominal pressures are too high after closure, or flap necrosis and donor site morbidity in the case of myofascial cutaneous flap closure [14].

With these considerations in mind, there has been interest in increasing abdominal wall compliance or expanding the amount of tissue within the abdominal wall. Lengthening the abdominal wall musculature may allow for primary fascial closure and thus, the best chance for successful hernia repair. This is currently describing in the literature by using one of three methods—progressive preoperative pneumoperitoneum (PPP) [15, 16], tissue expanders [15, 17], and botulinum toxin A (BTA) [18, 19]. The remainder of this chapter will focus on the role of botulinum toxin A in hernia repair.

Technique of Injection

Anatomy

The abdominal wall musculature is divided into the medial and lateral components. Medially the rectus abdominis muscle is surrounded by the anterior and posterior fascia. At the lateral edge of the rectus abdominis muscle, the fascial layers fuse to

form the linea semilunaris and then split to surround the muscles of the lateral compartment. Three muscle layers comprise the lateral abdominal wall, which is the focus of the area of the BTA injection. Anterior to posterior the muscular layers are as follows: external oblique, internal oblique, and transversus abdominis.

Our Technique

One month before planned incisional hernia repair, BTA injection is performed under sterile technique using ultrasound guidance in the interventional radiology suite. The entire abdomen and bilateral flanks are prepped and draped after midazolam and fentanyl are administered. The planned tract is anesthetized with 1% lidocaine. BTA solution is prepared by diluting 100–150 units of onabotulinumtoxin A (Botox®) into 100 units of preservative-free sterile saline. Three locations are chosen along the lateral abdominal wall utilizing ultrasound guidance to identify all three muscle layers. Using a 21 gauze 7 cm needle attached to the BTA/saline solution, the three layers of the abdominal wall are traversed at an angle while visualized under ultrasound. Care is taken not to violate the peritoneum. Injection is started in the transversus muscle, visualizing the solution bathing the muscle fibers. The injection is continuous as the needle is slowly pulled back into the internal oblique then external oblique muscles, with uninterrupted ultrasound visualization of the injection. This is repeated for the two other locations on the unilateral side. The identical procedure is performed on the contralateral lateral abdominal wall, totaling six injection sites and 200–300 units of BTA. Three hundred units are chosen unless the patient is small and frail with thinned muscle layers.

Data and Outcomes

The first trial experimenting with the use of botulinum toxin for the abdominal wall was performed in 2006. In this study, BTA was injected into the abdominal wall of rats to evaluate if muscle paralysis could decrease intra-abdominal pressure and increase intra-abdominal volume. Despite only a 3-day study period, the authors found significant differences in the pressure and volume between the control and BTA groups [20]. In 2009, Ibarra et al. published the landmark paper describing BTA injection before abdominal wall reconstruction for hernia repair. Twelve patients had bilateral BTA injection under electromyographic guidance. The first two patients underwent weekly transverse hernia measurements, and the authors noted no further reduction after 4 weeks. The next ten patients underwent a CT scan 4 weeks after BTA injection and were noted to have a mean decrease of >5 cm for the transverse hernia defect. There were no complications related to the BTA injection [18]. Since this publication, the literature for the use of BTA on the abdominal wall is increasing; however the research is very heterogeneous.

Studies Involving Ventral/Incisional Hernia Repair and BTA

In addition to the landmark study above, additional studies showed the abdominal wall changes that occur after BTA injection. Pre- and post-BTA injection CT scans have shown an increase in the length of the abdominal wall. Ibarra-Hurtado showed a mean increase in muscle length of about 2.5 cm per side. Other studies showed an increase of 4 cm per side [11, 21–23]. Ibarra-Hurtado also showed a reduction of the lateral abdominal muscle thickness by 1 cm [24]. This translates into both an increase in the abdominal wall volume and improved compliance. Both Ibarra studies reported they were able to close the abdominal wall defect either by open simple closure or Rives-Stoppa; however some patients required abdominal wall components separation. Four studies from the same group, published in 2016 and 2017, include up to 56 patients with each subsequent study examining updated outcomes from a cumulative patient population. While some of the specific methodology details are unclear in the individual papers, the largest cohort of 56 patients allows for a more detailed breakdown of the several arms of treatment. The study included patients who received 200 units of BTA versus 300 units of BTA and another group that received BTA and PPP. CT scan measurements were done for all participants before and after BTA to check the amount of muscle lengthening and the size of the defect. In all of this group's studies, the patients underwent laparoscopic or hybrid laparoscopic-open-laparoscopic repair of the hernia with intraperitoneal onlay mesh. If the defect was not able to be closed primarily, then an endoscopic component release was performed [11, 21–23]. In one of these studies, Elstner et al. reported up to a 58% decrease in the hernia defect size on CT scan [11].

Studies have been published where BTA injection was coupled with PPP when repairing larger hernias. The data in these papers is difficult to interpret as it is unclear how much each of the two adjuncts individually contributed to reestablishing enough domain to repair the complex hernias [11, 25].

Timing of Injection

As BTA does not work immediately, the timing of the injection in relation to the hernia repair needs to be considered. It takes 2 weeks to get the maximal clinical effectiveness of BTA; however Ibarra et al. found that the changes in the abdominal wall could take place up to 4 weeks. Therefore their recommendation was to perform the operation 1 month after BTA injection, which was their practice in both studies [18, 24]. The studies authored by Ibrahim reported injection 1–4 weeks prior to the planned repair except for one that reports injections were done between 7 and 14 days preoperatively [11, 21–23]. In contrast, Zendejas et al. published results of 22 patients who underwent BTA injection, where 13 patients had the injection the same day as the operation [26]. Only nine patients underwent preoperative injection 1–19 days beforehand. As it is unlikely that the benefits of the BTA injection were

present during the operation for most of these patients, the authors could not comment on hernia defect or abdominal wall musculature changes. Their focus was on evaluating postoperative pain and finding decreases in pain on hospital days #2 and #5 compared to controls.

Other Uses

One additional area of interest is the use of BTA specifically in patients with an acute open abdomen. Zielinski et al. performed BTA injection in 18 patients with open abdomens resulting from acute surgical diseases. After patients underwent initial laparotomy, a negative-pressure dressing or Wittman patch was placed and resuscitation completed for at least 12–24 h. BTA injection was performed after resuscitation was complete. The lateral abdominal muscle complex on each side was injected with 150 units of onabotulinumtoxin A (Botox®) divided into three locations, for a total of 300 units over the entire abdomen. The authors reported half the patients underwent BTA injection within 24 h of the first laparotomy, and overall they achieved an 83% fascial closure rate with one to eight serial abdominal explorations [27].

In addition to aiding in the closure of the abdominal wall, BTA injection has other potential benefits as well. One benefit may result from the fact that BTA paralysis lasts 3–6 months, working not only preoperatively but extending benefits postoperatively as well. Normally, the lateral abdominal wall muscle complex, when active, leads to forces of lateral retraction which is opposed by the linea alba [28]. When the linea alba is reapproximated with the hernia repair, it needs time to remodel and scar together. With the lateral paralysis in place, it allows the linea alba to heal for several months without the constant lateral forces. This can theoretically decrease hernia recurrence or separation of the reapproximated linea alba.

A second potential benefit is in the ability of BTA to modulate pain. BTA is known to inhibit substance P and calcitonin gene-related peptide. These molecules are factors involved in inflammation and pain sensation. BTA has already been shown to help in other myofascial and muscular pain syndromes; therefore it is very possible that the BTA injection can decrease postoperative pain and potentially lower opioid requirements [29–32]. A case report of a patient who received 300 units of onabotulinumtoxin A (Botox®) after laparoscopic ventral hernia repair reported a significant and durable decrease in pain [33]. Additionally, BTA injection has been described for abdominal cutaneous nerve entrapment syndrome; however the effects of BTA in this syndrome were not evaluated [34].

Reported Techniques of Injection and Formulations

The original description of the injection by Ibarra et al. involved using electromyography to identify five points of maximum activity on each side of the lateral abdominal muscle complexes. Each side was injected with 250 units of

abobotulinumtoxin A (Dysport®) with 50 units at each site. Total amount of bilateral abobotulinumtoxin A (Dysport®) was 500 units diluted in 5 ml of saline for a concentration of 100 units/ml. The second study by Ibarra et al. describes the same technique except with ultrasound-guided injection at five points placing the injection between the external and internal oblique muscles. Other authors all describe a similar technique of injecting 150 units of onabotulinumtoxin A (Botox®) diluted in saline to a concentration of 2 units/ml into each lateral abdominal wall muscular complex at three points, totaling 300 units injected into six points. At each point, ultrasound guidance is used to insure injection into all three muscle layers [11, 21–23, 26, 27, 33]. Ibrahim does report some use of an equivalent use of abobotulinumtoxin A (Dysport®) instead of onabotulinumtoxin A (Botox®). There is one paper with CT comparisons of patients who received 200 units versus 300 units of onabotulinumtoxin A (Botox®). Average gain in the lateral muscle length via CT measurement was 3.6 cm in the 200-unit group and 4.4 cm in the 300-unit group, a statistically significant difference [23]. There are no reports of use of incobotulinumtoxin A (Xeomin®) for the abdominal wall.

Specific Safety Considerations in Abdominal Hernia Use

None of the authors have described any complications from the use of BTA injections. There are potential risks that should be disclosed to all patients. As with any procedure, there are always risks of infection, bleeding, and pain. There is also a low but possible risk of peritoneal violation and damage to intra-abdominal structures such as intestine. Overall BTA has a very good safety profile, but it should be noted that injection of the abdominal wall for hernia repair is an off-label use. There is also the theoretical risk of the spread of BTA from the injection site leading to symptoms of botulism such as asthenia, generalized muscle weakness, diplopia, ptosis, dysphagia, dysphonia, dysarthria, urinary incontinence, and difficulty breathing. There is the highly unlikely but possible risk of death. There are several contraindications for the use of BTA. Specifically for onabotulinumtoxin A (Botox®), the label recommends that adult patients receive no more than 400 units in a 3-month period. There are also patients who have hypersensitivity reactions such as anaphylaxis or urticaria. Caution is necessary for patients with pre-existing neuromuscular disorders as they are at risk of increased clinically significant effects similar to botulism. A careful history to rule out peripheral motor neuropathic diseases, amyotrophic lateral sclerosis, or neuromuscular junction disorders such as myasthenia gravis or Lambert-Eaton syndrome is important. BTA should not be used in women that are pregnant or breastfeeding. Onabotulinumtoxin A (Botox®), incobotulinumtoxin A (Xeomin®), and abobotulinumtoxin A (Dysport®) contain albumin, which is a derivative of human blood so there are very unlikely but theoretical risks of transmission of illnesses. Additionally, there is the potential of developing antibodies against onabotulinumtoxin A (Botox®) and abobotulinumtoxin A (Dysport®) that may reduce the efficacy of future use. While incobotulinumtoxin A (Xeomin®) has a much lower reported rate of antibody formation, it has been observed [35].

Antibody formation increases when higher doses are given at shorter intervals. Administering BTA and aminoglycosides such as gentamicin can potentiate the toxin effects. As abobotulinumtoxin A (Dysport®) may contain trace amounts of cow's milk protein, it has the unique contraindication of requiring caution in those who are allergic. The units of abobotulinumtoxin A (Dysport®) and incobotulinumtoxin A (Xeomin®) are unique to its preparation and therefore are not interchangeable with other BTA medications such as onabotulinumtoxin A (Botox®). Additionally, abobotulinumtoxin A (Dysport®) warnings include potential immune reaction with intradermal use only.

Conclusion

BTA holds a promising role in complex hernia repair. Although data is limited, all evidence points to a good safety profile, and there are both subjective and objective benefits to its use. Future directions for investigation would need to elucidate optimum dosage, timing of administration and further clarify patient selection guidelines.

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Mesh Sutured Repairs of the Abdominal Wall

23

Gregory A. Dumanian and Steven T. Lanier

Introduction

When the ultimate tensile strength of newly apposed tissue remains above the level of the forces applied, the repair will remain intact. However, when distracting forces are greater than strength of a repair, the closure begins to gap as sutures tear through tissue at the suture/tissue interface (STI). Dehiscence represents an acute loss of integrity of the closure, often due to a large force applied over a short amount of time. Incisional hernia formation represents a slower deformation of the repair site due to the repetitive application of stress over time resulting in chronic suture pull-through and ultimately repair failure.

Larger suture filaments resist tearing through tissue in comparison to finer suture of the same tensile strength, for the same reason that large nails better support hanging pictures on drywall than do slender nails. Large suture filaments distribute forces at the STI over a broader surface area than does a thinner suture. However, drawbacks of large filament sutures are high-profile knots that are poorly tolerated by overlying tissues, potentially becoming infected and requiring removal.

In order to utilize a large-sized suture (for force distribution) with a relatively small knot, a mesh suture was conceptualized. The mesh suture is mostly air so that the filaments collapse at the tied knots for low profile and improved biocompatibility. Tissue ingrowth into the suture may magnify collagen deposition and the foreign body response at the repair site. Experimental mesh sutures have been shown to resist suture pull-through in comparison in vitro to clinically used solid sutures in cadaver human finger tendon [1] and dog cadaver rotator cuff models [2]. In vivo rat

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hernia [3] and porcine laparotomy models [4] have shown resistance to suture pull-through and double the ultimate tensile strength of closure at 8 days.

Based on these concepts and preclinical data, the mesh suture technique for approximating the abdominal wall was developed. Uncoated macroporous polypropylene hernia mesh is cut into strips and used as sutures—passing them through either side of the abdominal wall and approximating the tissue with tied knots. Surgical technique and outcomes are presented below.

Surgical Technique

To create mesh sutures, strips 20 mm wide are cut along the blue lines of a single piece of PROLENE Soft Prolene Mesh (Ethicon, Somerville NJ, 12 × 14 in. or 30.5 × 35.6 cm in size). This uncoated, macroporous, lightweight polypropylene mesh, when cut along the blue lines, generates strips that have higher ultimate tensile strength than a number one polypropylene suture [5]. Other macroporous uncoated meshes in the high lightweight to low mid-weight range could potentially be utilized for a mesh suture technique; however, the surgeon needs to understand a particular mesh's anisotropic properties in order to cut strips in the appropriate direction to maintain sufficient tensile strength. For example, Bard Soft Mesh (Davol, Warwick RI) is comprised of diamonds with relatively equal sides that are bisected with two fine filaments to create two smaller triangles. The surgeon should cut strips parallel to the two fine filaments. Composite partially absorbable meshes such as Ultrapro have not been tried. At present we have only gathered experimental data on the tensile strength of our preferred mesh for the technique, PROLENE Soft Prolene Mesh, and thus cannot endorse the adequacy of repairs using mesh strips of other brands and manufacturers.

In order to pass the strips through the abdominal wall, a number one polypropylene suture is tied to the end of the mesh strip. The needle of the number one polypropylene suture is then passed through the abdominal wall with a standard needle driver and simply used to pull the strip through the tissues. The mesh suture is tied with a square knot and an additional throw for security. The sutures are placed with 1 cm bites, spaced 10–12 mm from each other. (The reader can visit https://youtu.be/OuMp3EXAxzw for an illustration of the technique.)

Mesh sutures can be used as the sole closure device of the abdominal wall or can be used in combination with planar meshes. Standard surgical techniques of excision of scar, removal of old mesh, avoidance of subcutaneous fat in the suture loop, and incorporation of the posterior sheath are all important and not specific to a mesh suture closure.

Mesh sutured repairs achieve a high-tension closure with improved force distribution and less pull-through than a standard suture repair but with less total foreign material and less opening of tissue planes than required for a planar mesh.

Indications

Sutures alone are not sufficient for hernia repair due to an unacceptable chance of recurrence. At Northwestern, even with the addition of an anterior components release, suture closure alone yielded a recurrence rate of 23% at 14 months [6]. Use of a macroporous, uncoated, lightweight polypropylene mesh placed in the retrorectus space can decrease the hernia recurrence rate down to zero at over 2 years of follow-up for clean cases [7]. However, not all hernia cases can or should have a full retrorectus mesh placement, particularly cases with gross contamination or a compromised posterior sheath.

Our indications for a mesh sutured repair alone, without a concurrent planar mesh underlay, include:

- Umbilical hernias and small defects that do not warrant a full retrorectus mesh.
- Open abdomens and acute dehiscences.
- Non-midline defects or defects with altered anatomy (such as abdominal wall resection or flap harvest) in which defect geometry is not favorable for an planar mesh placement.
- Parastomal hernia repair with bowel obstruction.
- Hernia repair in high-risk patients with medical comorbidities that may not tolerate the additional operating room time required to perform a planar mesh repair and contaminated defects where utilizing a planar mesh risks mesh infection requiring removal. While both Carbonell [8] and Slater [9] have shown excellent outcomes with acceptable complication rates with the use of planar meshes in contaminated fields, both series still had an approximately 5% incidence of full mesh removal.

Umbilical Hernias and Small Defects

Umbilical hernias are common clinical entities with wide variations in treatment. Suture repairs are generally simple and with less surgical site occurrence (SSO), while mesh repairs have less hernia recurrence [10] but with higher surgical site infection (SSI) [11]. Mesh sutured repairs have the benefits of simplicity and force distribution, but without the need for a preperitoneal mesh. Typically, three to four strips are used for a 1–2 cm diameter defect. A video of a mesh sutured repair of an umbilical hernia can be found at https://www.youtube.com/watch?v=dbezjvIlUyQ. The surgeon should exercise caution for repair of umbilical hernias with coexisting rectus diastasis, as the superior-most mesh strip will be placed in tissues that are already stretched and potential susceptibility to pull-through. The same is true for epigastric hernias located in the center of rectus diastasis. At least 20 umbilical hernias have been repaired using this mesh suture technique with only one recurrence.

Open Abdomen and Dehiscence

Repair of the open abdomen is difficult, as tissues are swollen, inflamed, and potentially contaminated. For fascial dehiscence, there has already been one failure at the suture/tissue interface. The goals of closure are to limit the chance of a recurrent dehiscence, avoid development of an enterocutaneous fistula, and to achieve a long-term intact abdominal wall. Sheets of prosthetic mesh are avoided due to the required tissue dissection in an already inflamed field and the potential for contamination. Sutures have already failed. Bioprosthetic meshes used for force distribution are associated with high SSO in these cases. Polyglactin meshes to contain viscera and then skin grafts 2 weeks later are safe and effective at avoiding a recurrent dehiscence but require a complex second-stage hernia repair [12]. Mesh sutured repairs solve many of these considerations, as they can be placed in an inflamed field without significant concern for infection or sinus tracts as will be described in "Repair of Contaminated Incisional Hernias" section. They achieve improved force distribution in comparison to sutures, and they do not require opening of new tissue planes. An illustrative case of a massive open abdomen after a liver transplant taken back to the operating room three times is provided (Fig. 23.1). Sequential closure

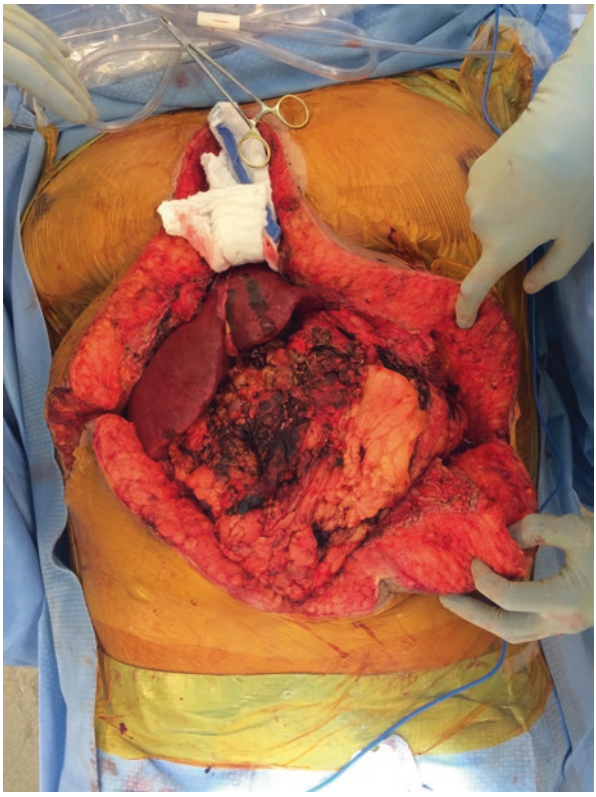

Fig. 23.1 Liver transplant patient 3 days after initial Mercedes incision with median sternotomy for vascular control

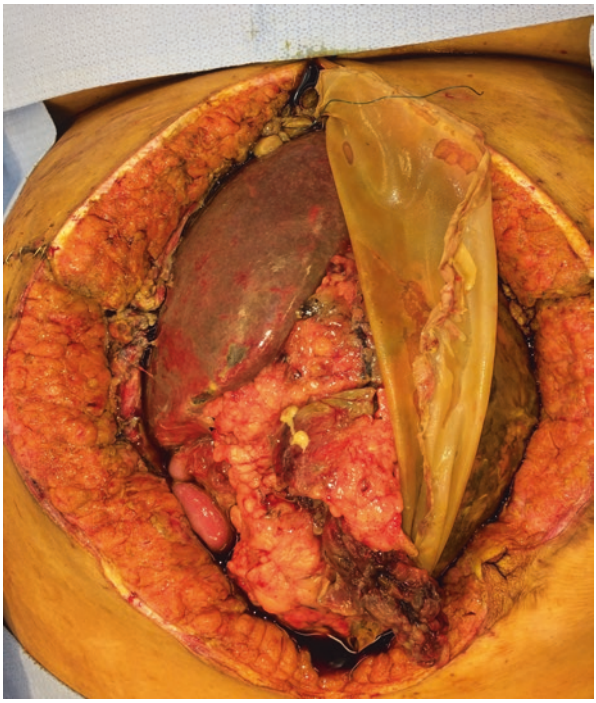

Fig. 23.2 Lateral incisions closed with mesh sutures. Midline temporarily closed with polyglactin mesh

over three separate operating room procedures was required (Figs. 23.2, 23.3, 23.4 and 23.5). Nine dehiscence and open abdomen cases have been closed in this manner over the last several years, with two patients returning to the operating room for a formal mesh repair in a well-nourished patient without wounds. No patient developed a sinus or chronic infection from this closure technique.

Non-midline Hernias

There are several difficulties with non-midline hernia repairs. Thin muscle fascia and the muscle itself away from the midline do not hold sutures well, often resulting in tissue tearing at the STI. In addition, intercostal segmental nerves are sizeable and located in the area of these lateral defects, increasing the potential to be ensnared by multiple sutures required to hold a planar mesh in place. For these reasons, flank hernias are regarded as extremely challenging to repair and in many hands are treated with giant prosthetic meshes with wide overlays and with minimal transfascial sutures for fixation [13]. Diametrically opposed to this approach is to simply repair the abdominal wall with a mesh suture that resists pull-through and is quickly incorporated into the tissues to decrease the chance of infection. By keeping the mesh sutures at the site of muscle division, these are anatomic repairs that may better avoid intercostal nerve injury.

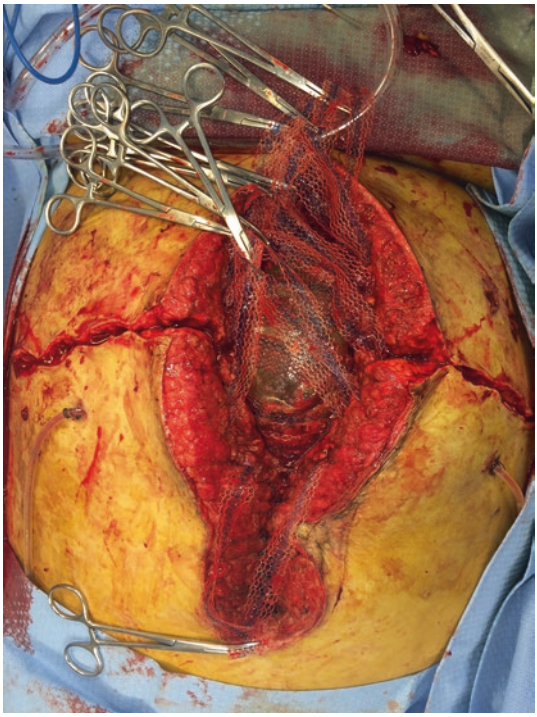

Fig. 23.3 Sequential polyglactin mesh tightening, abdominal wall closure with mesh strips

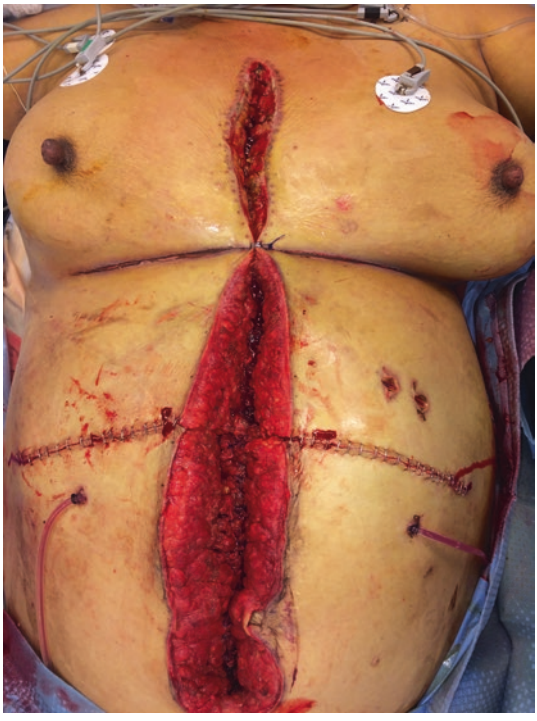

Fig. 23.4 Midline allowed to close with negative pressure wound treatment assistance

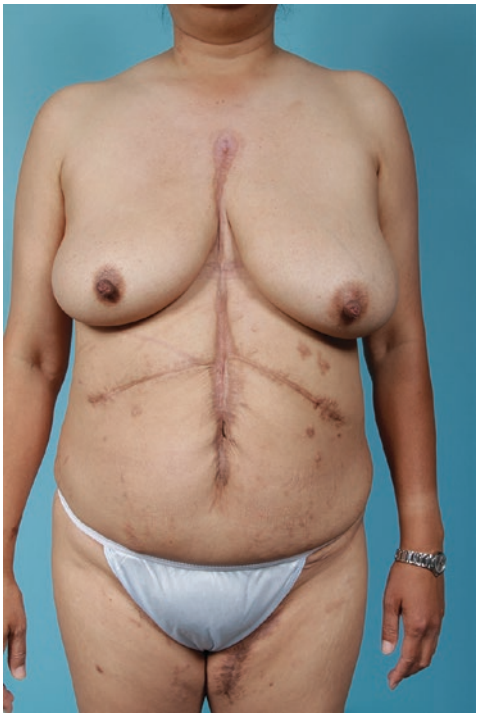

Fig. 23.5 Patient has remained hernia-free with over 1-year follow-up

A common misunderstanding regarding flank defects is that there is an element of denervation or a zone of muscle atrophy. Flank defects lateral to the semilunar lines are typically hernias of the internal oblique and transverse abdominis, with an intact external oblique. That is why the hernias often do *not* seem classic and do *not* have bowel palpable underneath the skin. In our recent study, 55% of patients had this hernia pattern of defects of the deeper two layers of the abdominal wall, 32% had hernias of all three layers, and only 13% had denervation injuries (often identifiable with an injury to the spine) [14].

Flank hernias exist in several common patterns. Defects lateral to the semilunar line after urology or other retroperitoneal access procedures are located along dermatome lines and do not have any denervation component. Kocher, reverse Kocher, and Mercedes incisions for hepatobiliary, spleen, and pancreas procedures involve the rectus muscles and can extend past the semilunar lines. These three incisions create a variable zone of denervation of the rectus muscle inferomedial to the incision. "Hockey stick" incisions are oriented typically along the dermatome lines and do not create large denervation zones, though they do cross the semilunar line. Finally, flank hernias associated with trauma often are located near or involve the pelvic brim and may require a reinsertion of the abdominal muscles to bone with anchors or trans-osseous sutures.

Mesh sutured repairs can be performed quickly due a lack of requirement for opening of large tissue planes. With the patient in lateral decubitus position, the abdomen is entered through the hernia defect, and the retracted internal oblique and transversus abdominis muscles can be located by palpation. The interval between these two

muscles and the overlying external oblique is developed. The only difficulty in this dissection is if the semilunar line is involved, as the planes are relatively fused at this site. After locating the layers, the operating room table is put into the reflexed position, and the mesh strips are passed through the internal oblique and transversus abdominis musculature (or even around a rib if that is required). The importance of reflexing the operating room table to bring the lateral tissues into better apposition greatly facilitates this repair technique. If there is significant tension, multiple strips can be placed and then tied down all at once, so as to avoid a single mesh strip/tissue interface bearing the entirety of the repair force, even for a short period. Following repair of the internal oblique and transversus abdominis as a single unit, the attenuated external oblique is resected to healthy muscle and approximated with mesh sutures as a second layer. If desired, a hybrid type of procedure with a narrow well-fixed planar mesh immediately under the external oblique can be employed. A mesh sutured repair of a patient after rib resection for abdominal aortic aneurysm access demonstrates the retracted internal oblique/transverse abdominis muscles which can be viewed at https://www.youtube.com/watch?v=Fx_vM0Ra90c. A right-angled clamp as opposed to a number one polypropylene suture for passage of the mesh sutures is used in this relatively early case that is still without a recurrence.

Parastomal Hernia Repairs

As mesh sutures seem relatively resistant to contamination as will be described in "Repair of Contaminated Incisional Hernias" section, it seemed natural to use them to tighten the musculature around a functioning ostomy at the time of a parastomal hernia reconstruction. Unfortunately, three or four patients treated in this manner went on to have their parastomal hernia recur as described below. Mesh sutured repairs have been performed expeditiously in parastomal hernias with an associated bowel obstruction, where a formal repair with a planar may be quite challenging.

Repair of Contaminated Incisional Hernias

Treatment of the patient with a pre-existing hernia in need of a bowel procedure or patients with hernias and infected mesh is hotly debated. Suture closure of the abdominal wall is simple, does not require the opening of tissue planes, and is associated with at least a 23% recurrence rate even if an anterior components release is performed [6]. Delayed primary closure to decrease the chance of infection requires a second trip to the operating room. Prosthetic planar mesh placement is controversial and could require the removal of the mesh if the bowel surgery requires revision or the mesh were to become infected [8]. Bioprosthetic mesh, touted for its resistance to infection, is still associated with high SSO and does not obviate the development of a recurrent incisional hernia [15].

We recently reported the outcomes of 48 patients treated with contaminated incisional hernias with mesh sutured repairs [16]. All patients were clean-contaminated, contaminated, or infected by Centers for Disease Control and Prevention definition.

All had pre-existing hernias greater than 5 cm wide by CT scan (range 5–25 cm), and the average separation of the medial border of the rectus muscles by CT scan was 10.5 cm. The average age was 62, and the average BMI was 29.8. Anterior components release performed through lateral incisions for perforator preservation was performed in 69% of the patients to decrease tension at the repair site and to have the ability to debride scarred or infected midline tissue.

With an average follow-up of 12 months, 3 patients had failure of the 48 midline incisions closed with mesh sutures, for a 6% hernia recurrence rate for ventral hernia repair. In four patients a parastomal defect was tightened around a functioning ostomy loop, and three of these repairs failed, yielding an *overall* failure rate of 13%. The overall SSO rate was 27% with an SSI rate of 19%, the majority of which were managed conservatively with antibiotics. Two patients with infected subcutaneous fluid collections returned to the OR for a washout, but the strips were left in place. These two patients have remained hernia-free. No patient had a delayed removal of mesh strips due to chronic sinus formation. When compared to similar cohorts reported for other techniques [16], a mesh suture repair had similar SSO and SSI, but is technically more straightforward and quicker, with the same or lower hernia recurrence rate. As all of the foreign material is located immediately under the surgical incision, removal of the sutures for re-exploration for infection would not be particularly challenging. While longer-term follow-up is needed for hernia recurrence rates, it is emphasized that this is a "get-out-of-Dodge" strategy for difficult clinical situations that is fast, does not require the opening of tissue planes (thus not compromising tissue vascularity), and still permits a planar mesh repair in a clean field at a later time. Perforator-sparing anterior components releases are an excellent adjunct to the procedure to reduce tension at the closure line.

Mesh Suture Closure as an Adjunct to Planar Mesh Repairs

As mentioned above, for clean midline ventral hernia defects, a planar mesh repair remains our primary technique of choice and has not had a recurrence in 100 patients with 2-year follow-up [7]. However, even for retrorectus mesh repairs, we perform the final tissue approximation of the medial border of the rectus muscles over the mesh with mesh strips rather than standard suture. Over and above decreased suture pull-through, we believe that mesh strips have improved biocompatibility in comparison to sutures as will be discussed below.

Drawbacks/Pitfalls

All of the procedures described are open surgeries with lengthier hospitalizations than achieved for minimally invasive surgeries. Incisions and resulting scars are long, often requiring the excision of skin made redundant by the abdominal wall approximation. Drains and soft tissue handling are necessities of all but the smallest mesh sutured repairs, as is a working knowledge of perforator preserving anterior components

releases. Attaching the introducing needle to the mesh strip is clumsy, though these procedures are still quicker in duration to alternatives using large planar meshes. Our relatively unsuccessful outcomes in the few parastomal hernias closed with mesh sutures are found in "Parastomal Hernia Repairs" section. There are no contraindications to the performance of a mesh sutured closure, though alternate strategies are typically used for truly infected cases. The greatest potential issue is draining suture sinuses from the increased surface area and amount of permanent foreign material located particularly at the knot. The amount of foreign material is far less than a planar mesh, though still more than an absorbable suture. As is discussed below, this has not been a clinical problem (Figs. 23.6, 23.7, 23.8, 23.9, 23.10 and 23.11).

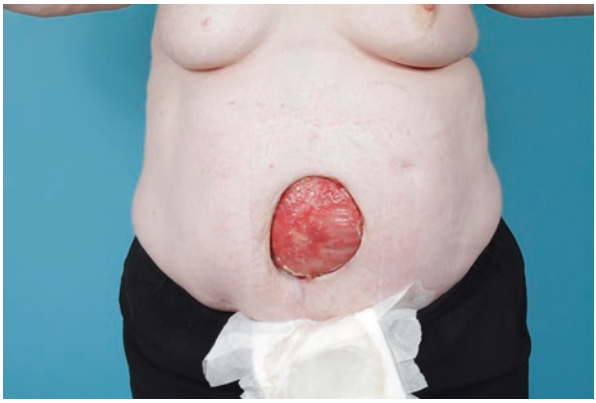

Fig. 23.6 A 60-year-old female with left rectus removal for breast reconstruction. Underwent a repair using a transversus abdominis release (TAR) with mesh and then had a postoperative mesh infection that required mesh removal. Presented with this open granulated wound

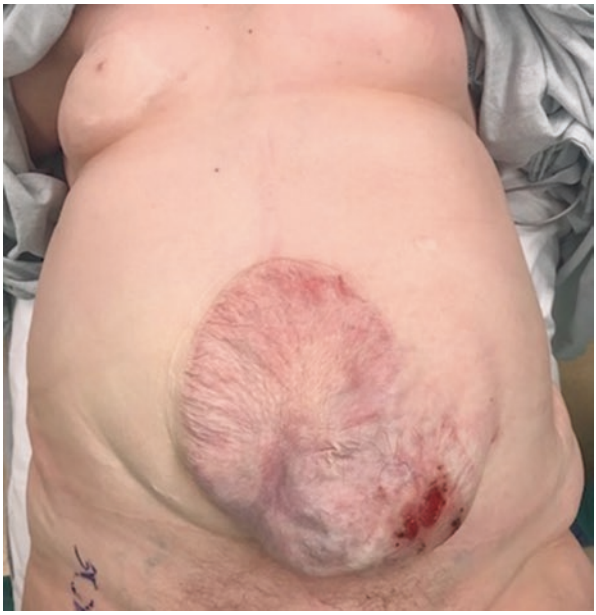

Fig. 23.7 One year after skin graft closure of wound, she developed new wounds on the left side of the hernia. Due to the prior TAR release, she could not have a components procedure, so she received botulinum toxin into the abdominal wall to improve compliance 1 month before surgery

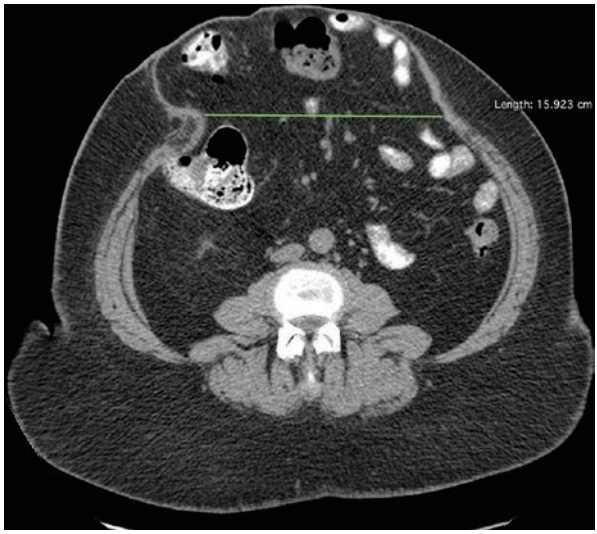

Fig. 23.8 CT scan demonstrates 15.9 cm separation between abdominal wall edges

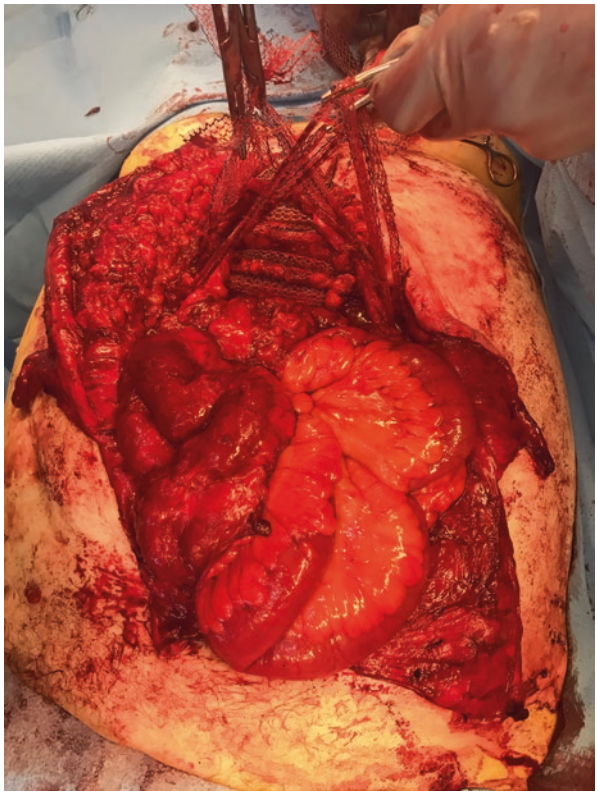

Fig. 23.9 Upper mesh sutures in place between left semilunar line and right rectus muscle

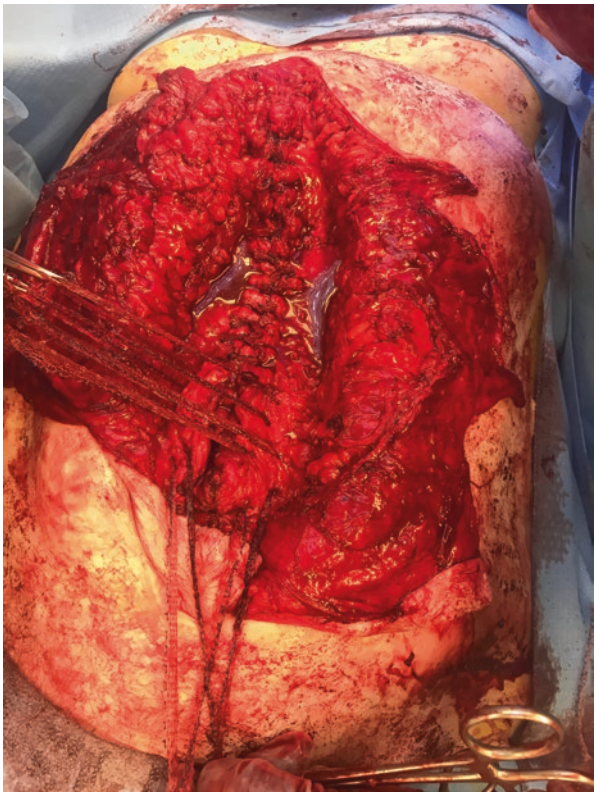

Fig. 23.10 Continued primary closure with mesh sutured technique

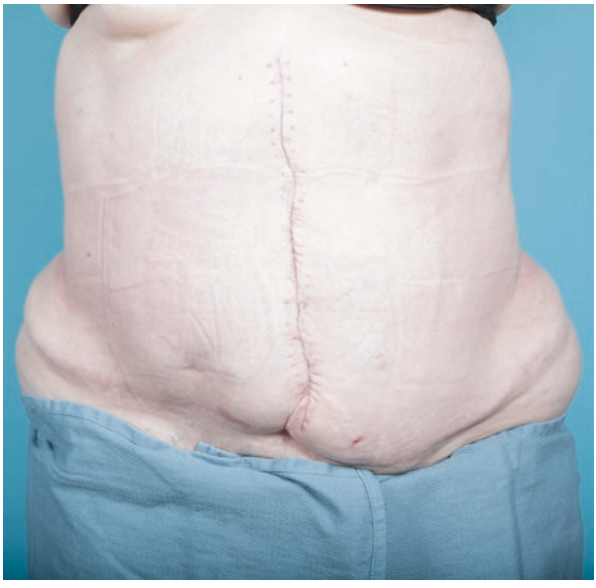

Fig. 23.11 Six-month outcome with intact closure and without wound issues

Discussion

The key to all high-tension tissue repairs (including the linea alba, rotator cuffs, Achilles, finger tendons, etc.) is for the strength of the repair to remain high. At the time of surgery, the strength of the repair is a complex mixture of the strength of the sutures, the number of sutures applied, knot integrity, and the resistance of the tissues to tear at the suture/tissue interface (STI). Soon after suture repair of tissues, and over the next several days, there is loosening of the suture tension by up to 50% [17], perhaps due to a "softening" STI from local ischemia, inflammation, or collagenases. The postoperative weakening of the physical construct of tendon repairs was first shown in 1941 and was determined to last approximately 5 days before biologic healing becomes additive to the total repair strength [18]. Early tearing of sutures through tendons is referred to as "gap formation" in the orthopedics literature and is due to the forces applied at the STI being greater than tissue tolerance. In hand surgery, early gap formation of a repaired finger flexor tendon of 1–3 mm is associated with either rupture or scar formation [19]. Analogously, early separation of the midline abdominal closure at 30 days of 15 mm or more as shown by migration of metal clips placed at the time of laparotomy or by CT scan demonstrates that early failure of the abdominal wall closure construct is predictive of incisional hernia formation [20–22].

Sutures concentrate forces at the STI, and for high-tension closures a zone of ischemia of variable size and dimensions is created. This zone of ischemia causes an internal pressure sore, though its size is small enough to permit remodeling over time through the creation of scar. Humans scar more than other animals and regenerate less [23]. Scar is not normal tissue, and it lacks pulsatile blood flow that accompanies normal wound healing [24]. It does not respond to tensile forces with hypertrophy as described by Wolff's law. Instead, scar deforms in response to normal tensile stresses, elongates, and weakens over time. If the strength of the scar falls below the outward forces applied to the abdominal wall by the viscera, an incisional hernia will develop. Scar is also not as strong as the native tissue it replaces, gaining only 70% of the strength of the native linea alba [25]. It is the replacement of the linea alba with scar that could be the cause of "late" incisional hernias over time [26].

It has been shown in preclinical animal models that mesh sutured repairs have a greater early tensile strength than suture closures, but the tissue tolerance of the mesh strips, especially in a contaminated field, then becomes important for clinical usage. Classic teaching is to limit permanent materials to a minimum and possibly to only use absorbable sutures and absorbable meshes (synthetic or bioprosthetic). In our reported series [16], several patients had their midline skin incisions left open with exposure of 0-polypropylene sutures (diameter 0.4 mm) and mesh strips (filament diameter 0.15 mm for Soft Prolene). Over time, the sutures required removal to permit healing, whereas we observed the deposition of granulation tissue over and around mesh strips during the course of secondary wound healing. Several other patients with seromas and exposed mesh strip knots had their skin opened in the office, and the wounds were allowed to close with local wound care. This clinical

experience is consistent with animal data that the foreign body reaction quantitatively differs depending on the filament diameter [27]. We propose that a high surface area/low filament size closure with mesh strips is more biocompatible than a low surface area/high filament diameter device such as a large monofilament suture. In addition, the high surface area conditions of a permanent suture will result in a magnified foreign body reaction that persists and is located immediately at the repair site. This compares well conceptually to large planar meshes that create scar burden far from the abdominal wall closure.

Mesh sutured repairs have simplified our abdominal wall paradigm. Clean midline cases that require either a long repair or associated treatment of rectus diastasis receive a narrow well-fixed retrorectus mesh. Almost every other clinical situation (other than parastomal hernias) have been treated successfully and simply with mesh sutures.

Conflict of Interest Statement Dr. Dumanian has financial interest in the Advanced Suture Co and the Mesh Suture Co. He could potentially benefit from the outcomes of this research. There are no additional conflicts to report for Drs. Dumanian or Lanier.

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Treatment of Parastomal Hernias

24

Zachary Sanford, Adam S. Weltz, and Igor Belyansky

Introduction

Parastomal hernias are a dreaded yet common complication following the creation of a surgical stoma. Their repair represents a significant surgical challenge as the presence of functional bowel passing through the abdominal wall by means of an iatrogenic defect makes fascial continuity impossible to restore. Although surgical intervention was once associated with high rates of recurrence and significant postoperative complications, modern techniques for parastomal hernia repair through incorporation of mesh reinforcement and minimally invasive procedures have brought about improvements in the perioperative and postoperative course.

Risk Factors and Incidence

Parastomal hernia formation following stoma creation remains extremely common in the extant literature necessitating thoughtful planning and patient education [1–3]. While the greatest risk for formation presents in the first 3–5 years following the creation of the diverting ostomy, parastomal hernias may form before and after this period as well [4, 5]. There are several associated risk factors that may predispose patients to greater likelihoods of parastomal hernia formation. Pathologies associated with increased intra-abdominal pressure or weakening of the abdominal wall increase a patient's risk of parastomal hernia formation [6, 7]. Chief among these are advanced age resulting in age-related thinning of abdominal wall musculature with concomitant loss of counter-tension to externally directed pressures [4]. Obesity represents an increasingly common modifiable risk factor in Western societies and has been directly correlated to increases in risk for parastomal hernia

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formation as measured by increases in BMI and abdominal circumference [8, 9]. Additional diseases implicated in higher-risk patients are chronic pulmonary disease or chronic cough syndromes, malnutrition, chronic steroid use, sepsis, or past history of previous abdominal wall hernia [5, 7, 10].

Diagnosis

Correct diagnosis of a clinically significant parastomal hernia can be made with adequate physical exam by means of having the patient perform a Valsalva maneuver, during which the clinician will be able to appreciate a bulging of hernia contents either on visual inspection or palpation of the ostomy site [11]. Equivocal findings on physical exam can be clarified with computed topography (CT) of the abdomen, although increasing reliance on imaging has resulted in a dramatic increase in the identification of incidental subclinical hernias that have no harmful impacts on patient quality of life [11, 12]. Some estimates place the rate of incidental parastomal hernia discovery by CT scan as high as 70%, raising concerns about the utility of conventional usage of diagnostic imaging in place of adequate physical exam [13]. These incidental findings are a source of potential iatrogenic exacerbation as many hernias do not require surgical correction but may still postoperatively present with high rates of recurrence or postoperative complications. If the patient lacks clearly defined complaints relating to the presence of a parastomal hernia and presents with no risk for strangulation, conservative management and routine follow-up exam should be strongly considered [10].

Repair of Parastomal Hernias

Operative repair of parastomal hernias is appropriate in acceptable surgical candidates who present with symptomatic hernias as discussed earlier. Symptomatic hernias are defined as those presenting with herniated abdominal contents at risk for strangulation or bowel obstruction although bleeding and ill-fitting stomal devices may benefit from surgical consideration [10]. Other less troubling considerations include local pain or irritation and insufficient cosmesis due to telescoping of bowel or retraction of the ostomy. The following represents a systemic review on the topic of surgical repair of parastomal hernias while offering discussions of tips and pitfalls where appropriate.

Stoma Relocation

Ideal stoma placement should be below the level of the umbilicus and often within the left or right lumbar region of the abdomen along surfaces without bony protuberances or redundant tissue or skin folds. An encircling disc of smooth skin should surround the stoma, making it easy for direct patient visualization and stomal care.

In the event where a stoma has been improperly constructed, placed in an emergency setting, or if the abdomen has undergone distortion as a consequence of the disease process additional surgery to relocate the stoma may be necessary [14, 15].

Although laparotomy was formerly the surgical approach of choice in relocating a previously established stoma, in experienced hands laparoscopy is now a commonly used modality. Compared to the substantially more invasive midline dissections required of laparotomy, laparoscopic techniques have been associated with reductions in postoperative patient pain scores, complication rates, intra-abdominal adhesion formation, and midline incisional hernia formation as the midline abdominal wall remains intact [16–20].

Relocation is not without its challenges, as the introduction of a new stoma site disrupts local abdominal architecture. The presence of a new defect in addition to the closure of a potentially large preexisting defect may make adequate restoration of abdominal wall integrity a challenge. The use of prosthetic devices to restore abdominal wall continuity has become increasingly common. The authors encourage the judicious selection and use of synthetic nonabsorbable materials. At present there is insufficient data to support claims as to long-term efficacy of biologic materials in abdominal wall repair that may offset their increased material costs.

The high rate of hernia recurrence associated with the creation of a stoma is comparable to the creation of a new stoma site during relocation and increases with each additional abdominal surgery. Some reports indicate parastomal hernia formation following relocation may approach 50%, although selection of a contralateral stoma site may reduce this risk [15, 21, 22]. As such, relocation is appropriate when necessary but should be discussed with the patient to manage postoperative expectations.

Primary Repair

Primary repair of parastomal fascial defects present often unacceptably high failure rates but may be considered as a means of last resort when other options are deemed unavailable or unsafe.

If attempted, the surgeon begins by making an incision approximately 5 cm from the mucocutaneous junction of the hernia defect and proceeds with dissection until the hernia sac is identified. The sac is then mobilized and the hernia reduced, taking care to avoid injury to the adjacent stoma. Cases where fascial edges are brought into approximation under tension are at risk of hernia recurrence when compared to techniques utilizing mesh [19, 21–24].

Parastomal Hernia Mesh Repair

Appropriate selection of mesh material is crucial in planning parastomal hernia repair. Traditionally, most parastomal hernia repairs utilize synthetic expanded polytetrafluoroethylene (ePTFE) mesh due in large part to its resilience against

forming intra-abdominal adhesions to exposed bowel and against erosion into adjacent structures [25–27]. These benefits must be weighed against the risk for ePTFE mesh to acquire postoperative mesh infection and raise concerns specifically in instances of contaminated or dirty surgical fields, such as in open bowel resection [26, 28].

Biologic mesh materials have been promoted by some experts to be use in contaminated fields [29]. Allograft and xenograft materials are derived human, porcine, or bovine donors and decellularized to form collagen matrices that serve as a stabile lattice suitable for mesh creation [30–34]. Collagen matrix materials were developed with the intention of implementation in clean-contaminated or contaminated surgical fields, suggesting they may be ideal materials in the repair of parastomal hernias [29]. Early reports suggest that limitations to the use of biologic meshes arise in heavily contaminated fields where bacterial loads can compromise tensile strength of the mesh and in their use with bridging techniques which result in unacceptable degrees of stretch and mechanical failure of biologics [35].

Newer composite meshes are now available on the market, and a variety of them may be used for parastomal hernia repair in IPOM (intraperitoneal onlay mesh) fashion. In addition, more recently several modifications to parastomal hernia repair techniques have been reported where natural abdominal wall spaces are utilized to hide the mesh from intra-abdominal contents [36, 37]. In such cases, the use of uncoated macroporous polypropylene medium-weight mesh (MPMW) is becoming quite common. Recent data suggests that the use of MPMW mesh in contaminated field may be a safe viable option, although much needed randomized prospective studies are lacking to make a strong recommendation for their use [38, 39].

Onlay Mesh

The onlay repair technique is a superficial reinforcement of the anterior abdominal fascia surrounding the stoma site, positioning mesh within the subcutaneous space [40, 41]. The technique has been widely adapted and reinterpreted by a number of hernia repair surgeons, all taking a subtle variation on the general principle [42–44]. One such approach as described by Rosin and colleagues presents a stomal reconstruction whereby the existing stoma is stapled to a close and retracted through a circumferential incision to then be reintroduced through a polypropylene mesh that is affixed to the anterior fascia [45]. By contrast, Leslie maintains the stomal mucocutaneous junction, instead opting for the utilization of a preexisting laparotomy scar to create an L-shaped incision from scar to ostomy which enables repair of coexisting parastomal and incisional hernias with mesh reinforcement [46, 47]. Tekkis has described a window exposure technique whereby a semicircular incision along the lateral edge of the stoma can allow for mesh reinforcement of three-quarters of the surrounding abdominal wall [48, 49]. When performing these types of repair, it is important to consider that superficial placement of mesh in the subcutaneous layer poses a risk for mesh infection secondary to wound morbidity.

Underlay Mesh Placement

The underlay technique derives its name from the tunneling of lateralized bowel superficial to a deeper mesh layer rather than penetrating the mesh material. First pioneered by Sugarbaker in 1985, the technique has since undergone numerous revisions and technical adjustments; however, all variations universally afford wide exposure of the fascial defect from within the intra-abdominal cavity [50, 51]. This allows for substantial mesh overlap and confers stability to the abdominal wall defect while attempting to mimic the physiologic functions of the abdominal wall.

With the development of laparoscopic techniques, the underlay technique is performed via a minimally invasive approach while avoiding the wound morbidity associated with laparotomy. Current studies show the incidence of parastomal hernia recurrence up to 10%, although consensus seems to suggest that the laparoscopic Sugarbaker technique is superior to the keyhole technique resulting in fewer recurrences [13, 42].

Underlay keyhole technique is so named for its resemblance to an actual keyhole, with the securing mesh having a slit placed from a lateral edge to the middle to accommodate the presenting segment of bowel and leaving the stoma undisturbed. This technique can be performed laparoscopically. The hernia sac and its contents are reduced. Minimum of 5 cm overlap is desirable between the mesh and fascia to ensure proper integration and stability. The aperture site around the stoma should be tightened with sutures without obstructing the conduit passing through it. Once the mesh is inserted and the intact stoma is threaded through the keyhole slit, the keyhole is sutured together and affixed to the anterior abdominal wall, either with sutures, tacks, or a combination thereof. This technique is associated with high rates of parastomal hernia recurrence [52–54].

Laparoscopic approach to the Sugarbaker technique leaves the mucocutaneous junction intact. Adhesiolysis is again completed and the colon is lateralized. After reduction of the hernia, the fascial defect is closed primarily and covered with a mesh prosthetic. Mesh is centered over the stoma site then fastened with several transfascial sutures, providing broad coverage for the lateralized colon. Care should be taken to prevent stenosis or angulation of the colon during mesh placement. When adequate coverage of the lateralized colon is obtained, tacks alone or a combination of tacks and sutures may be used to achieve sufficient stabilization of the prosthesis. The resulting flap created by the implanted mesh prevents parastomal hernia formation around the colon and has demonstrated acceptable rates of hernia recurrence [55].

Transversus Abdominis Release and Modified Retrorectus Sugarbaker

Posterior components separation via the transversus abdominis release (TAR) technique facilitates enlargement of the retrorectus space, allowing for wide mesh overlap of abdominal wall defects and facilitating closure of larger abdominal wall

defects. Open TAR in combination with Sugarbaker repair has been previously described by Pauli et al. [36]. In addition laparoscopic and robotic approaches to this dissection have been previously reported by our group.

In brief, preperitoneal dissection is initiated by taking down the falciform ligament while leaving its lateral attachments to the contralateral posterior rectus sheath intact. Importantly, the stoma remains in situ. Therefore to facilitate dissection of the retromuscular space, the surgeon should approach from the cephalad and caudad direction and progressing medially. The hernia sac may itself be opened in the retromuscular space, allowing for direct visualization of the stoma during dissection. The umbilical ligaments are similarly taken down, developing the space of Retzius. The contralateral posterior rectus sheath is then incised, and the preperitoneal space is joined with the left retrorectus space. The transversus abdominis muscle is subsequently exposed as the posterior lamella of the internal oblique is divided. Division of the transversus abdominis is then completed, leaving the glistening layer of the transversalis fascia intact below. Blunt dissection into the retromuscular space develops adequate space for positioning of mesh in addition to preparing the area for colonic conduit lateralization [36].

The posterior rectus sheath surrounding the neck of the hernia sac is often fused to the surrounding rectus muscle. Once dissected from its posterior abdominal wall attachments, there will be an accompanying defect in the posterior layer, which we extend laterally to aid in lateralization of the bowel conduit. The colon is then lateralized using a 3-0 barbed suture secured to the underside of lateral abdominal wall. A second 3-0 barbed suture is used to suture the posterior layer edges to the conduit while also restoring continuity by closing any remaining defects in the posterior layer [36].

When performed correctly, the distal bowel conduit will transverse laterally through the peritoneal and transversalis fascia layers and follow in the retromuscular space from lateral to medial toward the aperture site in the rectus abdominis muscle. We opt for 5–7 cm of the conduit to traverse the retromuscular space after which the parastomal defect is then closed. Appropriately sized macroporous medium-weight polypropylene mesh is tailored to the defect then positioned and secured with suture in the retromuscular space. The posterior layer is then closed. The approach offers wide retromuscular mesh overlap of the parastomal and midline defects while hiding the uncoated mesh from intra-abdominal contents.

Stapled Transabdominal Ostomy Reinforcement with Retromuscular Mesh

Dissection is carried out as outlined in the *Transversus Abdominis Release and Modified Retrorectus Sugarbaker* section. Stapled transabdominal ostomy reinforcement with retromuscular mesh (STORRM) begins when the abdominal wall is advanced to the midline, and a site is selected within the posterior rectus sheath

through which the stomal passage is created [56]. The stoma is passed through the posterior fascia into the extraperitoneal space, and the remaining posterior rectus sheath is closed. The extraperitoneal space is reinforced with medium-weight macroporous polypropylene mesh. The anterior rectus fascia and rectus muscles are laid in position, and a circular end-to-end anastomosis stapler is passed through the mesh within the posterior sheath and all superficial structures. Once fired, the stapler joins the anterior fascia with the mesh. This is then followed by externalization of the stomal conduit through the aperture.

The use of a stapler rather than individual cruciate incisions through the abdominal layers and the radial ring of staples it creates has demonstrated reduction in parastomal hernia formation. Williams et al. reported significant reduction in hernia recurrence by 54% with use of the STORRM technique [57].

Prevention of Parastomal Hernias

The placement of a stoma necessarily increases the risk of parastomal hernia as it creates a defect in a previously intact abdominal wall. The underling architecture of the abdominal musculature affords a degree of stability that if successfully incorporated into the creation of the stoma can potentially reduce the risk of hernia formation. One such method for incorporating this stability is drawing the stoma through the rectus abdominis muscle rather than into the lateral abdominal compartments [13, 58]. As the rectus abdominis lacks any segmented planes, a constant stabilizing force can be applied to the stoma and reduce the likelihood that a hernia can develop. This is in contrast to the successive aponeurotic planes present in the external oblique, internal oblique, and transversus abdominis as they are layered on top of one another in the lateral compartment. The weaknesses between each layer present the opportunity for a hernia sac to form and therefore is less desirable than utilizing the trans-rectus approach. Muscle-splitting technique should be utilized to reinforce the stoma, thereby maintaining physiological function of the muscle while preventing distal herniation of the stoma.

The diameter of the defect created in the abdominal wall will have a direct relationship on the likelihood of hernia formation. As such, the surgeon should take great care in creating an aperture only to facilitate passage of the bowel through the abdominal wall. Even a 1 cm difference in diameter can account for as much as a 15-fold increase in parastomal hernia formation based on findings presented studying individuals who received 2 cm versus 3 cm aperture [15]. For emergent stomal creation this may prove challenging due to bowel inflammation.

Utilization of mesh for the reinforcement of the stoma site prophylactically, while not universally adopted, has led to promising results in early outcome analyses showing little to no rate of herniation [59–64]. Similar findings have been reported utilizing the intra-abdominal underlay placement technique, suggesting the evidence is compelling in the decision as to whether prophylactic reinforcement mesh should be implemented [65].

Summary

Parastomal hernias are seen in nearly half of all patients with stomas. Although imaging has increasingly been implemented in the identification of this pathology, symptomatic parastomal hernias as identified on physical exam and constellation of presenting complaints only account for a minority of cases. Although equivocal findings can be confirmed by CT, obstruction and strangulation are immediate indicators that surgical treatment is necessary. Despite advancements in repair techniques, recurrence rates are a considerable challenge to the management of these hernias. The implementation of mesh reinforcement has demonstrated increasing success in resolution of symptoms with surgeons appreciating more favorable outcomes via minimally invasive surgical approaches. Care should be taken when possible to reduce all relevant predisposing factors to parastomal hernia formation at the time of stoma creation.

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Challenging Hernias: Spigelian, Flank Hernias, Suprapubic, and Subxiphoid

25

Patrick Dolan and Gregory Dakin

Introduction

The focus of this chapter will be on the available surgical techniques in managing challenging abdominal wall hernias. Although these hernias have different anatomic locations and etiologies, they are similar in that they are rare entities, and therefore there is little data to help guide optimal management and surgical approach. As with other hernia repairs, the operating surgeon can approach these hernias with open or minimally invasive surgery (MIS) techniques. Within MIS, there are total extraperitoneal (TEP), transabdominal preperitoneal (TAPP), and intraperitoneal onlay mesh (IPOM) options. Furthermore, the proliferation of single-incision laparoscopic surgery (SILS) and robotics offers other tools for the surgeon. Regardless of the approach, the essential tenets of a durable hernia repair still apply: reducing the hernia contents and sac and then performing a tension-free repair of the hernia defect with adequate overlap of a mesh. These approaches will be discussed in detail, along with associated risks and benefits based on the available data. Hernia-type specific challenges to repair will also be discussed.

History and physical examination may be sufficient to diagnose any of these hernias. Specifically, history of prior surgery at the area of discomfort, pain that worsens with Valsalva, and a reducible bulge that worsens on standing or Valsalva may be sufficient to make the diagnosis. Differential diagnoses to consider are other

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abdominal wall/flank masses (lipomas, sarcomas, endometriomas, etc.), abscesses, or rectus diastasis. If there is any question to the diagnosis, CT scan of the abdomen and pelvis can aid in making an accurate diagnosis of these hernias.

Spigelian Hernias

Anatomy and Pathophysiology

The semilunar line of Spieghel, which is the transition between the muscle fibers and the aponeurosis of the transversus abdominis, was first described by Adriaan van den Spieghel. Spigelian hernias, first described in 1764 by Klinklosch (as acquired and not secondary to trauma), are hernias that protrude through the abdominal wall at the part of the transversus aponeurosis between the semilunar line and the lateral border of the rectus sheath, also known as the "Spigelian fascia" [1]. The borders of the Spigelian fascia are the eighth or ninth rib superiorly, the pubis inferiorly, the lateral border of the rectus sheath medially, and the muscle fibers of the transversus abdominis (semilunar line) laterally (Fig. 25.1) [2]. Spigelian hernias can occur anywhere in this fascia.

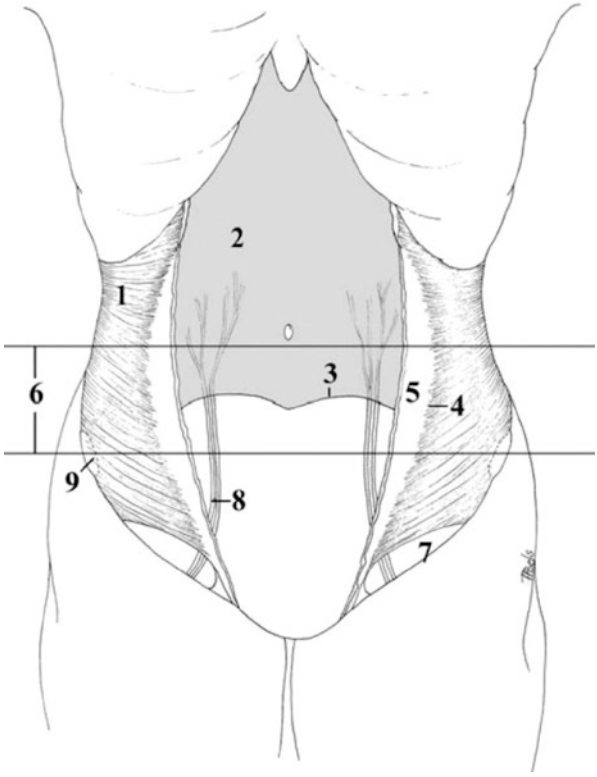

Fig. 25.1 Anatomy of the abdominal wall (rectus, internal, and external oblique muscles removed). (1) Transversus abdominis, (2) posterior rectus sheath, (3) arcuate line (semicircular line of Douglas), (4) semilunar line (line of Spiegel), (5) Spigelian aponeurosis, (6) Spigelian belt, (7) lateral border of the epigastric vessels, (8) inferior epigastric vessels, (9) anterior superior iliac spine

Above the arcuate line (also known as the semicircular line of Douglas), there is both a posterior and anterior rectus abdominis sheath, formed by the aponeuroses of the internal and external obliques and the transversus abdominis. The aponeurosis of the transversus abdominis contributes entirely to the posterior rectus sheath, and the aponeurosis of the external oblique contributes entirely to the anterior rectus sheath. The internal oblique aponeurosis splits and contributes to both anterior and posterior rectus sheaths. Below the arcuate line, there is only an anterior rectus sheath. The aponeuroses of the external oblique, internal oblique, and transversus combine to form the anterior sheath (Fig. 25.1). Most Spigelian hernias occur below the umbilicus around the arcuate line in the "Spigelian belt." It is thought that this is because the fascia is widest there and because this is where the fibers of the transversus abdominis aponeurosis run parallel to fibers of the internal oblique muscle [2].

Most Spigelian hernias penetrate the transversus and internal oblique aponeuroses, leaving the external oblique aponeurosis intact, and then dissect between the internal and external oblique muscle layers [3].

Etiology and Epidemiology

In the early literature, Sir Astley Cooper (1804) thought that these hernias protrude through natural weaknesses in the transversus aponeurosis caused by perforating vessels and nerves [4]. However, this theory was abandoned in the mid-twentieth century, as many observed that these hernias were frequently not near blood vessels. The most likely explanation for an acquired etiology is proposed by Zimmerman et al. (1944) as naturally occurring anatomic weaknesses both above and below the arcuate line [5]. Therefore, as with other ventral hernias, any process that causes increased intra-abdominal pressure and weakness of the connective tissue making up the transversus aponeurosis (aging, connective tissue disorders, etc.) are risk factors for developing a Spigelian hernia [4].

Spigelian hernias have also been described in the pediatric population and are thought to be congenital as opposed to acquired. They occur at the junction of the arcuate and semilunar lines, likely due to an inherent failure of fusion at that intersection point [6]. It is a rare problem in children, and therefore there is little data to help elucidate the etiology. A recent review of the pediatric literature published in 2015 analyzed 53 papers containing 78 patients under the age of 18 (62 male and 16 female) with 88 hernias. Of the 48 males with 55 non-traumatic hernias, 53% had the ipsilateral testis associated with the hernia sac. They also showed there was a significant difference in the average age of patients with a testis in the hernia sac and those without (7.9 months vs. 6.8 years, $p < 0.001$) [7]. These data support the theory of both congenital and acquired etiologies of Spigelian hernias.

As stated previously, these are rare hernias, with approximately 1–2% incidence, which is slightly higher in females [4]. Approximately 90% occur in the "Spigelian belt," the 6 cm area inferior to the umbilicus in the plane between the bilateral anterior superior iliac spines [8].

Surgical Technique

Open Repair

Repair via an open approach was standard of care until the first reported laparoscopic Spigelian hernia repair done by Carter and Mizes in 1992 [9]. There are two options for open repair, a primary or mesh repair. In either, the initial approach is the same. If the exact location of the hernia is known preoperatively, a transverse incision is made over the hernia. If the location of the hernia is unclear prior to the incision, it is preferable to create a paramedian, vertical incision to expose a longer portion of the Spigelian fascia. Although most of these hernias do not penetrate the external oblique aponeurosis, meticulous care still needs to be taken in subcutaneous dissection, as to not inadvertently enter the hernia sac and potentially damage intra-abdominal contents. Once dissection is carried down to the external oblique aponeurosis, it is opened along the length of its fibers [10].

In a primary repair, the sac can be excised and the neck closed with suture. With the intra-abdominal contents reduced and the sac excised, the defect in the internal oblique and transversus abdominis aponeuroses is then closed transversely. Then, the external oblique aponeurosis is closed, completing the repair [10]. Primary repair is only advisable with small defects and no patient risk factors (such as obesity, disorders of collagen synthesis, etc.) or in special clinical circumstances, such as emergent repairs with necrotic or perforated bowel resulting in contamination precluding mesh placement.

Although literature search does not identify head-to-head comparison specifically in Spigelian hernias, it can be extrapolated from other hernia literature that mesh repairs are preferable for reducing recurrence rate compared to direct repair [10]. The same general approach is used for mesh repairs, down to incising the external oblique aponeurosis. As opposed to the primary hernia repair, the hernia sac is dissected free from surrounding tissue and then invaginated through the defect. Proceed with dissection posterior to the transversalis aponeurosis, creating a large enough preperitoneal space to then insert a flat underlay mesh with 3–5 cm of overlap with the defect. The most common mesh materials used are polypropylene, polyester, or expanded polytetrafluorethylene (ePTFE), but other types of mesh can also be used, per surgeon preference. The mesh is then secured in place to the fascia using interrupted polypropylene suture in a circumferential fashion [10]. The fascia is then closed over the mesh.

MIS Repair

As with other abdominal wall hernia repairs, a variety of different minimally invasive approaches are available. However, there is little comparative data between approaches, and the choice between them should be made based on surgeon experience and preference (Fig. 25.2).

For the intra-abdominal TAPP and IPOM repairs, access to the intraperitoneal cavity can be obtained either with a Veress needle or open technique at the umbilicus. Diagnostic laparoscopy should be performed before further port placement, as patients can have bilateral Spigelian hernias, and the exact location of the hernias

will dictate which repair is feasible. If the defect is inferior enough to allow adequate space for a peritoneal flap to be created, it can proceed with a TAPP repair, placing two 5 mm ports, one on either side of the umbilicus laterally. A peritoneal flap is then created in a similar manner to transabdominal laparoscopic inguinal hernia repairs, dissecting around the entire hernia sac. It is important to start making the flap lateral to the semilunar line, to ensure adequate mesh overlap of the defect laterally. Once the hernia contents are reduced, the defect should be measured to choose an adequately sized mesh. The defect is then closed (intracorporeal or transabdominal via a counter-incision). A synthetic, nonabsorbable mesh (polypropylene, ePTFE) is then placed in the preperitoneal space with 3–5 cm overlap of the defect and fixated with either tacks or sutures (intracorporeal or transabdominal). The peritoneal defect is then closed, with tacks or sutures, completing the repair [11] (Fig. 25.3).

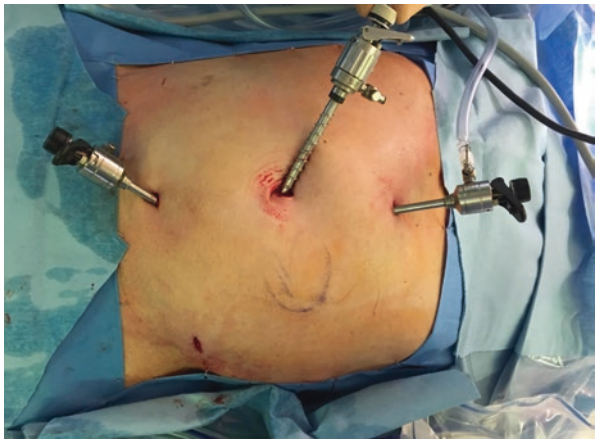

Fig. 25.2 Port placement for laparoscopic IPOM repair

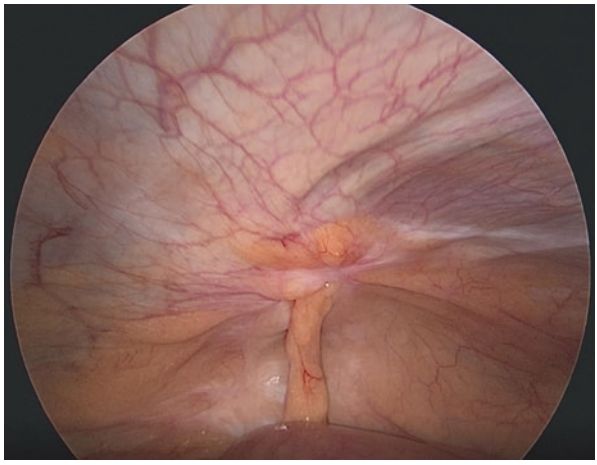

Fig. 25.3 Left-sided Spigelian hernia containing epiploic fat

If the defect is too cephalad and precludes adequate space to create a peritoneal flap, it is better to perform an IPOM repair. In this case, two 5 mm ports are placed midline above and below the umbilicus. The hernia contents are dissected free from the sac and reduced into the peritoneal cavity. The defect is then measured and closed. Mesh choice in this case should be a dual-sided mesh with an adhesion barrier on one side and one side that promotes tissue ingrowth. Mesh size should account for 3–5 cm overlap of the hernia defect. The mesh is introduced into the abdomen and placed flush against the abdominal wall, covering the closed defect. The mesh is then secured to the abdominal wall with inner and outer circular rows of tacks (or sutured laparoscopically/robotically) to prevent any intraperitoneal contents from sliding between the mesh and the abdominal wall (Figs. 25.4 and 25.5).

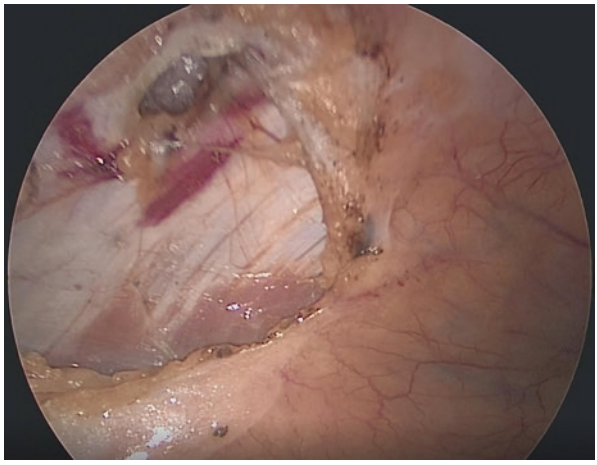

Fig. 25.4 Close-up view of the small hernia defect

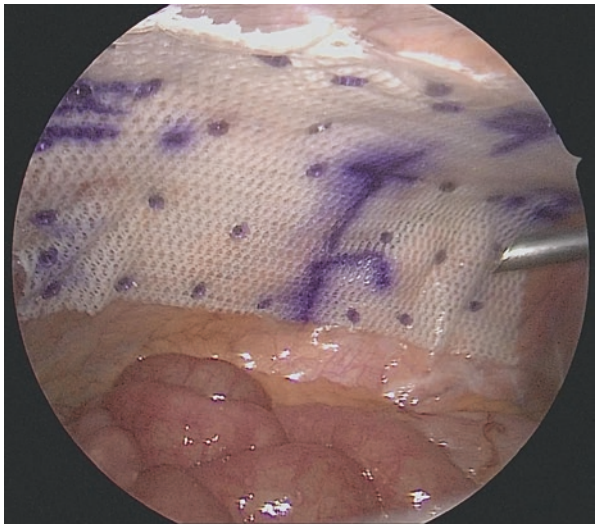

Fig. 25.5 Completed repair with an outer and inner crown of tacks securing the mesh

Flank Hernias

Anatomy and Pathophysiology

Flank, or Lumbar hernias, can generally be divided into three categories based on the anatomic location. The first is a hernia through the inferior lumbar, or Petit's, triangle. It is eponymously named after its discoverer, who first described a strangulated hernia through this defect in 1738 [12]. It is an upright triangular space bordered by the external oblique muscle anterolaterally, latissimus dorsi muscle posteromedially, and the iliac crest inferiorly. The "floor," or most anterior aspect, of the triangle, is the internal oblique muscle and lumbodorsal fascia. This anatomic triangle is observed in approximately 63–82.5% of cadavers, and the size varies greatly depending on the origins of the external oblique and latissimus dorsi muscles. The more lateral the external oblique and more medial the latissimus dorsi muscles insert into the iliac crest, the larger Petit's triangle becomes, which may cause increased risk of hernia formation [13].

The second type of flank hernia is one through the superior lumbar, or Grynfeltt's, triangle, also eponymously named after its discoverer, who first described borders of the superior lumbar triangle in 1866 [12]. It is an inverted triangular space bounded by the internal oblique muscle anteriorly, the sacrospinalis muscle posteriorly, and the 12th rib and serratus posterior inferior muscle superiorly [13]. The floor of the triangle is also formed by the lumbodorsal fascia [12]. A common site of herniation through this triangle is where the 12th intercostal neurovascular pedicle penetrates the lumbodorsal fascia [14]. There are several other anatomic factors that contribute to the development of a hernia at this location, mainly the length and angle of the 12th rib as well as the size of the quadratus lumborum and serratus posterior muscles. A short, obese person with more horizontal ribs, and therefore a larger Grynfeltt's triangle, is at higher risk for developing a hernia through this space [14] (Fig. 25.6).

The third type of flank hernia is a large, diffuse hernia, which can be either congenital or acquired (trauma or incisional). Any hernia protruding through the space bordered by the costal margin superiorly, iliac crest inferiorly, the erector spinae muscle medially, and the external oblique muscle laterally, not confined to the triangles described above, falls into this category of flank hernia [14] (Fig. 25.7).

Etiology and Epidemiology

There are two main etiologies for flank hernias, congenital and acquired. Congenital hernias account for approximately 20% of all flank hernias and appear in infancy, typically associated with other malformations [15]. The other 80% are acquired, 55% of which are primary or spontaneous [16]. Risk factors for these hernias, as with anterior abdominal wall hernias, are any conditions that lead to increased intra-abdominal pressure, disorders of collagen synthesis, and obesity. The remaining of the acquired hernias are secondary hernias, either due to trauma, typically

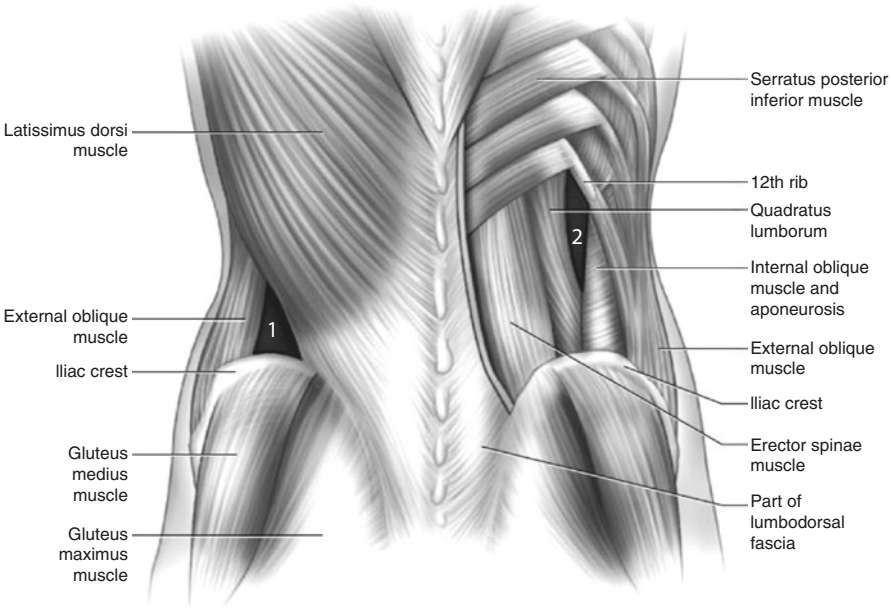

Fig. 25.6 View of the boundaries of the inferior and superior lumbar triangles

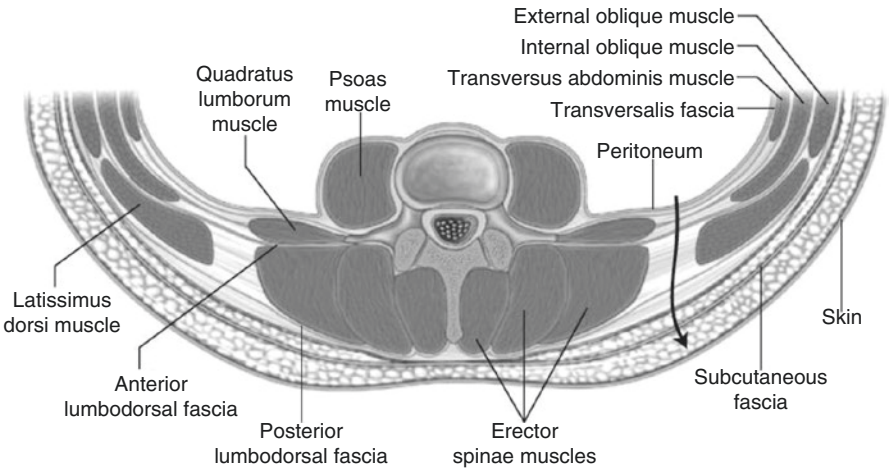

Fig. 25.7 Cross-sectional view of the posterior abdominal musculature

high-velocity blunt force trauma such as motor vehicle accidents [17], prior surgery, or infection. Incisional hernias can happen after nephrectomies, adrenalectomies, aortic aneurysm repairs, or any other operation requiring a flank incision [15]. An infectious etiology for a flank hernia is exceedingly rare and becoming less common, likely due to improved treatment of infectious diseases. Some possible

infectious processes that can cause flank hernias are osteomyelitis of the iliac crest or ribs, lumbar abscesses, hepatic abscesses, or superinfected retroperitoneal hematomas [15].

Surgical Technique

Open Repair

There is an overall paucity of data to guide optimal management of flank hernias. One prospective cohort study published in 2012 comparing laparoscopic to open repair showed laparoscopic repairs were associated with a shorter hospital stay (2.5 vs. 5.1 days, $p < .001$), fewer days requiring pain medication (6.8 vs. 15.9, $p < .001$), and comparable recurrence rate at 5 years. However, the size of the hernias in the open group were also larger (14.5 vs. 11.7 cm, $p = .01$), and therefore the study concluded that laparoscopic repair is likely preferred, unless the hernia is greater than 15 cm [18].

Depending on the desired approach, the patient can be placed in the lateral decubitus position for a posterior approach or supine for an anterior retroperitoneal approach. This decision is governed by hernia location, size, and surgeon preference. Either an oblique or transverse incision (or through the prior incision, for an incisional hernia) is made over the site of the hernia. Hernias through the superior triangle are found deep to the latissimus dorsi muscle, and inferior triangle hernias are not covered by a muscular layer. Safe, meticulous dissection is required in either case to avoid inadvertently entering the hernia sac. The sac is dissected free from all surrounding tissue and then reduced into the peritoneal cavity [13]. A synthetic mesh (polypropylene, ePTFE, polyester, etc.) is then placed in the preperitoneal space with 5 cm overlap of the defect in all directions. The mesh is then fixed to the lumbodorsal fascia using nonabsorbable suture where possible. In the case of a hernia through the inferior triangle, inferior fixation sutures will need to be placed through the periosteum of the iliac crest. For hernias through the superior triangle, superior fixation sutures will need to be placed through the periosteum of the 12th rib, taking care to avoid injuring the neurovascular bundle that runs inferior to the rib [18]. After the mesh is secured, the fascia should be closed without tension, if possible.

MIS Repair

For an IPOM repair, the patient is placed in the semi-lateral decubitus position with a 45-degree elevation, allowing the patient to be rotated to either a fully flat or full lateral position. Access to the peritoneal cavity can be either via Veress needle or open Hasson technique at the umbilicus, where a 10 mm port is placed. Additional 5 mm ports are then placed midline both superior and inferior to the umbilicus. After safe access to the abdomen is obtained, the hernia contents are reduced, lysing adhesions as necessary. Medial mobilization of the colon at the peritoneal reflection may be necessary for adequate exposure of the hernia defect, until the psoas muscle is fully exposed. For inferior triangle defects, the dissection should extend inferiorly

to Cooper's ligament. For superior triangle defects, dissection extends to the diaphragm superior to the costal margin. During dissection, care needs to be taken to identify and preserve retroperitoneal structures as well as the lateral femoral cutaneous nerve at the anterior superior iliac spine. After the defect is fully exposed with enough of a landing zone to have 5 cm overlap of the defect in all directions, the defect is measured and appropriate mesh size chosen. Any mesh with an adhesion barrier (polyester, polypropylene, ePTFE) can be used. An attempt at closing the hernia defect should be made, either with intracorporeal suture or transfascial sutures. Depending on the size of the defect, this may be difficult to do without tension. Thus, one must use judgment in this portion of the case. Adequate mesh fixation can be challenging due to the bony borders of the hernia defects. For superior triangle hernias, the superior aspect of the mesh can be secured with intracorporeally placed suture, tacking the mesh either to the diaphragm or the periosteum of the 12th rib. As with open repairs, care needs to be taken to avoid damaging the neurovascular bundle that runs inferiorly along the rib. For inferior defects, the mesh can either be fixed to Cooper's ligament or directly to the iliac crest by one of two methods. One possibility is to drill a hole into the iliac crest and then pass a suture through the hole and then through the mesh [19]. Another possibility is to use titanium bone anchors (Mitek GII, JuggerKnot) that are drilled directly into the iliac crest. There are two strands of polyester suture attached to these anchors that can then be passed through the mesh and tied intracorporeally to secure the inferior part of the mesh [20]. After the mesh is secured to the bony structures, the remainder of the mesh can be secured using a laparoscopic tacking device, placing tacks circumferentially in the mesh (Fig. 25.8).

A second MIS option is a TEP repair. The patient is placed in full lateral decubitus position. A 12 mm incision is then made in the midaxillary line halfway between the costal margin and the iliac crest. The incision is then taken down to the

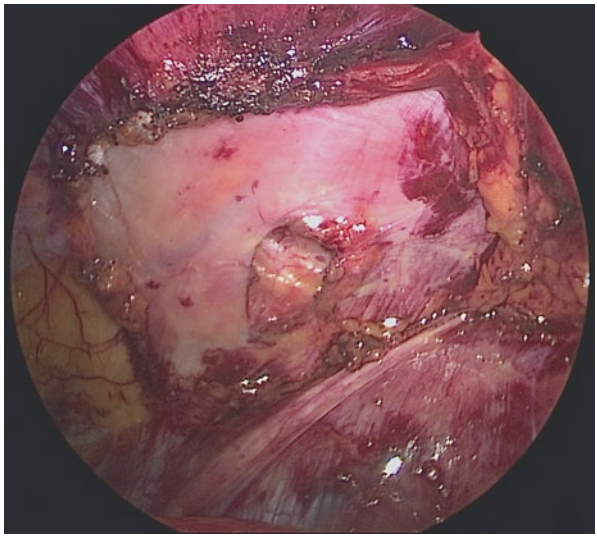

Fig. 25.8 Superior lumbar triangle hernia defect exposed after medial mobilization of the descending colon

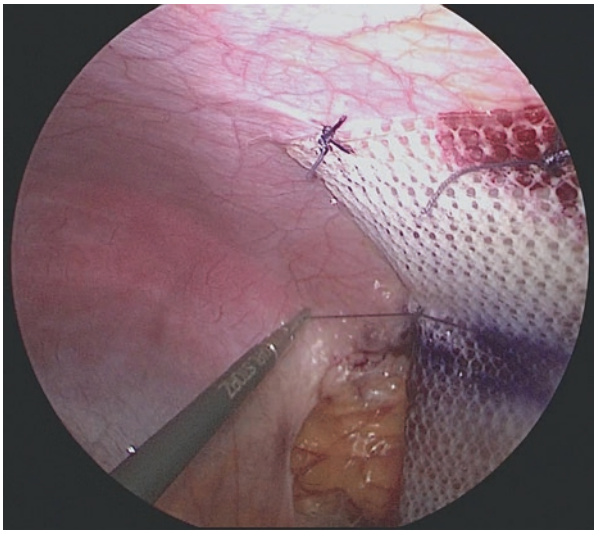

Fig. 25.9 Suture fixation of the mesh superiorly

peritoneum using a muscle-splitting technique. Either using blunt finger or balloon dissection, a plane is created between the transversalis muscle and the peritoneum. A 12 mm port is then placed, and then two 5 mm ports are placed superiorly and inferiorly in relation to the 12 mm port in the midaxillary line under direct visualization. The hernia sac is then dissected free, and the hernia is reduced back into the abdominal cavity, taking care to not violate the peritoneum. If the peritoneum is not violated, any mesh without an adhesion barrier can be used (polypropylene, ePTFE, polyester). Again, the mesh needs to be sized for at least 4–5 cm overlap with the hernia defect. The mesh is then placed into the preperitoneal space and secured to the bony structures and lumbodorsal fascia in a similar manner to described above [21] (Fig. 25.9).

Suprapubic and Subxiphoid Hernias

Anatomy and Pathophysiology

The incidence of incisional hernia after laparotomy is approximately 11–20% [22, 23]. Suprapubic and subxiphoid hernias are both typically incisional hernias, typically located in the midline. Suprapubic hernias are located within 3–4 cm superior to the pubic symphysis [23]. They can occur after low midline laparotomies, Pfannenstiel and other incisions used for gynecologic, colorectal, or urologic procedures, or suprapubic catheterization [24]. These are challenging hernias to repair due to their proximity to bony and vascular structures, as well as the bladder.

The subxiphoid space is bordered by the sternum and ribs superiorly, the rectus and linea alba anteriorly, and the diaphragm posteriorly and inferiorly [25]. Subxiphoid hernias are defined as being within 3–4 cm inferior to the xiphoid

process. They typically occur after median sternotomy after a wide variety of cardiac procedures. Like suprapubic hernias, they are challenging due to their proximity to bony structures, making mesh fixation difficult. When dealing with these hernias, care must be taken to avoid injuring the heart, diaphragm, and neurovascular bundles that run inferiorly to the ribs.

Etiology and Epidemiology

The most common procedure leading to a suprapubic hernia is a radical prostatectomy, but similar hernias can occur after any procedure involving the uterus, bladder, or sigmoid colon/rectum requiring incisions close to the pubic symphysis [26]. The incidence of suprapubic hernias quoted in the literature is comparable to other abdominal wall incisional hernias.

Reported incidence of subxiphoid hernias is approximately 1–4.2% after median sternotomy. However, it is difficult to estimate as most of these hernias do not cause symptoms and are underreported by patients [25]. Patient-related and technical factors have been implicated in the development of these hernias, such as disorders of collagen synthesis, obesity, age, and wound infection [27].

Surgical Technique

Open Repair

As with other incisional hernias, there are several different options for suprapubic and subxiphoid hernia repair and mesh placement. Primary repair should only be used in specific clinical circumstances, such as gross contamination in an emergency setting. A variety of different mesh placements are possible, including both onlay, mesh placed above the fascial defect, and underlay, mesh placed below the fascial defect. Underlay mesh placement can either be retromuscular, preperitoneal, or intraperitoneal (must use a dual-sided mesh). Theoretically, underlay mesh placement is preferable, as it may be protective against mesh infection in the event of a superficial wound infection [28]. Preperitoneal underlay mesh technique for both suprapubic and subxiphoid hernias will be described below.

For suprapubic hernia repairs, the patient is placed in a supine position, and a three-way Foley catheter is placed to allow for intraoperative bladder distension to aid in safe dissection around the bladder [29]. A vertical midline incision is then made over the hernia. For preperitoneal mesh placement, if possible, entering the hernia sac should be avoided, and the hernia sac should be completely dissected from all surrounding attachments and inverted into the abdomen. The peritoneum is dissected free from the posterior fascia to allow enough space for mesh placement. If the peritoneum is entered, and there is no plan to place a dual-sided mesh, the defects in the peritoneum should be closed with absorbable suture. Dissection should be carried out in all directions to allow for at least 3–5 cm overlap of the mesh. Knowledge of lower abdominal anatomy is essential when dissecting

inferiorly, and care needs to be taken to avoid dissection into the bladder, as well as the abundant neurovascular structures near the pubic symphysis. After dissection is complete, the defect should be measured and an appropriate size mesh is chosen. As with other hernia repairs, the choice of mesh material is per surgeon preference, most commonly polypropylene, polyester, or ePTFE meshes are chosen. The main challenge of this repair is inferior mesh fixation, as the defect is typically very close to the pubic symphysis, and this is typically the area of highest recurrence [28, 29]. There are two options for inferior fixation of the mesh. The first is using monofilament suture to fix the mesh directly onto the pubis and Cooper's ligament [28]. The second is using bone anchor fixation. Using a cordless drill with a 3 mm drill bit, entry fixation points are made into the pubic bone or iliac crest. Then, bone anchors are placed in the fixation points. There are two strands of polyethylene suture attached to the anchors, which are passed through the mesh and tied down, securing the mesh to the pubis or iliac crest [29]. With the mesh secured inferiorly, the rest of the mesh is then secured with transfascial sutures.

In open subxiphoid hernia repairs, an upper midline incision is made as in the suprapubic hernia repair. Careful dissection is performed around the hernia sac to avoid entering the peritoneum. Any defects made need to be subsequently closed with absorbable suture. The hernia sac should be dissected circumferentially and reduced into the abdomen through the fascial defect. The peritoneum is then carefully dissected from the posterior rectus sheath, until there is adequate space for synthetic mesh placement with 3–5 cm overlap of the defect. Superior dissection may be difficult, due to a scarred xiphoid process, which may need to be removed for adequate exposure of the defect [25]. After the dissection, the mesh is placed in the preperitoneal space. As with suprapubic hernias, mesh fixation in subxiphoid hernias superiorly can be challenging, due to the proximity to the costal margin and sternum. The most superior aspect of the mesh may need to be placed intraperitoneally and sutured to the surface of the diaphragm to obtain adequate overlap of the hernia defect [30]. The remaining mesh should be secured with transfascial sutures in a circumferential fashion.

MIS Repair

Laparoscopic TAPP repair of suprapubic hernia is a durable option as one prospective study of patients undergoing repair between 1996 and 2004 showed a 5.5% recurrence rate with a mean follow-up of 21.1 months [24]. In this technique, the patient is placed in the supine position, and a three-way Foley is placed. Intraperitoneal access can be achieved via Veress needle, open technique or optical trocar per surgeon preference and patient factors. Three ports are used, typically with a 12 mm port at the umbilicus, and two 5 mm ports on either side of the umbilicus laterally. The hernia contents are dissected free from the hernia sac, and any other intraperitoneal adhesions preventing reduction of hernia contents are lysed using a combination of blunt and sharp dissection. To provide adequate exposure of the pubic bone, Cooper's ligaments, and the inferior epigastric and iliac vessels, a peritoneal flap is created similar to laparoscopic inguinal hernia repairs. The peritoneum is incised horizontally starting at the median umbilical fold, long enough to

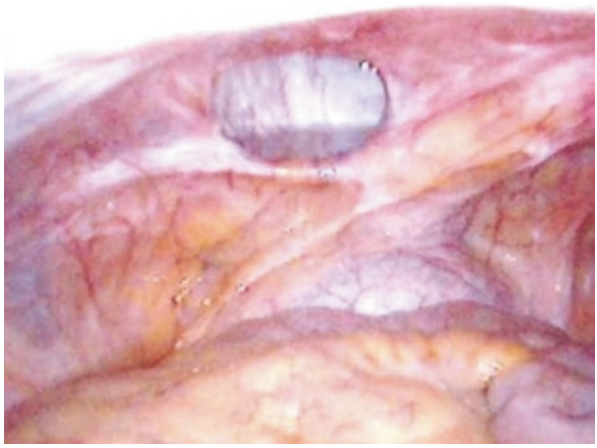

Fig. 25.10 Suprapubic hernia with bladder distension (Courtesy of David B. Earle, MD, FACS, with permission)

be able to place the mesh, and the dissection is then carried inferiorly. The hernia defect is then measured, and an appropriately sized (3–5 cm overlap with the defect) synthetic mesh is chosen, usually ePTFE or a dual-sided composite polyester mesh. Sutures may be placed on the mesh to aid in manipulation and placement beneath the hernia defect. The mesh is introduced into the abdomen and positioned with inferior overlap of the pubis to ensure good coverage of the defect and reduce chances of recurrence near the pubic bone. Tacks are then placed through the mesh onto the pubic bone and Cooper's ligaments bilaterally for inferior mesh fixation. Care needs to be taken when placing tacks in the pubic bone and Cooper's ligaments, as tacks placed too lateral and anterior can damage neurovascular structures. Tacks are then placed circumferentially to further secure the mesh and prevent any intra-abdominal contents from slipping underneath the mesh (Fig. 25.10).

The first published report of laparoscopic subxiphoid hernia repair was in 2001, ten patients underwent IPOM repair using ePTFE mesh, with one recurrence in a range of 20–42-month follow-up [31]. The patient is placed in a supine, split-leg position. The peritoneum is entered either with a Veress or open technique, and a 12 mm port is placed either supra- or infra-umbilically, depending on the caudad extent of the hernia. Two 5 mm ports are then placed in the midclavicular line bilaterally on either side of the umbilicus. Hernia contents are then dissected free from the sac, in combination with taking down the falciform ligament to the hepatic veins. If possible, the hernia defect is then closed either transabdominally or intracorporeally. Mesh size is chosen to allow for at least 3–5 cm overlap of the defect in all directions; synthetic mesh choice is either a dual-sided polyester or ePTFE mesh. Sutures can be placed in the mesh to help with intra-abdominal manipulation. The mesh is placed into the abdomen and pulled flush against the abdominal wall. The most cephalad portion of the mesh is then secured to the diaphragm either using tacks or laparoscopic suturing [31, 32]. At this point, care must be taken to avoid placing tacks or sutures too deep through the diaphragm, risking cardiac or other intrathoracic injury. After the mesh is secured superiorly to the diaphragm, an outer and inner crown of tacks is placed through the mesh into the abdominal wall circumferentially, completing the repair.

Conclusion

The hernias described above are rare defects with scarce literature to guide management. They present unique challenges in diagnosis and adequate mesh fixation due to proximity to bony structures. However, despite their rarity and complexity, the essential tenets of hernia repair still apply: reduction of hernia contents, tension-free closure of the defect (when possible), and covering the defect with an appropriately sized mesh. These steps are paramount to performing a durable hernia repair, regardless of the chosen approach (open vs. MIS, TAPP vs. TEP vs. IPOM, laparoscopic vs. robotic).

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Recurrent Ventral Hernia Repair

26

Charlotte Horne and Ajita Prabhu

Introduction

Recurrent ventral hernias pose many technical challenges to a general surgeon. Each year over three billion US dollars are spent on approximately 350,000 ventral hernia repairs [1]. Reducing recurrence rates by as little as 1% could result in 3.2 million dollars in savings [1, 2]. Although a significant effort has been put forth to delineate both patient factors and technical factors that increase likelihood of recurrence, recurrence still represents a significant cause of morbidity postoperatively. Risk of recurrence has decreased significantly with the routine use of prosthetic mesh reinforcement; however, recurrence rates remain high with reported recurrence rates of 25–44% after second and third repair, respectively [3, 4]. Recurrent hernia repairs are technically difficult operations for many reasons: there is potential for dense adhesions to the abdominal wall, often mesh has been placed and anatomical planes have been disturbed by previous dissection, and there may be device-related complications such as mesh infection or mesh-related pain. Additionally, there may be concerns for loss of domain and/or potential for difficulty achieving soft tissue coverage of the hernia repair if the overlying skin is compromised due to infection or ulceration. It is imperative to understand why possible previous hernia repairs have failed and address any patient factors preoperatively that put patients at increased risk for recurrence. Herein, we present an algorithm for the workup and management of these complicated patients (Fig. 26.1).

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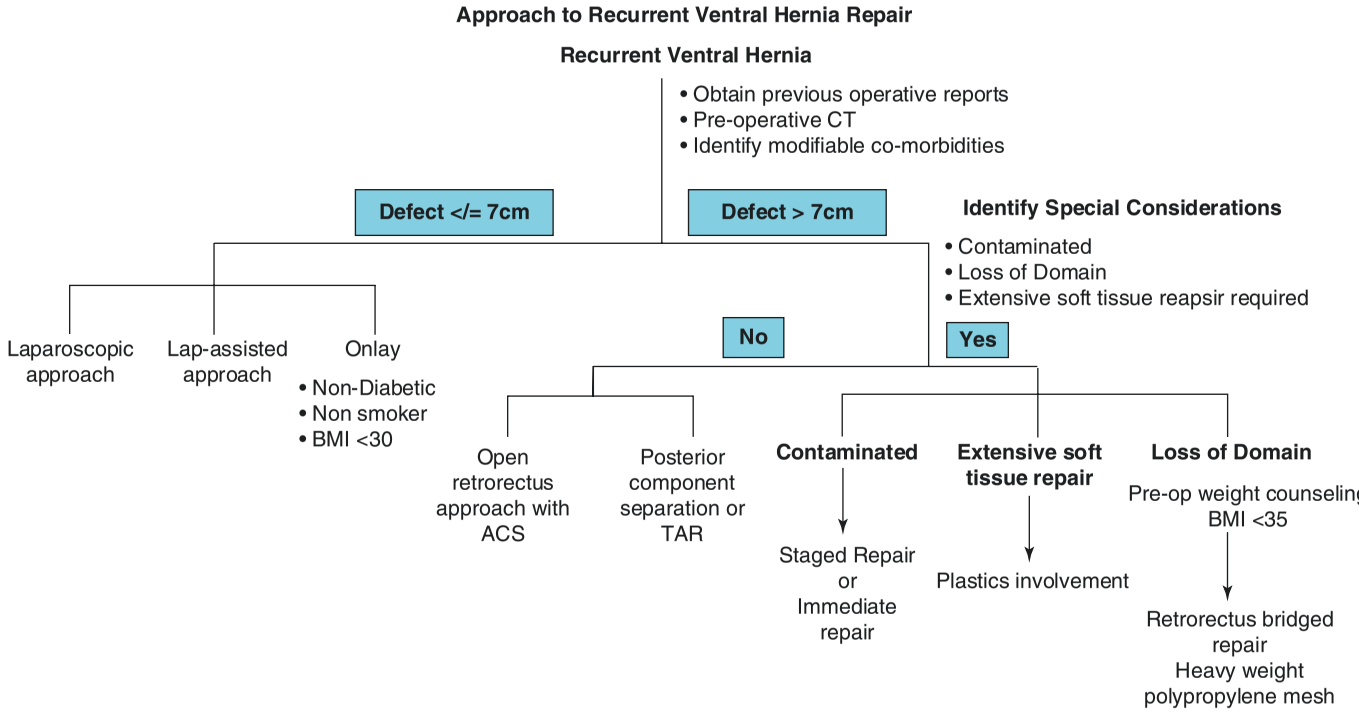

Fig. 26.1 Algorithm for ventral hernia approach. ACS (anterior component separation). TAR (transversus abdominis release). Posterior component separation or TARs should not be performed with concurrent anterior component separation as this may destabilize the lateral abdominal wall, resulting in a flank hernia

Approach to the Patient

When evaluating a patient for recurrent ventral hernia repair, it is important to determine any modifiable risk factors that can increase likelihood of recurrence. Often, such factors have not been addressed at prior operations and may be responsible in part for recurrences. Postoperative surgical site infection is one potentially preventable occurrence that is closely linked to increased risk of recurrence [5]. Potential patient factors that increase likelihood of postoperative infection include obesity with BMI >40, diabetes, COPD, active smoking, and immunosuppression [6]. Efforts to optimize modifiable factors prior to elective hernia repair should be pursued to ensure a successful subsequent repair. Furthermore, preventable comorbidities such as smoking, diabetes, and obesity are also known to directly increase hospital charges, and modification of these factors preoperatively may therefore help to offset costs of care of these complicated patients [2].

Smoking

Active smoking is known to compromise healing due to peripheral vasoconstriction as well as reduced cutaneous blood flow [7]. Active smokers have an approximately 2.5 times increase in relative risk of wound complications when compared to nonsmokers [7]. Grade A evidence exists supporting the avoidance of elective hernia repair in active smokers [8]. Patients should stop smoking at least 4 weeks prior to undergoing elective surgery as this has been shown to decrease postoperative complications [9]. Because there is reasonable data to suggest that the wound healing problems associated with smoking are likely related to the contents of cigarette smoke and not the nicotine itself, the authors allow nicotine replacement therapy with either nicotine gum or patches, but not e-cigarettes as the contents are not standardized. Urine nicotine metabolite testing has the ability to distinguish between active smoking and nicotine replacement therapy and therefore is the test of choice used by the authors to ensure smoking cessation compliance. In our practice, smoking cessation is discussed in the office as an imperative prior to surgery for complex abdominal wall reconstruction (it is discussed but not necessarily required for minimally invasive hernia repair). Patients are informed that urine nicotine testing will be performed if they are active smokers at the time of the office visit. Patients are tested 4 weeks prior to their planned surgery dates to allow time for cancellation of cases in the case of non-compliance.

Diabetes

Diabetes is a common comorbidity that may lend itself to postoperative surgical site infection in patients with uncontrolled blood glucose undergoing ventral hernia repair. Specifically, a hemoglobin A1C >7 has been found to be associated with

increased risk of wound infection [10]. Therefore, the authors routinely check Hgb A1c preoperatively in all patients undergoing recurrent ventral hernia repair, with the goal of achieving a value of 7 or less. When Hgb A1c is greater than 7, the authors usually engage the primary care physician and/or an endocrinologist to assist with improving blood glucose control prior to surgery. In the postoperative period, hyperglycemia with blood glucose level >140 mg/dL has also been found to be associated with increased risk of surgical site infection [11]. Still, meticulous glycemic control postoperatively may be complicated by hypoglycemia and is therefore discouraged as the risk outweighs the potential benefits [12]. Some authors suggest that 140–160 mg/dL may be the optimal range for postoperative blood glucose in diabetic patients [13].

Obesity

Addressing weight in the preoperative setting can be a challenging discussion for both surgeons and patients. Nevertheless, weight loss should be discussed with obese patients undergoing recurrent ventral hernia repair as obesity is associated with increased risk of surgical site infection, prolonged hospital stays, and increased risk of recurrence [14–17]. Obesity increases technical difficulty, leads to increased operative time, and causes increased intra-abdominal pressure and decreased tissue healing [2]. The best approach to preoperative weight reduction is still yet to be determined. Some series suggest that a multidisciplinary approach to weight loss results in sustained weight loss; however, other data suggest that this weight loss is not durable in the long term [17, 18]. An optimal BMI prior to surgical intervention has not been established, but it is well known that increasing BMI correlates with increasing risk of postoperative morbidity [19]. Pernar et al. set out to determine a BMI threshold at which there was a significant increase in postoperative complications. They demonstrated that 16.5% of patients with BMI >40 that underwent open ventral hernia repair had a postoperative complication compared to 5.6% in patients with BMI <25. They also showed that when controlled for other medical comorbidities, BMI >40 alone increases odds of postoperative complication 3.4 times [19].

Increased risk of complications is not limited to open repair exclusively, as patients with BMI >40 have a fourfold increased risk of recurrence when undergoing laparoscopic hernia repair [20]. Bariatric surgery either prior to definitive recurrent repair or concurrent with laparoscopic hernia repair has been evaluated. Currently the data is limited to small, single institution retrospective analyses. There have been promising results in patients who underwent bariatric surgery prior to complex ventral hernia repair [21]. A study by Newcomb et al. showed no recurrence at 2–50 months postoperatively, and patients also had a significant decrease in BMI from an average of 51 kg/m^2 preoperatively to 33 kg/m^2 prior to hernia repair [21]. Although this study showed effective weight loss after bariatric surgery, patients undergoing concomitant bariatric surgery and ventral hernia repair are known to have increased 30-day unplanned reoperation, unplanned

readmission, and 30-day postoperative complications [22]. Although studies suggest that concomitant laparoscopic ventral hernia repair during bariatric surgery is safe, the authors prefer to avoid placement of intraperitoneal barrier coated mesh at the time of a clean-contaminated case as it has been suggested that barrier coating may harbor infection and potentially result in wound complications [23]. Some patients with complex surgical histories and multiply recurrent hernias may not be candidates for a laparoscopic bariatric intervention. Additionally, adequate preoperative evaluation with a multidisciplinary team prior to bariatric surgery is essential, and patients with a recurrent ventral hernia and obstructive symptoms may not be able to complete the process prior to requiring surgical intervention for their hernia. Still, in patients that are candidates for bariatric surgery, it is recommended that they undergo bariatric surgery prior to ventral hernia repair when possible.

Other options for preoperative weight loss for patients who are not candidates for bariatric surgery include guided lifestyle modification, diet and exercise programs that may be commercially available, or medical weight loss programs such as the protein-sparing modified fast [18]. The authors prefer the latter when patients are able to enroll in the program, as it can be very successful when the patient is engaged and participating. Protein-sparing modified fast can also allow for a relatively quick weight loss which may be beneficial in patients who are very symptomatic from their hernias. This may also be an effective weight loss method in patients who are unable to exercise, often due to joint or back pain caused by obesity. BMI <30 kg/m^2 is associated with overall improved outcomes and decreased hernia recurrence [2, 15, 20]. In the setting of elective recurrent ventral hernia repair, it is essential to encourage weight loss in patients with BMI >30 kg/m^2, and it may be reasonable to defer patients with BMI >50 kg/m^2 from an operative intervention due to the high risk of morbidity [2, 7].

The authors feel strongly that to maintain the investment of both the patient and the surgeon in the weight loss process and preparation for surgery, it is best to discuss the plan for weight loss, document the goal for weight loss including the expected time frame, and see patients back in the office 3 months after setting weight loss goals. While many patients are not yet ready to schedule surgery at that point due to remaining excess weight that must be lost, often this signals an ongoing investment by the surgeon in the patient's care and can help patients ultimately reach their weight loss goal.

Choice of Approach to Hernia Repair

When approaching recurrent ventral hernia repair, numerous patient and technical factors should be considered. Size of defect, location of previous mesh placement, presence of chronic infection or fistulas, and medical comorbidities and BMI all play roles in determining the best surgical approach. Obtaining previous operative reports assists in determining what previous prosthetic was utilized and its location and help to guide operative intervention. CT scan imaging of the abdomen and

pelvis is also very useful in determining the characteristics of the hernia defect and the surrounding anatomy and is routinely obtained in our practice for evaluation of recurrent ventral hernias [24].

Laparoscopic Recurrent Ventral Hernia Repair

A laparoscopic approach to the repair of a recurrent ventral hernia has many advantages. Laparoscopic ventral hernia repair has been shown to have decreased wound events, decreased postoperative pain, and overall decreased length of stay when compared to an open approach [20, 25]. Data also reports low recurrence rates (3.5–5.7% at 41 months), and, even the setting of multiply recurrent hernias, a higher risk of recurrence has not been shown after laparoscopic hernia repair [26–28]. Obese patients may benefit from laparoscopic ventral hernia repair over open when managing a recurrent hernia as there is a decreased risk of postoperative wound complications and the ability to recognize smaller fascial defects not previously appreciated in patients with BMI >30 kg/m^2 [24].

These hernia repairs can be completed in an entirely laparoscopic fashion or in a hybrid open and laparoscopic fashion (lap-assisted hernia repair) where the hernia contents are reduced through a small laparotomy incision and the mesh is placed laparoscopically. Regardless of approach, it is imperative that previous operations, mesh placements, and location of the abdominal wall defect are delineated as these factors will determine optimal trocar placement.

In patients with significant intra-abdominal adhesions, a combined laparoscopic and open approach (hybrid/laparoscopic assisted) may be considered. Laparoscopic-assisted approach is similar to laparoscopic approach in that much of the operation is performed through small incisions. In addition, a small laparotomy incision can facilitate adhesiolysis and closure of fascial defects with substantial mesh overlap of the defects while obviating the need for a generous laparotomy incision that might otherwise be required for an open approach. Advantages to completing the hernia repair via a hybrid or lap-assisted approach include the ability to perform adhesiolysis in an open fashion which reduces the risk for missed enterotomy as well as the ability to close the fascial defect [29]. Additionally, this allows the surgeon to place a mesh with significant overlap of the defect without making a large laparotomy incision, which may contribute to wound morbidity and longer recovery time.

The current practice of closure of the fascial defect during laparoscopic hernia repair is often dependent on the operating surgeon's routine preference. The benefits of routine closure potentially include an improved cosmetic outcome as well as potential decreased risk of postoperative seroma formation [30–32]. A meta-analysis and literature review by Yanaga et al. was conducted which showed fascial closure (IPOM plus) was associated with decreased risk of recurrence, 0–7.7% risk compared to 4.4–29%, and decreased risk of seroma formation, 0.5–78% compared to 0–11.43% [30]. However, more recent studies showed that there was no significant difference in postoperative surgical site infection, hernia recurrence, or seroma formation between a bridged repair or repair with fascial closure [31, 32]. Currently, in

the author's practice, routine closure of the fascial defect is performed when technically feasible.

One main limitation to laparoscopic hernia repair for recurrent hernias is defect size. Heniford et al. and Hauters et al. demonstrated that hernia defect size was associated with increased risk of recurrence after laparoscopic ventral hernia repair [20, 26]. Hauters et al. found that despite having more than 5 cm overlap, when the mesh size to defect size ratio was less than 8, this was associated with a 70% risk of recurrence [26]. As defect size increases, laparoscopic bridge repair may result in mesh eventration, or pseudohernia occurrence, over time, which can be both dissatisfying to patients and ineffective as a long-term repair. Although laparoscopic repair has been successful with defects that are larger, recurrence rates increase significantly as the width of the hernia defect increases [26, 28]. While there is currently no upper limit of defect size that can be approached laparoscopically, we currently recommend laparoscopic intraperitoneal onlay mesh repair for defects ≤7 cm in greatest width.

Open Recurrent Ventral Hernia Repair

Factors that lead to multiply recurrent hernias often necessitate an open repair. For instance, patients with large or multiple defects, significant intra-abdominal adhesions, or compromise of the overlying skin integrity may require open approach. Patients with recurrent hernias and chronically draining sinus tracts, infected mesh, or enterocutaneous fistulas are frequently considered for staged open repairs in the authors' practice, as the initial goal of the operation is typically source control for contamination and infection, with subsequent definitive abdominal wall reconstruction once eradication of infection has been accomplished. There is some recent literature to suggest that permanent synthetic mesh repair may be safe and effective in clean-contaminated and contaminated cases [33]; however, this has not yet been widely adopted as standard of care in the United States. Further studies are ongoing to determine the safety of permanent mesh repair in clean-contaminated and contaminated fields. For patients undergoing definitive abdominal wall reconstruction, important preoperative considerations prior to attempted repair include location and type of mesh previously used and presence of concurrent chronically draining sinus tracts or enterocutaneous fistulas as these will determine operative approach and mesh selection. When performing definitive reconstruction in clean-contaminated and contaminated cases, the authors use macroporous, midweight polypropylene mesh for repair.

The goal of an open ventral hernia repair, whether primary or recurrent, is to optimize patient factors, prepare the wound by taking down adhesions or fistulas, reapproximate midline, and obtain adequate coverage with appropriate reinforcement [34]. Reapproximating the midline should be the goal when safe and feasible in repairing recurrent ventral hernias. Compared to a bridging technique, fascial closure has been shown to have a decreased risk of recurrence as well as surgical site occurrence when compared to bridging the defect [35, 36]. A review of the

current open surgical procedures for incisional hernia showed that recurrence rates were not statistically different between the mesh placement in a sublay and onlay position; however, both methods were superior to a bridged or primary closure after component separation for giant hernia repairs [35]. In the practice of the authors, onlay mesh repair is generally reserved for small- to medium-sized defects and clean cases in nonobese, non-smoker, nondiabetic patients. In these cases, a modified Chevrel approach, described by Stoikes et al., is preferred [37]. Bridged intraperitoneal repair is not preferred because the mesh is exposed to both the intra-abdominal contents and the subcutaneous tissue as well as decreased abdominal wall functionality due to the lack of restoration of normal abdominal wall anatomy [36]. When performing a sublay repair, the authors prefer to place the mesh in a retrorectus position, which was initially described by Rives in 1973 [38]. This allows the mesh to be placed in a well-vascularized plane and increases mesh coverage with muscle and soft tissue, which is protective against mesh infections.

To reapproximate the midline and restore the linea alba, a component separation is sometimes necessary. The first components separation, external oblique release, was introduced by Ramirez et al. in 1990 as a method to perform functional transfer of muscular components of the abdominal wall to close large hernia defects [39]. Other approaches to component separation have been described, including endoscopic, perforator sparing, and posterior. A well-known drawback of anterior component separation is the creation of large subcutaneous flaps which have been shown to result in significant wound morbidity [40, 41]. Still, this technique can be particularly useful when the hernia sac has dissected into the subcutaneous space, and the ventral surface of the rectus abdominis is therefore exposed, lending itself to approaching the external oblique muscle without additional wound morbidity.

Although the Rives-Stoppa repair is an effective method of herniorrhaphy for many situations, this technique may provide insufficient release in larger hernia defects [42, 43]. The Rives-Stoppa technique takes advantage of the space in the preperitoneal plane below the umbilicus. Dissection here allows for significant mobilization and midline reapproximation but also creates a space capable of incorporating a sizeable piece of mesh to provide adequate coverage of large ventral hernias [44]. In addition, posterior component separation with transversus abdominis muscle release allows for even further advancement of the rectus fascia, preserves neurovascular innervation, and provides a space that will accommodate a sizeable piece of mesh [43]. The authors generally prefer to use a midweight bare polypropylene mesh for this repair. This technique is becoming increasingly popular due to the ability to create a large space for adequate prosthetic coverage, a previously unviolated anatomical plane even in multiply recurrent hernia repairs, as well as placing the mesh in the sublay position theoretically decreases risk of postoperative surgical site occurrence and infection. This technical approach to recurrent ventral hernias has many technical advantages as the open approach facilitates adhesiolysis in complex abdomen, wound morbidity is not increased as with external oblique release, and the space created can accommodate an appropriately sized mesh for giant ventral hernias which helps to minimize recurrence, and it allows for placement of mesh in the sublay position [43, 45].

Special Considerations

Contaminated Fields

As surgical site infections are a well-known factor associated with increased hernia recurrence, it is likely that potential contamination will have to be managed when repairing a recurrent hernia [15, 20]. The type of reinforcement material utilized in these repairs must be carefully considered to minimize surgical site infection as well as repeat recurrence. Traditionally, biologic mesh was favored in contaminated situations due to the high incidence of postoperative wound morbidity. Recommendations from the Ventral Hernia Working Group suggest against synthetic mesh in both grade 3 (contamination of the wound or suspicion of contamination) or grade 4 (frankly infected wounds) as using biologic mesh in these situations does not require mesh resection even in the face of active infection [34]. Data in repair of grade 3 and 4 hernia repairs with biologic mesh demonstrates recurrence rates of approximately 12% and surgical site infection rates of 15–36% [46, 47]. There is data that supports the safety of using synthetic material in a contaminated field. Lopez et al. evaluated placement of synthetic and biologic meshes in contaminated fields and saw no difference in surgical site infections (SSI) between the two groups but a 35% recurrence rate in situations when biological cases were used compared to 8.3% when synthetic mesh was used [48]. Introduction of biosynthetic mesh provides another potential option in the repair of contaminated hernias. One example of biosynthetic mesh, Gore BioA, is composed of an absorbable copolymer that is gradually absorbed by the body in approximately 6–7 months. A multicenter, prospective trial evaluated the use of this synthetic material in grade 2 and grade 3 [34] hernia repairs. Postoperative wound events occurred in 28% of patients, and recurrence occurred in 17% of repairs at 2 years [49]. This represents a significant decrease in surgical site occurrence as well as hernia recurrence when compared to repair with non-cross-linked porcine dermis [50]. Still, given the somewhat high recurrence rates using biosynthetic mesh in contaminated fields, caution must be used in performing repairs with absorbable materials and should be saved for select circumstances. Additional biosynthetic meshes have subsequently been developed, however thus far there is insufficient literature available to comment on their performance in contaminated hernia repairs.

Multiple reinforcement techniques have been utilized for contaminated/grade 3 hernia repairs. In these situations, the choice of mesh is at the discretion of the surgeon with knowledge that there is an increased likelihood of recurrence if biologic mesh is used [34, 47, 48, 50]. When performing recurrent ventral hernia repair in contaminated fields, it is necessary to be meticulous about decreasing infectious burden. This includes debridement and/or removal of infected skin and soft tissue and removal of all infected mesh. Primary repair with staged reconstruction once infectious burden is eradicated should be strongly considered. Use of prosthesis in repair should be carefully considered. Synthetic or biosynthetic mesh use in grade 3 hernia repairs is likely safe and has decreased recurrence rates without significant

increases in surgical site infections [33]. Permanent synthetic meshes should be used in grade 3 hernia repairs in the hands of experienced hernia surgeons with high-volume practices as studies are still ongoing as to whether this practice may eventually be considered standard of care [51].

Loss of Domain

Special consideration must be given to patients with hernias exhibiting loss of domain, where an equal or greater volume of viscera resides outside of the abdominal cavity compared to that contained within the abdomen [52]. In these cases, achieving closure of the abdominal wall over the hernia repair can be extremely challenging and in some cases may even result in respiratory compromise as a result of intra-abdominal hypertension if the abdomen is closed tightly. While some degree of intra-abdominal hypertension may be tolerated, care must be taken to avoid what can ultimately be serious or fatal consequences of abdominal compartment syndrome [53, 54]. Various approaches to loss of domain hernias have been described, including use of botulinum toxin, tissue expanders, and progressive preoperative pneumoperitoneum in order to expand the abdominal cavity for replacement of the herniated viscera [55]. While literature has suggested that such interventions may be safely performed and relatively well tolerated [55], the authors prefer to perform a retrorectus approach with bilateral transversus abdominis release and large bridged repair in the retrorectus space utilizing bare heavyweight polypropylene mesh [56]. In this case, it is particularly important to prepare patients preoperatively with weight loss where appropriate, as weight loss results in significant visceral reduction and therefore improved ability to achieve closure of the abdomen without undue respiratory compromise. In these challenging cases, heroic attempts to achieve reapproximation of linea alba are avoided in favor of achieving a bridged repair with strong synthetic mesh and adequate soft tissue coverage over the repair (Fig. 26.2).

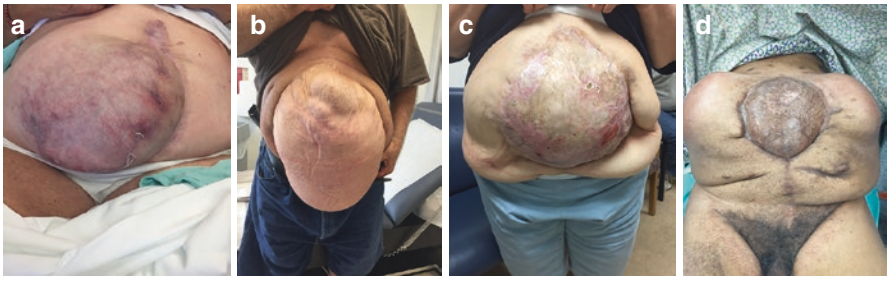

Fig. 26.2 Examples of loss of domain and complex soft tissue problems associated with recurrent ventral hernia repairs. **Panel A**: extremely thin skin covering a large recurrent ventral hernia. **Panel B**: loss of abdominal domain. Note that most of intra-abdominal organs appear to be outside of the abdominal compartment. **Panel C**: loss of abdominal domain with very delicate skin covering the hernia defect. **Panel D**: example of the use of tissue expanders prior to definitive hernia repair

Soft Tissue Coverage

In circumstances where overlying skin and subcutaneous tissue are thin, ulcerated, or of poor quality due to underlying pressure of the hernia contents or presence of skin grafts, consideration must be given to achieving soft tissue closure of the hernia repair. During the initial office visit, often the potential for soft tissue closure after excision of poor quality or devascularized skin can be assessed by having the patient lay supine on the examination table and attempting to "pinch" the edges of viable skin together. If the abdominal wall is fixed or "woody" in character and the good quality skin edges do not approximate on exam, strong consideration should be given for plastic surgery consultation. Potential planned interventions for this problem could include placement of tissue expanders or rotational versus free myofascial flaps [57, 58]. Specific attention should be devoted to avoiding ischemic wound events, as the result of such occurrences may be catastrophic and result in exposure of the prosthetic device and ultimate compromise of the repair. Such operations are best undertaken at tertiary or quaternary level referral centers best suited for a multidisciplinary approach. Smoking is considered by the authors to be an absolute contraindication for such cases.

Summary

Recurrent ventral hernia repairs remain a constant challenge to the general surgeon. When approaching recurrent ventral hernia repair, preoperative patient optimization is essential to minimize patient factors that contribute to recurrence. A tailored approach for each patient is necessary to offer the most successful operative intervention. Careful consideration should be given to prior operative history and prosthetic use, as well as modifiable patient factors, soft tissue coverage of repair, and planned operative approach to ensure the best outcomes. The authors propose the following logarithm when determining best operative approach for the repair of recurrent ventral hernias.

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Loss of Abdominal Domain

27

Marco Alban Garcia

Introduction

The surgical resolution of giant hernias represents a challenge for abdominal wall surgeons. It is necessary to know the anatomical and physiological changes in the abdominal wall and abdominal cavity, which develop during the evolution of a giant hernia, in addition to the management of systemic and local changes, to avoid perioperative complications.

The success of surgery depends upon good methodology in the diagnosis, preoperative management with adjuvant techniques, surgical technique, and postoperative care. Also, the multidisciplinary management of these patients is indispensable. It is ideal that these patients be treated in hospitals with experience in the management of giant hernias.

There are several reasons why patients with hernias can develop giant defects: limited access to health, poor information, low sociocultural level, and delayed referral from primary care physicians.

Classification

Classifications for ventral and incisional hernias were first proposed by Chevrel and Rath, followed by Korenkov et al., Ammaturo et al., Chowbey et al., Dietz et al., Muysoms et al., and Hadeed et al. Some agreement exists regarding the basic

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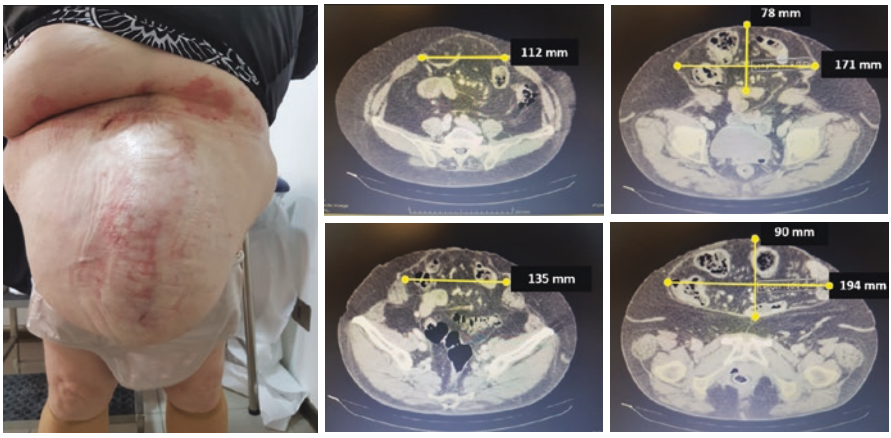

Fig. 27.1 Giant ventral hernia with loss of domain with a defect with transverse diameter of 12–15 cm and a hernia sac of 20 × 10 cm with a volume representing approximately 30% of the volume of the abdominal cavity and that falls in front of the pubis reaching the thighs

criteria of morphology and size of the hernia gap, although none has gained widespread acceptance in the literature. The classification proposed by the European Hernia Society (EHS) as (a) small, <5 cm in width or length; (b) medium, 5–10 cm in width or length; and (c) large, >10 cm in width or length is the result of a comprehensive discussion of the criteria to be included and also of how to precisely define them [1]. The EHS classification is generally regarded as an improvement on the previous classifications, but no reference was made to loss of domain hernias in that classification. This demonstrates the difficulty of defining the pathological status and the impossibility of proposing a standardized surgical approach to this clinical condition [2].

The EHS classification takes only the width as a measurement for the defect size and considers W3 hernias as the largest with more than 10 cm. This does not consider the size and volume of the hernia sac and does not consider its reducibility and loss domain [3] (Fig. 27.1).

Giant inguinoscrotal hernias have been defined as those that extend below the midpoint of the inner thigh when the patient is in the standing position, but there is no standardized classification. Some authors classify them as type 1, up to the middle third of the thigh; type 2, up to the knee; and type 3, below the knee [4] (Fig. 27.2).

There is usually no correlation between the size of the ring and the volume of the hernia sac. We can find small defects with large hernia sacs with abundant intestinal loops, and on the other hand, we can see hernia defects with rings of large diameter but with hernia sacs that contain small volume and content. For this reason, there is no consensus on the definition and classification of giant hernias with loss of abdominal domain.

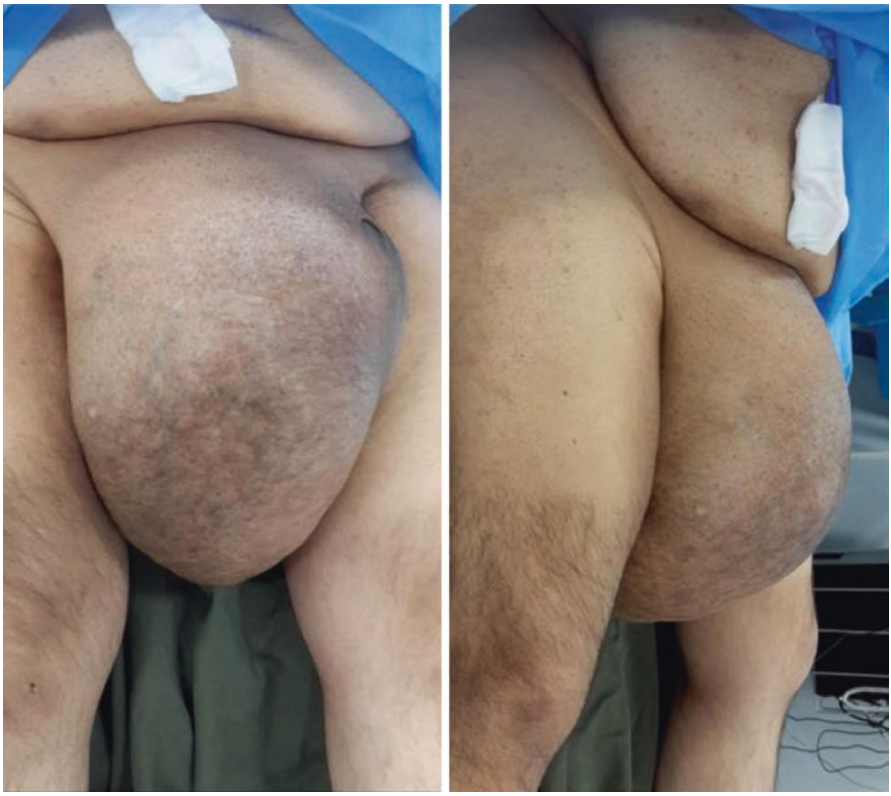

Fig. 27.2 Giant inguinoscrotal hernia, type 2 (up to the knee)

Definition

"Loss of abdominal domain" is not well defined in the literature. The majority of authors describe it as a large abdominal wall hernia with a significant amount of abdominal content herniated through a defect in the abdominal wall into a hernia sac of great size that forms a secondary abdominal cavity.

The diameter of the hernia defect is generally greater than 10 cm, and the contents of the hernia sac exceed the capacity of the abdominal cavity; technically it is one in which about 20–50% or greater of the abdominal contents are located outside of the abdominal cavity (Fig. 27.3).

Chevrel described an abdominal ventral hernia whose contents were held in place by adhesions and not reducible, thus losing their "right of domain" with the diameter of the wall defect ≥15 cm in transverse dimension [5]. Mason defined them as those in which it was not possible to reintroduce the contents of the sac into the abdomen with a hernia sac with a volume over a liter or a diameter of the

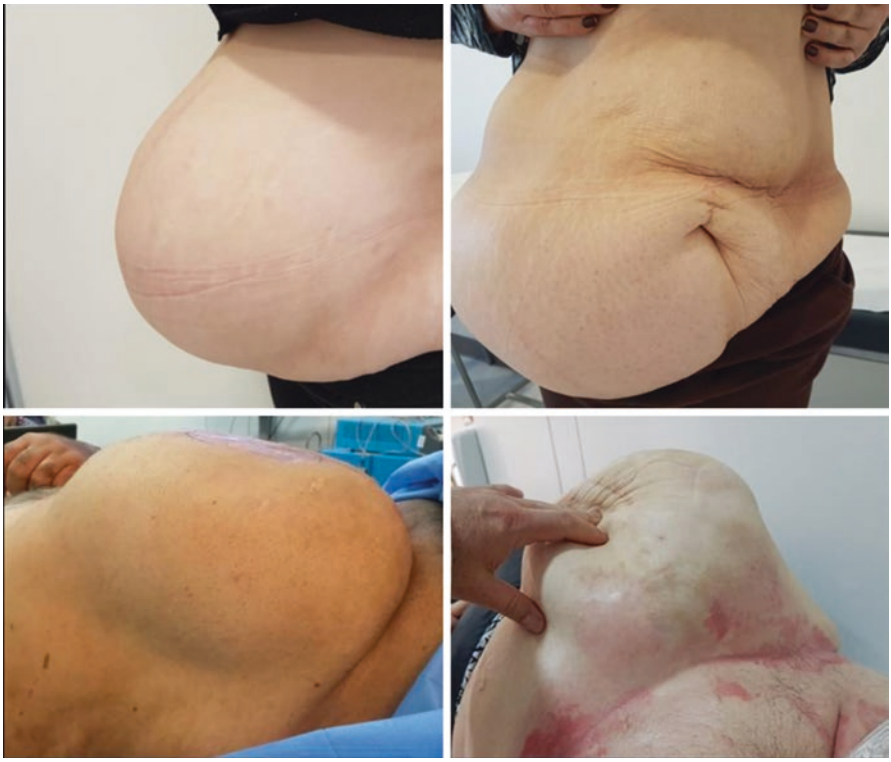

Fig. 27.3 Patients with giant ventral hernia with loss domain. The hernia sac represents a volume greater than 20% of the volume of the abdominal cavity (Video 27.1)

hernia ring exceeding 12 cm [6]. Kingsnorth considers these hernias as those in which the peritoneal sac has a volume of more than 15–20% of the natural volume of the abdominal cavity [7]. According to Tanaka et al., if the ratio of the volume of the sac over the volume of the abdominal cavity is greater than 25%, it is considered a predictor for loss of domain [8]. Herszage considered hernias large up to 10 cm, giant up to 20 cm, and monstrous when the defect is more than 20 cm.

Pathophysiology

Giant hernias produce a morbid condition with local and systemic alterations during its development and growth, altering the quality of life of patients.

Local alterations affect the muscles of the abdominal wall and diaphragm, the intestine, mesentery, subcutaneous tissue, and skin. Systemic alterations produce postural musculoskeletal dysfunction, chronic gastrointestinal and genitourinary dysfunction, pulmonary dysfunction, and psychosocial issues.

Local Alterations

Muscles of Abdominal Wall

Large hernias are accompanied by marked reduction of muscle-aponeurotic tissue of the abdominal wall, muscle atrophy of the abdomen with a large loss of their anatomical and physiological features that determine severe visceral and respiratory impairment [9]. The tendency of a giant hernia is to progressively increase the traction of the lateral rectus muscles, caused by the antagonist action of the lateral muscles of the abdomen, with the consequent enlargement of the hernia fibrotic ring, and small resistance offered by the hernia sac and the herniated contents of their own weight. The low intra-abdominal pressure changes the function of the diaphragm, and the patients develop respiratory alterations [10] (Fig. 27.4).

Volume of the Abdominal Cavity

The abdominal cavity decreases its volume through the following mechanism: as the bowel protrudes through the hernia defect, intra-abdominal pressure begins to decrease, and the abdominal wall muscles contract and retract from the linea alba to the lateral, thereby increasing the size of the hernia defect and the contents of the

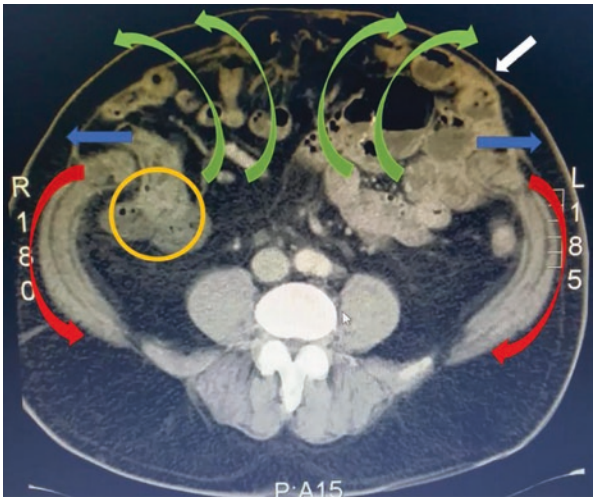

Fig. 27.4 Pathophysiology of the giant hernia with loss of domain: traction of the lateral rectus muscles, caused by the antagonist action of the lateral muscles of the abdominal wall (red arrow), enlargement of the hernia ring (blue arrow), abdominal cavity decreases its volume because bowel protrudes through the hernia defect (green arrow) and the intra-abdominal pressure begins to decrease, chronic inflammation of the mesentery and intestine (yellow circle), the skin and subcutaneous cellular tissue suffer alterations by a mechanical effect of compression by the great sac, resulting in the atrophy (white arrow) (Video 27.2)

sac which is vulnerable to trauma as there is no muscular wall that protects the abdominal contents [11–14]. In large hernias, the amount of viscera which progressively stretch and hold the hernia sac is such that it can form a "second abdomen" (Fig. 27.4).

Mesentery and Intestinal Loops

The herniated viscera adapt to local and extra-abdominal factors. The mesentery extends and becomes thickened by the difficulty of venous and lymphatic return, and there is chronic bowel dilatation due to loss of balance between the visceral and parietal tonus [9, 12]. A chronic inflammation of the mesentery and intestine develops, caused by direct mechanical irritation by the continuous friction with the rim of the ring. This inflammation conditions the formation of bowel adhesions, between mesentery and omentum, to the ring and hernia sac. In addition, there is a decrease in the venous return of the portal flow and the cava to the thorax due to the decrease of the intra-abdominal pressure and compression of the hernia ring, which causes congestion of all the abdominal viscera [11–14] (Fig. 27.4).

Skin and Subcutaneous Tissue, Fistulas

The skin and subcutaneous cellular tissue suffer alterations by a mechanical effect of compression by the large sac, resulting in atrophy. Abreast of a peritoneal sac, the skin is reduced to a poorly vascularized dermis, devoid of its supporting subcutaneous tissue [7, 12, 14]. The eventual result of this cutaneous hypoxia is the appearance of trophic ulcers which are observed, on occasions, in giant incisional hernias. A trophic ulcer has precise and corresponding manifestations: always situated at the midline, symmetrical, and sits at the vertex of the protrusion where the skin is thinnest. In chronic cases, atrophic ulcers may appear that are bacterial or fungal in origin that can contaminate the operative field. There will also be a tendency for infections in the skin folds around the sack [15].

Flament et al. described two types of ulcers in patients with hernias with loss of domain:

(a) Uncomplicated ulceration: these ulcers are most often infected, despite the absence of intestinal fistula formation.
(b) Complicated ulcers: the trophic ulcer is a prelude to more serious complications such as fistulas and eviscerations.

The rupture of a herniation ("burst abdomen") is a rather rare complication which converts a herniation into an evisceration through a breakdown of the peritoneal and cutaneous supportive layers. These events are end results of neglected trophic ulcers [15] (Fig. 27.4).

Systemic Alterations

Musculoskeletal Dysfunction

As the hernia sac grows excessively, a "second abdomen" is formed, which now weighs more than the abdomen itself and tends to cause the patient to bend forward following the weight of the sac. To compensate, it will force the patient to perform a hyperlordosis of the lumbar spine with its consequent painful lumbar syndrome or low back pain [13, 14]. When the linea alba is disrupted, the rectus abdominis muscles become dysfunctional, and the columns are mechanically uncoupled. This results in greater pressure on the posterior column, leading to chronic back pain and spine curvature disorders.

Ventilatory Dysfunction

As the intestinal loops migrate into the sac, the intra-abdominal pressure decreases in direct relation to the herniated volume. This alters the balance between intrathoracic and intra-abdominal pressures by modifying the normal diaphragm shape, which is flattened, resulting in inspiratory and expiratory restriction. Ventilation in these patients depends to a large extent on the capacity of the thoracic muscles [14]. The low intra-abdominal pressure changes the function of the diaphragm promoting its lowering and progressive lethargy. As a result, patients may have respiratory problems due to the synergistic changes in the abdominal wall, the discoordination between the chest wall, diaphragm, and abdominal muscles. This results in a decrease in total respiratory compliance almost entirely due to a decrease in chest wall compliance—whereas the lung remains substantially unchanged—which induces an increase in mechanical work of breathing and O2 consumption by accessory respiratory muscles [10]. Patients develop chronic respiratory failure, often latent, with functional tests and minimal change in blood gases in the absence of preexisting restrictive or obstructive pulmonary disease [16]. However, in patients with low respiratory reserve, all preoperative care must be taken and surgical maneuvers aiming to minimize the increased work of breathing [16].

Chronic Gastrointestinal Dysfunction

Patients with large hernia sacs develop altered intestinal transit through two mechanisms; the first is because of the difficulty of increasing the intra-abdominal pressure due to abdominal muscles displaced from the midline and with difficulty contracting, and the second as obstructive effect when the intestinal loops are included in the contents of the hernia sac, which produces obstruction of the passage of intestinal material by a hernia ring that obstructs the flow, in addition to the compression of the viscera among themselves inside the sac [14].

Dysfunction for Urination

Rarely, the bladder is inside a hernia sac and causes obstructive dysfunction. Most of the time, it is simply due to dysfunction of the bladder detrusor muscle due to the inability to raise the intra-abdominal pressure and favor the action of the bladder [14].

Psychosocial Issues

The deterioration of the quality of life due to the alterations that the giant hernia causes in the patient, such as the low self-esteem due to the aesthetic alteration and the poor access to a hernia specialist in some places, makes the patients and their family environment have a significant emotional commitment with psychological alterations that also require professional support.

Management of the Hernia with Loss Domain

The objectives of surgical management in an incisional hernia are the recovery of the anatomy and functionality of the abdominal wall, prevention of recurrence, and adequate tissue cover. For this the closure of the midline is of vital importance, since the restructured wall functions as the primary support and the abdominal continent and prevents excessive stress on the mesh. Achieving these three goals in a parietal reconstruction (in the case of a giant hernia) is a major surgical challenge, so all available resources must be used.

Different methods for the closure of the midline in giant hernias have been described in order to reduce the operative morbidity, especially the possibility of the development of the intra-abdominal compartment syndrome due to the closure of a giant defect and the concomitant increase of the intra-abdominal pressure.

The most used surgical techniques, in order to achieve an increase of the perimeter of the abdominal cavity based on relaxation incisions in the lateral muscles of the abdominal wall, are the anterior separation of components [17] and the transversus abdominis release techniques [18]. Another option is the Albanese technique, with good results [19]. There are modifications of the anterior separation of components technique widely used as Carbonell-Bonafe modification [20], endoscopic assisted minimally invasive release of the external oblique [21], and subcutaneous endoscopic approach described by Daes et al. [22]. In the same way, the transverse abdominal release technique can be done by minimally invasive and robotic approach.

The common objectives of these techniques are (1) to avoid the tension on the midline closure and (2) to increase the abdominal capacity permitting an easy return of the viscera to the abdominal cavity, thus achieving domain recovery.

Anterior Separation of Components

The technique of anterior component separation was first described by Ramirez et al., whereby the muscular layers of the anterior abdominal wall could be separated and medially mobilized in order to close the midline in large ventral defects, restoring the anatomy. Ramirez et al. described development of the avascular plane between the external and internal oblique muscular layers through relaxing incisions lateral to the rectus sheath, combined with mobilizing the posterior rectus sheath to the midline. Combined with freeing the rectus from its attachments to the posterior sheet [17]. The technique is extensively described in previous chapters.

Carbonell et al. describe a variation of the Ramirez technique with the installation of a 30 × 50 cm mesh between the plane of the external and internal oblique muscles, reinserting the medial border of the external oblique muscle toward the mesh and internal oblique muscle (Level 1) and if needed releasing the rectus from its aponeurosis through its posterior face using another retromuscular mesh (Level 2) [20].

Endoscopic assisted minimally invasive [21] release of the external oblique has also been described as a technique that reduces complications of soft tissues of open technique, and Daes et al. [22] described a subcutaneous endoscopic approach, in his series of hernias between 6 and 10 cm only required the release of unilateral external oblique muscle, through a supraaponeurotic subcutaneous dissection with balloon and only one working port apart from the optical port. The closure of the defect and reinforcement with mesh was performed by IPOM technique.

Transverse Abdominal Release Technique TAR

Novitsky et al. described the transverse abdominal release technique. The TAR procedure is a continuation and modification of the traditional retrorectus Rives—Stoppa repair. It is a myofascial release of the transversus abdominis muscle. This technique involves a wide area from the diaphragm to the pelvis and from paraspinal muscles of both sides. A major benefit of the TAR approach is that no skin flaps are raised for the reduction of the hernia, which may yield lower postoperative wound complications. The technique is extensively described in previous chapters [18].

Albanese Technique

Albanese designed his “triple incision” on the oblique major muscles (OM), the minor oblique, and the posterior leaf of the rectus sheath, respectively. This can be associated with the use of a mesh [19].

Adjuvant Techniques

There are other nonsurgical techniques whose purpose is to increase the perimeter and capacity of the abdominal cavity based on the elongation of the muscles of the abdominal wall; these techniques called “adjuvants” are progressive preoperative

pneumoperitoneum (PPP) [23], tissue expanders [24], and botulinum toxin [25, 26]. Other more radical techniques have been described for the treatment of giant inguinoscrotal hernias with loss of domain, like debulking of abdominal contents with extensive bowel resections in the form of total or hemicolectomy, omentectomy, splenectomy, and even small bowel resections [27].

Progressive Preoperative Pneumoperitoneum (PPP)

Progressive preoperative pneumoperitoneum gradually elevates intra-abdominal pressure, achieving the following systemic and local changes in the cavity and abdominal wall [13, 23, 28–31] (Fig. 27.5):

- Stabilizes diaphragmatic function and improves ventilatory mechanics
- Distends the muscles of the abdominal wall, which increases the capacity of the abdominal cavity
- Allows pneumatic lysis of adhesions facilitating dissection of the hernia sac and its contents
- Improves portal, mesenteric, and intestinal circulation
- Produces peritoneal irritation through the ambient air, optimizing the inflammatory response, and improves healing
- Allows to identify other areas of weakness in the abdominal wall not evident
- Decreases midline tension
- Decreases the visceral volume up to 40% [13]
- Improves tolerance to herniary content reduction, reducing immediate hemodynamic, ventilatory, and postoperative complications related to intra-abdominal compartment syndrome

PPP requires frequent insufflation of air into the abdominal cavity. Goñi Moreno used oxygen in his first case and later changed to ambient air. You can use oxygen, CO2, nitrous oxide, and ambient air, which has less absorption than oxygen and CO2 [31].

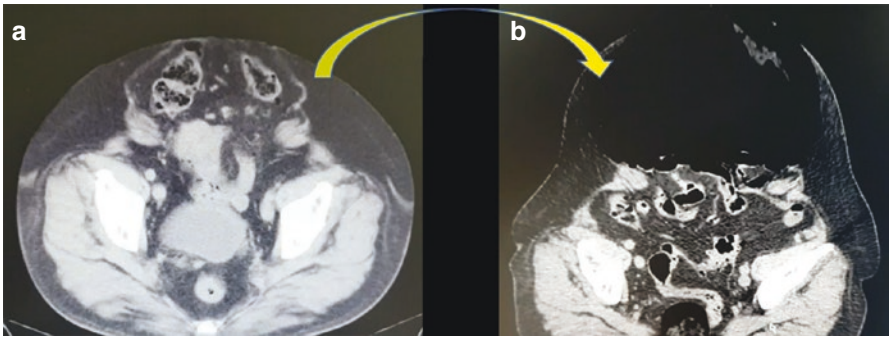

Fig. 27.5 (**a**) Ventral Hernia, prior to initiation of PPP, (**b**) after 15 days of PPP (Video 27.3)

The procedure can be performed in the operating room or in the patient's bed under aseptic conditions, local anesthesia, and sedation, by a detachable Veres needle or by Seldinger technique; you can use a double lumen catheter or a pigtail catheter placed percutaneously at Palmer's Point or other remote site from the hernia. Once the catheter is in the abdominal cavity, ambient air is passed through it. The catheter can be inserted under ultrasonographical or CT-guided control by the interventional radiologist. The subsequent insufflation of the abdominal cavity can be performed as an inpatient or ambulatory procedure. Air is insufflated daily in an amount of 500–1500 cm^3 [12–14, 31].

Intra-abdominal pressure should not exceed 15 mmHg. The duration of PPP depends on hernia type and size; approximately 1–2 weeks in giant inguinoscrotal hernia, 2–3 weeks in giant ventral hernia, and the total volume will range from 5000 to 10,000 cm^3. If the patient manifests a feeling of fullness, pain, nausea, shortness of breath, tachycardia, hypertension, hypotension, or decreased blood O2 saturation, the PPP must be suspended.

PPP has a low rate of complications (7%): hematoma, seroma, abdominal wall emphysema, pneumothorax, pneumomediastinum, pneumopericardium, deep venous thrombosis, pulmonary thromboembolism, intestinal obstruction, hemoperitoneum, peritonitis, catheter dysfunction (local emphysema, infection, displacement to preperitoneum), pneumonia, and metabolic acidosis.

Botulinum Toxin

Botulinum toxin (BTX) is a neurotoxin that is isolated and purified from *Clostridium* bacteria which produce eight different serotypes. Only A and B serotypes are commercially available for clinical use, with type A being the most commonly utilized. BTX blocks the release of acetylcholine in addition to pain and inflammatory mediators at the presynaptic cholinergic nerve terminal. The injected skeletal muscle with BTX becomes flaccidly paralyzed with diminished pain sensations resulting in 4–6 months of reversible paralysis or chemical muscle denervation. In the abdominal lateral wall, BTX should result in improved abdominal wall compliance, decreased lateral abdominal wall retraction with less midline tension, and pain modulating benefits, with potential applications in abdominal wall reconstruction settings in patients with loss of domain. Ibarra-Hurtado et al. demonstrated in patients with ventral hernia with loss domain a 50% reduction in transverse hernia diameter at week 3 [25]. Another study in inguinoscrotal giant hernias resulted in a 26% gain of intra-abdominal volume [26].

Tissue Expanders

Expansion of musculofascial tissue using temporarily implanted expanders as a precursor to reconstructing the abdominal wall was first described by Hobar, Byrd, and colleagues for congenital defects and later by the same group for posttraumatic defects. Gradual expansion should allow for reapproximation of autogenous,

innervated, healthy tissue. Possible locations for the expanders are subcutaneous, intermuscular sites between the external and internal oblique muscles, intramuscular sites between the internal oblique and transverse abdominis muscles, and intraabdominally. Placing expanders in the plane between the transverse and internal oblique muscles appears ill-advised because this area contains the nervous and arterial supplies for these two muscles and the rectus [32].

Measurement of Abdominal Cavity Volumes and Hernia Sac

The treatment of giant ventral hernia with loss of domain is considered to be dangerous because fascia closure under tension is life-threatening due to the risk of intra-abdominal hypertension (also known as abdominal compartment syndrome). To mitigate this postoperative risk, the adjuvant preoperative techniques have been used in the work-up of large incisional hernias. Predictive preoperative factors for these complications (including compartment syndrome) have been poorly described. It is essential that these patients have imaging, such as CT scan without contrast that evaluates the anatomy of the wall and abdominal cavity, in addition to measuring the volumes of the abdominal cavity and hernia sac.

The volumes to be measured are the incisional hernia volume (IHV), the abdominal cavity volume (ACV) excluding the IHV, the total peritoneal volume (PV, i.e. IHV + ACV), and the IHV/PV. The height and width of the hernia should also be calculated.

Dumont et al. [23] described in 2009 the increase of the length of the muscles of the abdominal wall and hernia ring after PPP and coined the concept of passive extension in the muscles. Sabbagh et al. [33] in their study in 2011 described that an IHV/PV ratio $\leq$20% was predictive of tension-free fascia closure of ventral hernias with loss domain. He showed that 89% of the patients meeting this criterion had tension-free fascia closure and no need for resection to decrease the intra-abdominal pressure. When the ratio was $\geq$20%, only 12.5% of the patients had tension-free fascia closure without resection. Meir et al. [34] considered a high IHV/PV ratio to be an indication for PPP but did not quantify the parameter. Kingsnorth et al. [7] suggested that physiological respiratory adaptation is necessary if the volume is above 15–20%. Sabbagh adopted the threshold of 20% suggested by Kingsnorth et al. This value may have been chosen as a result of the systematic use of PPP. In 2009, Tanaka et al. [8] reported on their use of peritoneal volume expansion prior to the surgical treatment of ventral hernias with loss domain. They used the IHV/ACV ratio to determine the extent of PPP. Tanaka et al. [8] applied a threshold of 25% for the IHV/ACV ratio but did not specify how they had decided on this value. Rappoport et al. [13] in 2014 demonstrated similar results in their study. They measured the elongation of the rectus muscles and lateral muscles of the abdominal wall after PPP and also demonstrated a decrease in visceral volume of approximately 47% after PPP, a significant change, attributable to a clear diminution of the caliber of the intestinal loops and the thickness of intestinal wall (Fig. 27.6).

The determination of abdominal cavity and hernia sac volumes and measurement of the length of the abdominal wall muscles, before and after the application

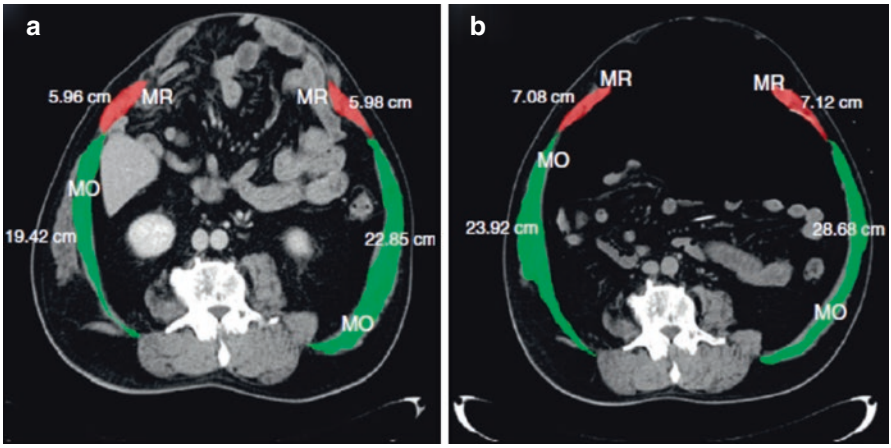

Fig. 27.6 (**a**) CT scan previous PPP, with the abdominal cavity and the hernia sac totally occupied by bowels. MR anterior rectus abdominis muscle and MO oblique muscles, with their length measures in centimeters. (**b**) CT scan after 2 weeks of PPP, with change of length of the rectus and oblique muscles and reduction of the visceral volume in 46.9%

of adjuvant techniques, allows for correct surgical planning, selection of technique for each case, and prediction of feasibility of the closure of the midline without tension.

The Sum of the Forces

During the perioperative period of the approach of a giant hernia with loss of domain, a symbiosis between the different adjuvant and surgical techniques is required. The decrease in the diameter of the hernia ring and the elongation of the muscles of the abdominal wall reached after the application of Botox, plus the elongation of the muscles and decrease of the visceral volume that is achieved with the PPP, allows the patient to reach his surgery with a flaccid and elongated abdominal wall that facilitates the closure of the midline. If we add the advancement of the myofascial flaps of both sides with the techniques of anterior or posterior separation of components applied in a more manageable abdominal wall, the union of the rectus muscles in the midline is feasible in large defects of the abdominal wall.

This symbiosis is called "the sum of the forces" in our unit of hernias (Fig. 27.7).

This allows patients to have less chance of complications secondary to a tension repair, such as intra-abdominal compartmental syndrome and recurrences. The effect of Botox also decreases postoperative pain with less analgesia requirements and better and faster ambulation and return to activities. During PPP, there is an adaptation to high intra-abdominal pressures of up to 15 mmHg, which allows a better tolerance after surgery, without respiratory or hemodynamic compromise.

The sum of the forces offers significant advantages compared to the individual advantages of each surgical technique and adjuvant.

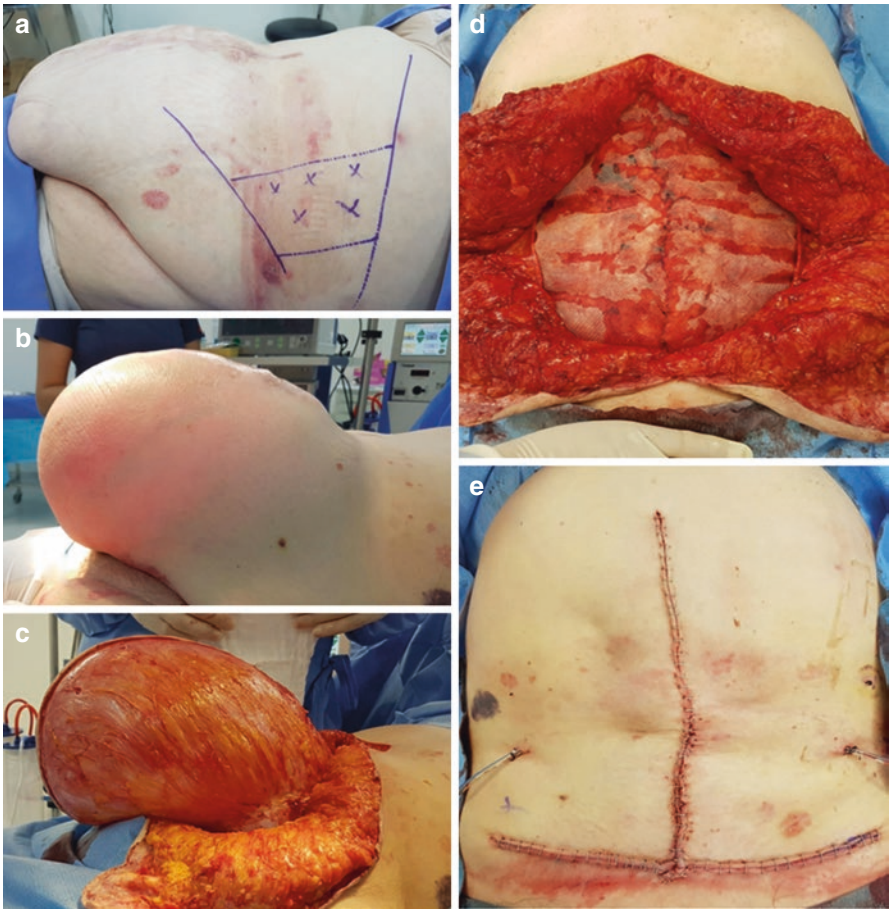

Fig. 27.7 Giant ventral hernia. (**a**) BTX infiltration in lateral abdominal wall. (**b**) After 5 days of PPP. (**c**) Dissection of the hernia sac with the abdominal cavity with pneumoperitoneum. (**d**) Anterior component separation. (**e**) Abdominoplasty (Video 27.4)

According to our experience and as demonstrated in our study of 14 patients with giant hernia with loss of mastery with a mean age of 69 years and a BMI of 31.5, the "sum of the forces" have achieved safe results with 6% of relapse with a follow-up at 24 months, without major morbidity, without mortality, and improving the quality of life of our patients.

Optimization of Surgery by a Multidisciplinary Team

The management of a giant hernia with loss of domain requires preparation of the patient and the multidisciplinary team that is treating the patient.

Rarely does a hernia with loss of domain present as an emergency case—the giant hernia diameter decreases the possibility of an intestinal obstruction. Therefore,

the vast majority are elective cases, allowing sufficient time for optimal preparation of the patient and their comorbidities.

The patient must stop smoking at least 1 month before and 2–3 months after surgery, reducing respiratory and wound complications. They must have optimal nutrition, with albumin greater than 3.5 g/dL; otherwise there must be nutritional optimization. Diabetics with HgA1c greater than 7 have a greater possibility of wound infection and poor wound healing. In these cases, the intervention of the endocrinologist is indispensable.

For patients with poor baseline functional status, a preoperative rehabilitation plan is established.

Decreased weight is critical. Obese patients are more likely to have surgical wound complications and a chronically high intra-abdominal pressure that favors tension in the midline closure, increasing the possibility of recurrence. Preoperative weight loss reduces the volume of the liver, omentum, and retroperitoneal fat. Patients with obesity should be previously managed by the nutritionist of the obesity/bariatric team. Therefore, the patient should be treated by a team of multidisciplinary professionals.

The patient's work-up should include a complete collection of information from their clinical history, surgical history, postsurgical complications, any open abdomen, and/or recurrences. Operative records should be accessed to obtain information of the types of sutures and meshes used.

The evaluation with CT scan in Valsalva should include the measurement of volumes of the abdominal cavity and hernia sac to determine the percentage of loss of domain, in addition to 3D images of the abdominal wall. For this reason, it is essential to have a radiologist with interest in abdominal wall imaging.

Likewise, the interventional radiology team must have experience in the installation of PPP catheters and evaluate the patient during the period of insufflation of the PPP, due to possible dysfunction of the catheter by displacements or other causes.

The use of botulinum toxin should be by surgeons with experience in this management for its correct dosage and infiltration in the abdominal wall. Subsequent radiological tests to determine changes in the abdominal wall and hernia and to plan the surgery are also advised. Approximately 1 month after infiltration, surgery can be performed and the patient hospitalized according to each case in a period of 5–10 days. During the PPP period, patients should have antithromboembolic measures such as compression stockings and low-molecular-weight heparin, as well as respiratory and motor kinesiotherapy. The nursing team must have enough experience to recognize signs of intra-abdominal hypertension and to know the initial actions to avoid complications.

The surgical team may, if necessary, include plastic surgeons for an abdominoplasty in case of large dermal flaps that require resection and better aesthetic results (Fig. 27.7).

In the immediate postoperative period, patients should be closely monitored due to the possibility of intra-abdominal compartment syndrome, especially in those cases in which no adjuvant measures were used. Due to the possibility of operative wound complications, the team must have specialized nurses in the advanced management of wound complications. For this reason, these patients must be referred to hospitals that have professionals with experience in giant hernias.

Summary

In summary, hernias with loss of domain represent a great surgical challenge due to the complexity of their management. The complexity of these cases and associated morbidity requires them to be treated by experienced teams in high-volume institutions. With the correct selection of cases, expert multidisciplinary equipment, preoperative optimization of the patient, detailed preoperative study, application of adjuvant techniques, knowledge of advanced techniques of hernioplasty and protocolized postoperative care, and the treatment of hernias with loss of domain can be carried out safely and with good results.

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Fixation vs. No Fixation in MIS Inguinal Hernia Repair

28

Christopher Yheulon and S. Scott Davis Jr.

Introduction

Fixation of mesh during minimally invasive inguinal hernia repair is a highly debated topic. The main reason to advocate for fixation is to prevent mesh migration, theoretically decreasing the likelihood of recurrence. The main argument against certain forms of fixation is a risk of acute pain and chronic pain due to fixation into muscles, nerves, and bone. Some surgeons advocate for no fixation at all, while those advocating fixation use many methods including absorbable and permanent forms of sutures, staples, and tacks applied to various structures within the posterior inguinal anatomy. Alternative to penetrating fixation such as surgical glue and self-fixating mesh is also being widely utilized, potentially changing if and how most surgeons fixate mesh in minimally invasive inguinal hernia repair.

Advocacy for Fixation

In 1994, Phillips et al. published a multicenter retrospective review of 3229 patients who underwent laparoscopic inguinal hernia repair (LIHR) to determine risk factors for recurrence [1]. In this data set, there were 54 recurrences. The authors cite that undersized mesh is the leading cause of recurrence (60%), while the second most common (32%) was because "the mesh was never stapled." The authors concluded to recommend secure stapling during LIHR. However, there was no standardization

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of the procedure or description of fixation methods. In addition, there was no data analysis comparing the recurrence group with patients who did not recur to discern causality. This is further convoluted as 42% of recurrences associated with lack of fixation were repaired in a laparoscopic "plug-and-patch" method, a technique largely considered antiquated today. Of those that were performed with more current methods, there were no recurrences in the 578 totally extraperitoneal (TEP) repairs, and only 6 recurrences out of 1944 transabdominal preperitoneal (TAPP) repairs attributed to lack of fixation/stapling (0.3%). This may indicate that technique as opposed to fixation was more predictive of recurrence.

In 1998, Felix et al. published a retrospective review of 10,053 TEP or TAPP repairs with 35 failures noted [2]. All surgeries were performed by experienced surgeons, varied slightly in technique, but all fixated both medially and laterally. In this study, 12 recurrences (34%) were associated with inadequate fixation alone. Again, it was impossible to compare the adequacy of fixation in patients who did not recur limiting the ability to define inadequate fixation as causal. Yet this study in particular served as a benchmark for fixation in LIHR for well over a decade [3].

Fixation Versus No Fixation

As LIHR grew in popularity, surgeons began to debate the need for fixation. Although studies as those mentioned above argued for fixation to decrease recurrence, others implicated fixation techniques in nerve injury, chronic pain, and increased operative costs. In 2011, Teng et al. published a meta-analysis 772 patients within randomized controlled trials (RCTs) comparing fixation of mesh versus no fixation of mesh during LIHR [4]. Patients were followed for a period of 8–36 months. There was no significant difference with regard to recurrence (OR 2.01 favoring fixation, $p = 0.43$), or postoperative pain, but there were significant reductions in operative time (4 min, $p = 0.02$). However, this study is limited by its rate of recurrence. There were only 4 recurrences within the 992 hernias repaired, 3 in the non-fixation group, and 1 in the fixation group. This rate of recurrence (0.4%) for either method is markedly better from larger meta-analyses (2.7%) [5]. A larger sample size or longer follow-up period may be necessary to discern true recurrence rates.

In 2016, Claus et al. performed a study investigating mesh migration in 60 TEP repairs. Although patients were randomized, only 10 were assigned to the control group (fixation), while 50 were assigned to the experimental group (non-fixation). The mesh in each group was marked with three surgical clips for future radiographic investigation, and X-rays were taken immediately postoperatively and at 30 days from surgery. There was no difference in the distance of migration in either group (0.1–0.3 cm in fixated group, 0.1–0.35 mm in non-fixated group) [6]. The results of this study are encouraging toward non-fixation; however, the short follow-up period and small sample size make the results challenging to apply clinically. In addition, although there was no difference in the mean migration between the two groups, perhaps a more appropriate analysis would compare the percentage of patients in

each group who had a total migration beyond the upper limit of normal. It would be reasonable to expect those extreme outliers to have an increased rate of recurrence. However, no such analysis was performed.

Permanent Versus Absorbable Tacks

The debate surrounding fixation not only involves the decision to fixate but also how to fixate, should it be performed. Some surgeons theorize that metal tacks will cause more pain than absorbable tacks given their permanence**.** However, there are no published human studies comparing permanent versus absorbable penetrating fixation methods in LIHR. The best data available related to this topic is inferred from ventral hernia repair. Animal models in ventral hernia repair demonstrate that permanent tacks have more tensile strength but also cause more inflammation and adhesions [7]. Christoffersen et al. published a study examining the rate of recurrence of 816 patients who underwent incisional hernia repair while comparing the use of permanent or absorbable tacks [8]. Over a follow-up period of up to 4 years via survey results, there was a significantly higher rate of recurrence with absorbable tacks (HR 1.53, $p = 0.008$), but no difference in severe chronic pain. Overall, there is a paucity of data comparing permanent and absorbable tacks in LIHR leaving us unable to conclude any significant differences in outcomes between the two fixation modalities.

Penetrating Fixation Versus Glue Fixation

As fixation itself has been implicated in some studies to increase chronic pain, surgeons began to investigate noninvasive fixation methods such as surgical glue as an alternative. There are two types of glue studied including biologic (fibrin) and biosynthetic (cyanoacrylate). In a 2012 review of surgical sealants, fibrin glue costs approximately $50 per mL, while cyanoacrylate sealant costs $175 per 0.5 mL [9]. This is compared to the cost of a permanent penetrating fixation device, costing approximately $225 [10]. No studies exist comparing the two glue fixation methods to each other. Although some studies have demonstrated a significant reduction of cost with glue fixation, it is difficult to extrapolate such findings due to country and hospital contracts [11].

In 2016, Antoniou et al. published a meta-analysis including 9 RCTs and 1454 patients comparing tacker mesh fixation versus glue mesh fixation during LIHR. Patients were followed for 6–24 months [12]. There was no significant difference in rates of recurrence or overall morbidity. There was a significant reduction in chronic groin pain in the glue fixation group (OR 0.46, 0.22–0.93). However, only 5 of the studies included relevant data on chronic pain decreasing this population to 454 patients, which is not powered to detect such a reduction.

Overall, glue fixation likely decreases chronic pain, does not lead to increased recurrence, and may be less costly than penetrating fixation techniques.

Self-Fixating Mesh

Self-fixating mesh (SFM) has existed for less than a decade. Although there is a paucity of data regarding its use for LIHR, there is literature regarding its use in open repair. In 2017, Ismail et al. published a meta-analysis of 3722 patients investigating the outcomes of SFM compared to suture fixated mesh in open inguinal hernia repair [13]. There was no difference with regard to recurrence or overall morbidity. However, there was a reduction in operative time (−7.85 min, $p = <.0001$) as well as a nonsignificant trend in reducing chronic groin pain in the SFM groups (OR 0.75, $p = 0.09$).

To date, there are only two small RCTs examining the use of SFM in LIHR. In 2012, Cambal et al. examined 50 patients undergoing TAPP with SFM versus 50 patients fixated with fibrin glue [14]. There was a significant decrease in operative time in the SFM group (4.5 min, $p = 0.006$), but no difference with regard to acute or chronic pain. There were no recurrences in the study, but the follow-up period was only 3 months. In 2016, Ferrarese et al. performed a similar study with 60 patients followed for a mean of 11 months [15]. There were no recurrences, and there were no significant differences between the SFM and fibrin glue groups in any outcome to include operative time.

Conclusions

There are both a wealth and dearth of literature regarding fixation techniques for LIHR. The data regarding SFM is encouraging, but larger randomized controlled trials must be performed. Perhaps the only benefit with SFM is improved operative time. Even so, reducing operative time has been shown to improve outcomes in a variety of minimally invasive surgeries to include a nonsignificant trend in LIHR ($p = 0.14$) [16]. Overall, we agree that the best guidance on fixation for LIHR mirrors the 2015 International Endohernia Society guidelines on laparoscopic (TAPP) and endoscopic (TEP) treatment of inguinal hernia [17].

Evidence

Level 1A: Fixation and non-fixation of the mesh in TEP are associated with equal risk of postoperative pain or recurrence.

Level 1B: Fibrin glue fixation is associated with less chronic pain than stapling.

Recommendations

Grade A: If TEP technique is used, non-fixations must be considered in all types of inguinal hernias except large direct defects.

Grade B: In case of TAPP repair, non-fixation should be considered for primary and first recurrences of both direct and indirect hernias.

Grade B: For fixation, fibrin glue should be considered to minimize the risk of acute postoperative pain.

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Open Techniques: Mesh and Non-mesh Anatomical Repairs

29

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Open inguinal herniorrhaphy remains the most commonly performed repair for inguinal hernias in the world. The surgical management of hernias has undergone extensive evolution over the past century, always with the goal of definitive repair with minimal morbidity for the patient. The choice of repair should be tailored to the patient and the clinical circumstances. Both tissue repairs and tension-free repairs have merit in experienced hands and in the correct setting.

Evolution of Inguinal Herniorrhaphy

Standardized inguinal hernia repair began as tissue repairs. More than 70 different types of named tissue repairs for inguinal hernia exist in the surgical literature. Three of the more commonly studied and practiced open tissue repair techniques—Shouldice, Bassini, and McVay—are still in use today. The Bassini repair was first performed in 1887 and became a standard of care for inguinal hernia repairs. Bassini championed reinforcement of the posterior inguinal canal using the transversalis fascia, transverse abdominal muscle, and internal oblique muscle. However, increased recurrence rates in the hands of less experienced surgeons allowed for the Shouldice repair to gain prominence in the early 1950s [1].

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In the 1950s and 1960s, Francis C. Usher introduced the use of polyethylene in the repair of inguinal hernias. The concept of a "tension-free" repair was first developed in the 1980s and aimed to improve upon the well-established tissue repairs that had been performed since the 1800s [2]. The tissue-based repair, first popularized by Bassini, helped to standardize the repair of inguinal hernias. However, despite refinements to the method, by Shouldice, McVay, and others, recurrence rates remained between 10 and 15% in most published literature. The use of prosthetic mesh creates a tension-free repair by eliminating the need to pull fascial layers together during the procedure [3]. The mesh is placed between the layers of external and internal oblique, becoming well-incorporated in the lower abdominal wall. The use of this technique results in a reduction in recurrence risk by 50–75% [4]. Furthermore, a Cochrane review of over 20 randomized trials comparing Lichtenstein with tissue repairs showed less chronic pain, faster return to normal activities, and shorter hospital stays. As a result, the tension-free repair quickly became the standard of care for inguinal herniorrhaphy [5].

The minimally invasive techniques that were subsequently developed for inguinal hernia all utilized the same tension-free principles. As such, while there are differences in wound morbidity and postoperative pain, there is no significant difference in the recurrence rate between open and minimally invasive tension-free repairs.

Relevant Neuroanatomy

There are three nerves within the inguinal canal: the *ilioinguinal*, the genital branch of the *genitofemoral*, and the *iliohypogastric* nerves. The ilioinguinal nerve is typically the first nerve encountered during surgery, located over the spermatic cord within the investing fascia of internal oblique muscle. This fascia should be preserved, as it helps protect the nerve from mesh and reduces perineural scarring.

The genital branch of the genitofemoral nerve lies on the underside of the spermatic cord, running adjacent to the spermatic vein (seen as a "blue line" under the cord). During dissection of the spermatic cord, this nerve and vein together should be kept with the deep cremasteric fascia that covers it. Excessively traumatic dissection may also damage the vas deferens and sensory nerve fibers of the testicle, producing orchialgia, azoospermia, and dysejaculation [6, 7].

The iliohypogastric nerve runs between the internal and external oblique, protected from mesh by the investing fascia of the internal oblique muscle. Laterally, the nerve becomes intramuscular within the internal oblique. The nerve can be exposed by opening the anatomic cleavage between the internal and external oblique, exposing superiorly to visualize the aponeurosis of the internal oblique.

General Principles

Patients are placed in supine position with arms fully extended. Administration of local anesthetic may be performed prior to or after sterile draping is completed. For most open inguinal hernia repairs, administration of local anesthetic is sufficient for completion of a tissue repair. However, general anesthesia is also acceptable. A solution of 0.25% bupivacaine with epinephrine is commonly utilized, with the total possible volume dependent on the patient's weight. Local anesthetic is placed medial to the anterior superior iliac spine (ASIS) to provide an ilioinguinal nerve block and along the length of the proposed incision to create a surgical field block [8].

A straight line between the ASIS and the pubic tubercle should guide the initial incision. Some surgeons prefer an oblique incision 2–3 cm above the ASIS-pubic tubercle line. Others may prefer a more horizontal incision within the Langer lines of skin tension. Regardless, following the skin incision, the external oblique aponeurosis is exposed by dissecting through the Scarpa's and Camper's fasciae [8].

The external oblique aponeurosis is opened through the external inguinal ring. The medial and lateral edges of the external oblique aponeurosis are grasped with a hemostat and pulled away from the cord structures. The iliohypogastric nerve may be identified at this time and preserved. The cord structures are then bluntly mobilized off the external oblique and inguinal floor. A swipe of the index finger under the cord structures at the pubic tubercle will allow for circumferential mobilization and placement of a Penrose drain around the cord structures. Mobilization of the cord structures will expose the shelving edge of the inguinal ligament and the iliopubic tract. Division of the cremasteric muscle in a longitudinal fashion occurs next. Once mobilized, the cremaster muscle is ligated. Following identification of the hernia sac, the surgeon may proceed with either a high ligation or complete reduction of the sac into the preperitoneal space without excision [8]. A relaxing incision is created by making a vertical incision from the pubic symphysis and extending it superior only to the anterior rectus sheath for 3–4 cm, thereby exposing the rectus abdominis muscle.

Bassini Repair

The initial steps in the procedure are described above in the general principles. The reconstruction begins by opening the transversalis fascia from the internal inguinal ring to the pubic tubercles, exposing the preperitoneal fat. Opening of the transversalis fascia allows for the creation of the "triple layer" (transversalis fascia, transversus abdominis, and the internal oblique muscle). The first stitch involves the triple layer, the pubic tubercle, and the rectus sheath. The repair is carried out laterally, with the triple layer sutured to the shelving edge of the inguinal ligament, in an interrupted fashion, until the internal ring is closed medially (Fig. 29.1). Typically, six to eight nonabsorbable interrupted sutures are required. The external oblique aponeurosis is then closed using an absorbable suture [9].

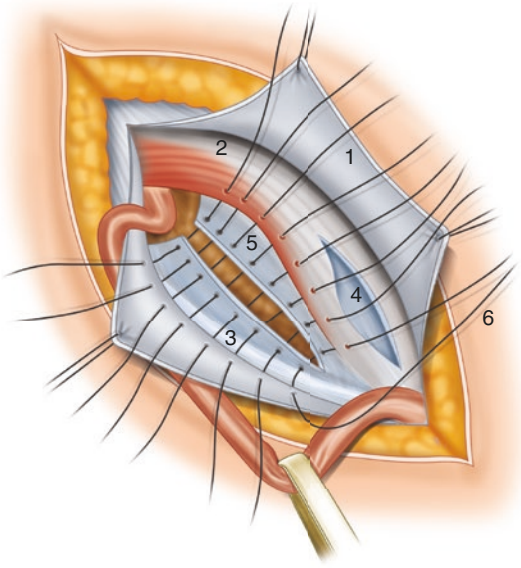

Fig. 29.1 Bassini technique. External oblique aponeurosis (1), internal oblique muscle (2), inguinal ligament (3), relaxing incision (4), transversalis fascia (5), nonabsorbable suture (6)

McVay Cooper's Ligament Repair

McVay repair addresses both inguinal and femoral defects and is the ideal procedure for femoral hernia repairs in contaminated settings whereby prosthetic mesh is contraindicated. Similar to Bassini and Shouldice approaches, the transversalis fascia is incised, exposing the preperitoneal space. The upper flap is mobilized. Cooper's ligament is identified. The upper transversalis flap is sutured to Cooper's ligament, beginning at the pubic tubercle and moving laterally, progressively closing the femoral space, in an interrupted fashion. A transition stitch between the transversalis fascia, Cooper's ligament, and the inguinal ligament occurs at the femoral vessels. The transition stitch allows for the repair to be continued laterally along the inguinal ligament and above the femoral vessels laterally to the internal ring (Fig. 29.2). A relaxing incision (2–4 cm) is made through the anterior rectus sheath vertically, originating from the pubic tubercle [9].

Shouldice

The Shouldice Hospital was opened in 1945 in Toronto, Canada, and is currently located in Thornhill, Canada, with an annual average of 7000 patients. Major tenets of the Shouldice repair include a low body mass index, local anesthesia for nearly all groin operations, and early ambulation (the patient is helped off the operating room table and ambulates to his/her wheelchair) [10].

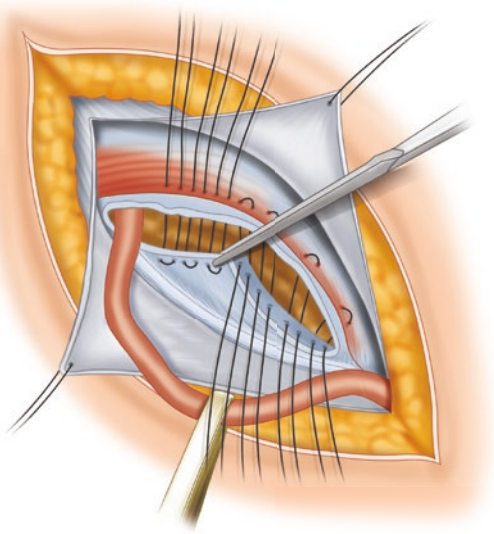

Fig. 29.2 McVay technique. Interrupted suture placement prior to closure

Technique

Procaine hydrochloride 1–2% is commonly used with a maximum volume of 100 cm^3 (2%) or 200 cm^3 (1%). An incision is made along a line joining the anterior superior iliac spine and the pubic crest. The external oblique aponeurosis is identified, and 20–30 cm^3 of local anesthetic is injected deep to the aponeurosis. The external oblique aponeurosis is then divided from the superficial inguinal ring to the deep inguinal ring. The cremasteric fibers are incised longitudinally from the pubic crest to the internal ring. The lateral portion of the cremasteric fibers containing the external spermatic vessels and the genital branch of the genitofemoral nerve are clamped and ligated (Fig. 29.3). An indirect sac will lie on the medial side of the spermatic cord. The sac should be reduced into the preperitoneal space. The posterior wall should then be incised using a scissor by extending an incision from the medial side of the deep inguinal ring to the pubic crest (Fig. 29.4). Opening of the posterior wall will allow for observation of the preperitoneal fat within the preperitoneal space of Bogros [10].

Reconstruction commences using gauge 32 or 34 stainless steel (as used in the Shouldice Clinic) or polypropylene. Two sutures will be required, each contributing two suture lines to the repair. The first suture is anchored at the pubic crest and incorporates the iliopubic tract, transversalis fascia, transversus abdominals, internal oblique muscle, and lateral border of the rectus abdominis (Fig. 29.5). This suture line is moved laterally to the internal ring. At the internal ring, the suture reverses course and moves lateral to medial, creating the second suture line. This second line of suture incorporates the iliopubic tract to the transversalis fascia,

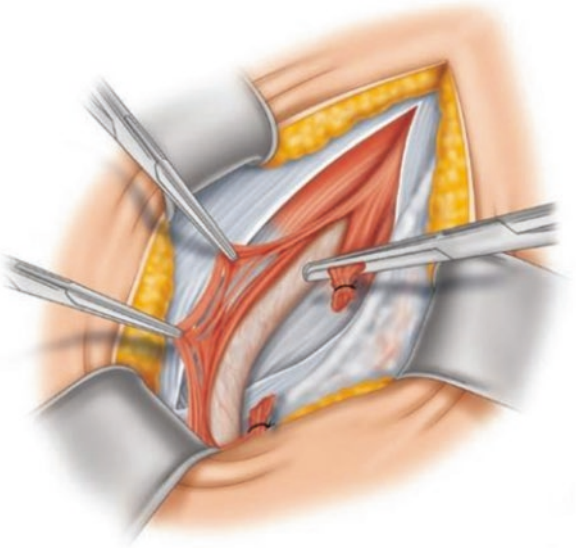

Fig. 29.3 Shouldice technique. Division of the cremaster muscle and genital branch of the genitofemoral nerve

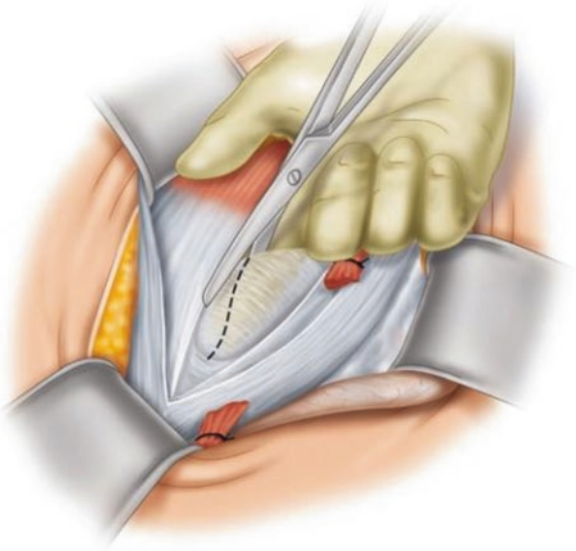

Fig. 29.4 Shouldice technique. Division of the transversalis fascia

transversus abdominis, and the internal oblique muscle. The previously transected cremaster stump can be incorporated in the second line of suture (Figs. 29.6 and 29.7). The suture is advanced to the pubic crest and tied to the first stitch [10].

The second suture will create the third and fourth suture lines. The third line begins at the internal ring and incorporates the transversalis fascia, transversus abdominis, and the internal oblique muscle and the undersurface of the lateral

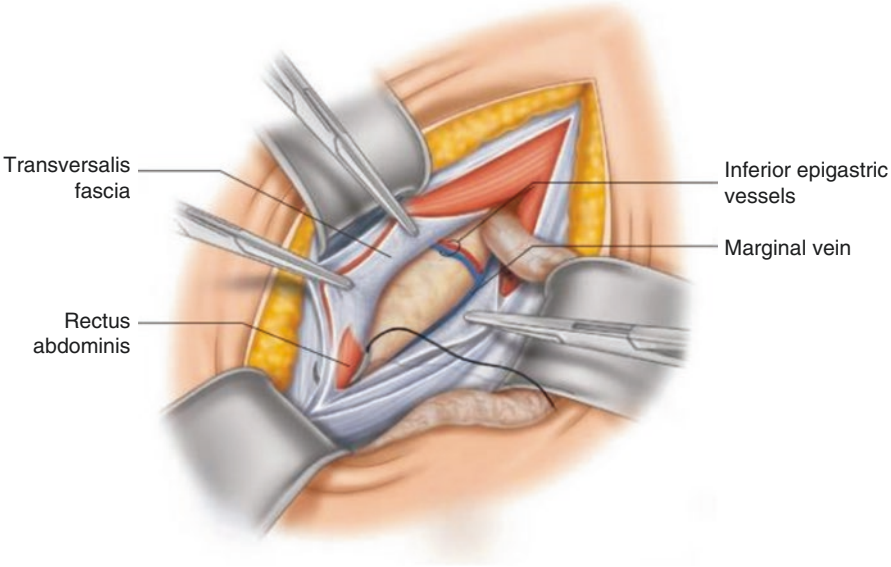

Fig. 29.5 Shouldice technique. Suture Line 1 is anchored to the pubic crest and incorporates the iliopubic tract, transversalis fascia, transversus abdominals, internal oblique muscle, and lateral border of the rectus abdominis

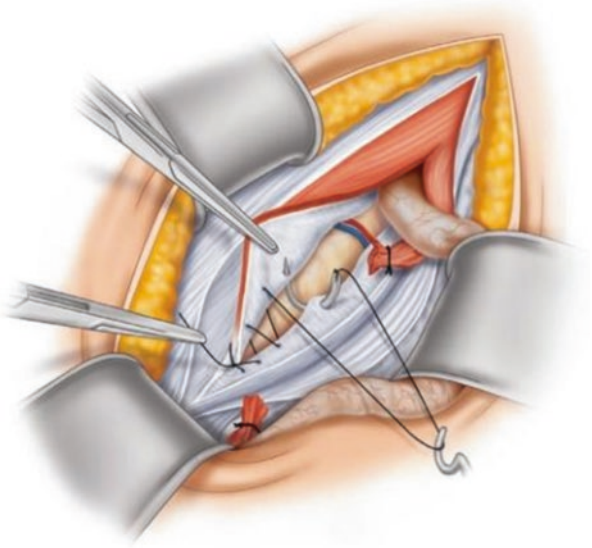

Fig. 29.6 Shouldice technique. Suture Line 1 proceeding laterally toward the internal ring

portion of the external oblique aponeurosis (Fig. 29.8). The suture will move in a lateral to medial direction and reverse course at the pubic symphysis to create the fourth suture line (Fig. 29.9). The fourth suture line will incorporate the undersurface of the external oblique aponeurosis and once again the edge of the transversalis

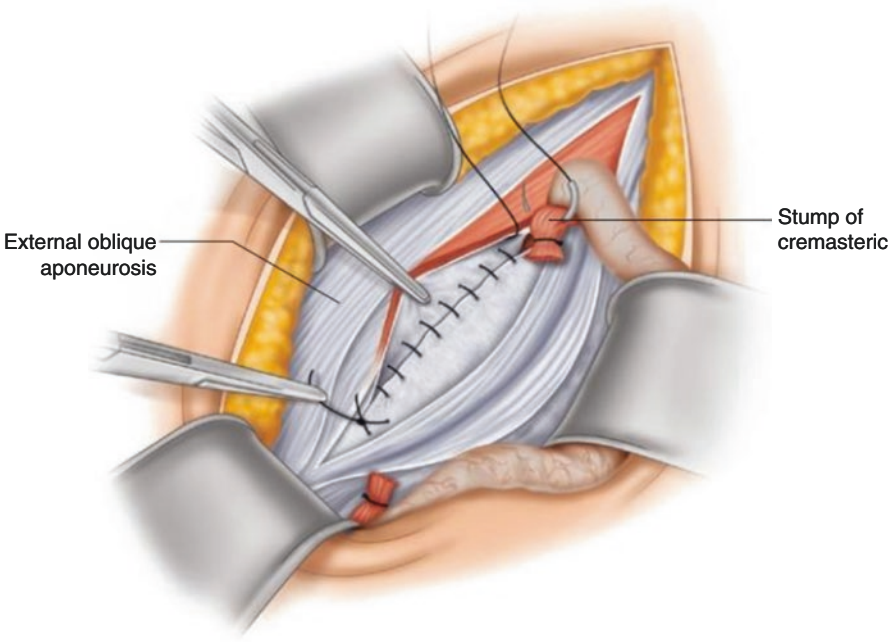

Fig. 29.7 Shouldice technique. Conclusion of suture Line 1 at the internal ring as the lateral cremasteric stump is incorporated below the triple layer

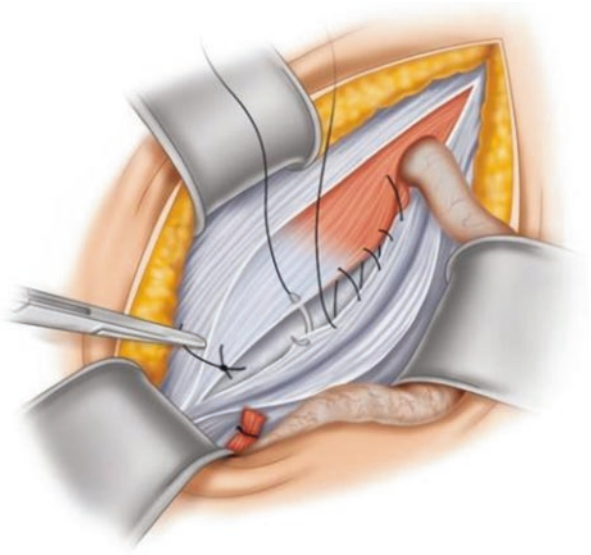

Fig. 29.8 Shouldice technique. Suture Line 2 as it proceeds medially from the internal ring toward the pubic symphysis

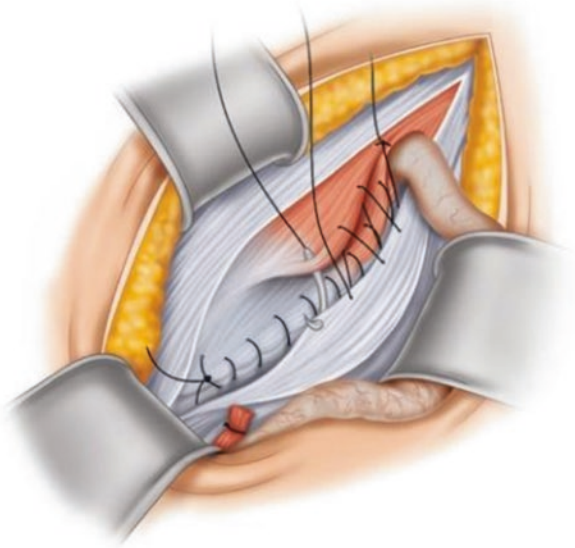

Fig. 29.9 Shouldice technique. Suture Line 3 originating at the internal ring as it proceeds medially toward the pubic symphysis

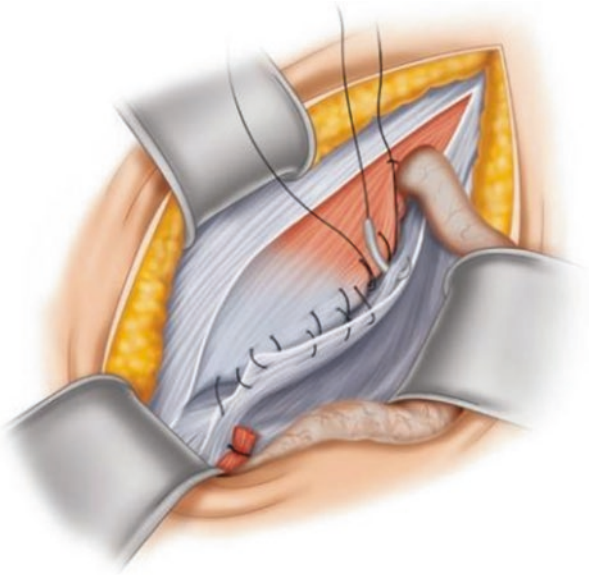

Fig. 29.10 Shouldice technique. Conclusion of suture Line 4 at the internal ring

fascia, transversus abdominis, and the internal oblique muscle layer (Fig. 29.10). The fourth line moves in a medial to lateral direction to the level of the internal ring and tied [10]. The spermatic cord is returned to its normal position. The external oblique aponeurosis is closed using an absorbable suture (we commonly use Vicryl). We close Scarpa's fascia with absorbable suture material, and the skin is closed with staples or a running subcutaneous suture.

Lichtenstein

The procedure can be performed under local, sedation, or general anesthesia, depending on patient variables and the degree of dissection expected [11]. A 5–6 cm skin incision is made from the pubic tubercle and extended laterally along a Langer's line. Dissection is carried down through the subcutaneous tissue and Scarpa's fascia to the level of the external oblique aponeurosis. The aponeurosis is opened in the direction of its fibers, extending down to open the external inguinal ring. The lower leaf of the external oblique aponeurosis is secured and freed from the spermatic cord. At this point, the ilioinguinal nerve should be identified and protected. It can be seen coursing along the anterior surface of the spermatic cord. Care should be taken so as to preserve its investing fascia. The upper leaf of the external oblique fascia is then secured and freed from the internal oblique underneath. This plane should be dissected superiorly to expose the aponeurosis of the internal oblique muscle and identify the iliohypogastric nerve running along its anterior surface within the investing fascia. The plane between the external and internal oblique is avascular, and dissection can be carried out quickly and atraumatically.

The spermatic cord is then bluntly dissected away from the inguinal floor. This dissection is performed within the avascular plane between the cremasteric fibers and the rectus muscle attachments to the pubis. While performing this maneuver, care should be taken to preserve the spermatic vessels and the genital branch of the genitofemoral nerve, which run on the underside of the cord. The plane should be developed approximately 2 cm past the pubic tubercle and proximally to the internal ring. The internal ring should always be explored to identify an indirect defect (Fig. 29.11).

The cremasteric muscle layer should be opened on the anterior surface for approximately 3–4 cm longitudinally at the level of the internal ring. Complete skeletonization of the cord structures is not advised due to the risk of trauma to the vas deferens, spermatic vessels, and nerves. If a hernia sac is identified, it should be dissected away from the cord structures using gentle traction and judicious use of electrocautery. Dissection of the sac is continued until it is free down to the level of the internal ring, where it can then be inverted into the preperitoneal space. Routine ligation of the hernia sac is not recommended due to the risk of increased postoperative pain. Furthermore, it has been demonstrated that non-ligation of the sac does not increase recurrence rates. However, in the case of large, non-sliding scrotal hernia sacs, the sac can be ligated to prevent overzealous dissection that predisposes to ischemic orchitis. This should be performed midway through the canal, and the distal sac should be opened anteriorly to prevent hydrocele formation. If the internal ring is too large, one or two Marcy sutures can be placed to close down the transversalis fascia.

The direct space should always be explored. The direct sac can be inverted back into the preperitoneal space with multiple sutures to the transversalis fascia, taking care not to involve the lower edge of the internal oblique muscle and add undue

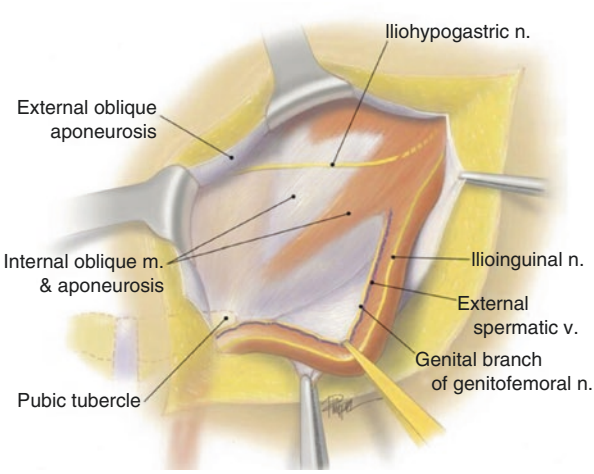

Fig. 29.11 Neuroanatomy of the inguinal canal

tension on the repair. Narrow-necked direct sacs can be closed with a purse string suture. The femoral ring should be routinely evaluated via the space of Bogros through a small opening in the canal floor.

Attention should then be directed to proper placement and fixation of the prosthetic mesh. A monofilament, macroporous mesh should be used due to its resistance to infection. A 7 × 15 cm piece of mesh should be shaped with a tapered medial edge and squared lateral edge. A modification of an inferior triangular extension can be used to cover femoral defects as well (Fig. 29.12).

While gently retracting the spermatic cord superiorly, the tapered medial edge of the mesh should be sutured, with monofilament, nonabsorbable suture, to the rectus sheath just above its insertion on the pubic bone. The mesh should overlap the bone by 1–2 cm to help prevent medial recurrence. One should avoid suturing the mesh to the periosteum of the pubis due to the risk of chronic pain. The lower edge of the mesh is secured, via running monofilament suture, to the inguinal ligament until just lateral to the internal ring. In the case of femoral hernia, the triangular extension of mesh can also be fixated to Cooper's ligament to adequately cover the defect.

A slit is then made on the lateral edge of mesh, leaving two-thirds of the width above the slit and one-third below. The upper tail is then passed under the cord, and the two tails are then brought around to encircle the cord and are secured to each other with a clamp. While retracting the cord inferiorly, the upper edge of the mesh is laid flat on the internal oblique aponeurosis and secured with 2–3 interrupted absorbable sutures. The placement of the superior edge of mesh between the internal and external oblique layers provides sufficient fixation while avoiding potential trauma to the iliohypogastric nerve. If the nerve was exposed during dissection and will be in contact with mesh, the nerve can be resected with proximal ligation to prevent neuroma and then buried in the

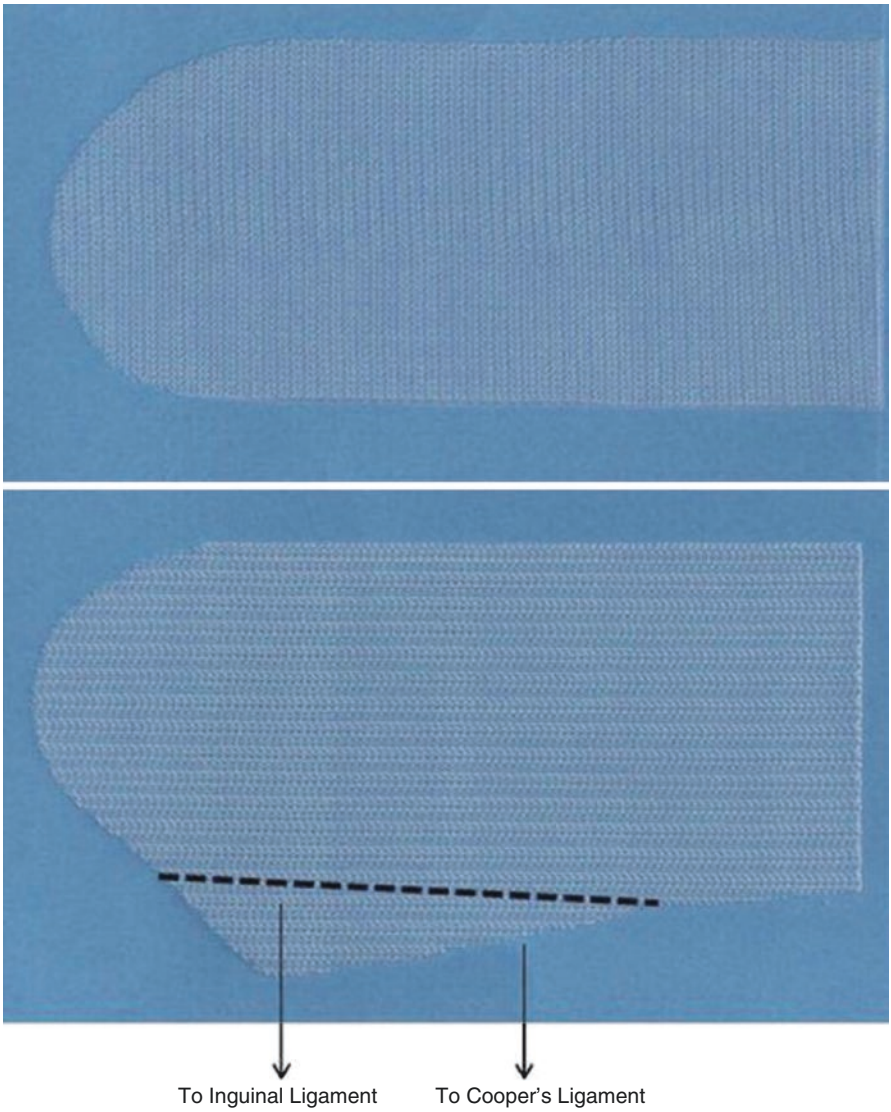

Fig. 29.12 Standard inguinal hernia mesh shape, 7 × 15 cm (top). Modified mesh shape for concomitant femoral defects (bottom)

internal oblique muscle. Once the superior edge is fixed, the two tails are brought by suturing each with monofilament suture to the inguinal ligament just lateral to the inferior edge completion knot. Avoid fixation of the tails to the internal oblique muscle. The external oblique aponeurosis is then closed over the cord and mesh using running absorbable suture. The skin is closed with absorbable sutures or skin staples (Fig. 29.13).

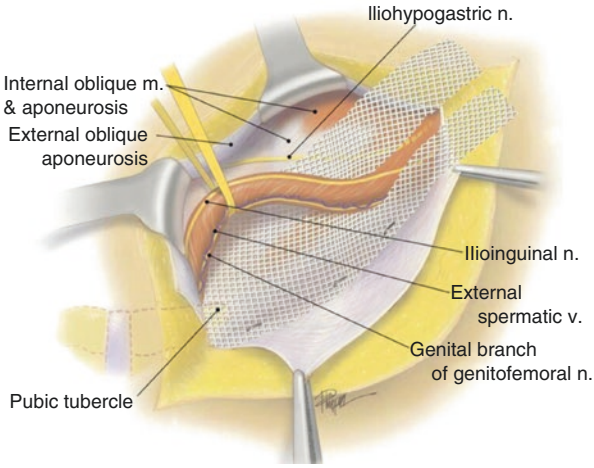

Fig. 29.13 Mesh placement in inguinal floor

Plug-and-Patch

The plug-and-patch technique was originally developed as a modification of the original Lichtenstein technique, adding a mesh plug to help fill hernia defects to promote scarring. The dissection of the groin is identical to the previously described Lichtenstein repair.

The original use of the plug was by Lichtenstein himself, who created a plug by rolling a 2 cm × 5 cm piece of flat Marlex mesh into a mesh "cigar" to be inserted into femoral and recurrent defects. The plug was then held in place using two nonabsorbable sutures. For larger defects, he would use a wider strip of mesh over the first. Upon insertion of the mesh, the plug would uncoil to fill the defect [12, 13].

In 1989, Gilbert described the use of a hand-rolled plug in an umbrellalike configuration. The tip would be inserted through the defect completely and, once released, would expand to cover the defect within the preperitoneal space. The mesh he used was a 2.5 in. × 2.5 in. piece of Marlex mesh [14] (Fig. 29.14).

Rutkow and Robbins went further by developing the umbrella/cone plug [15]. Instead of the fanning out within the preperitoneal space, the cone was inserted so that the widest point of the cone was level with the fascia. The cone was then secured in place with sutures. In addition, they added the use of a flat mesh over the cone plug as a way to prevent a new hernia, but considered this optional to the repair. Between 1989 and 1992, they reported their recurrence rate as being 0.1% (Fig. 29.15).

Rutkow and Robbins worked with the Bard Company to produce the first standardized mesh plug for widespread use [16]. The PerFix plug included eight layers of mesh leaflets to help protect against mesh contraction and migration, as well as

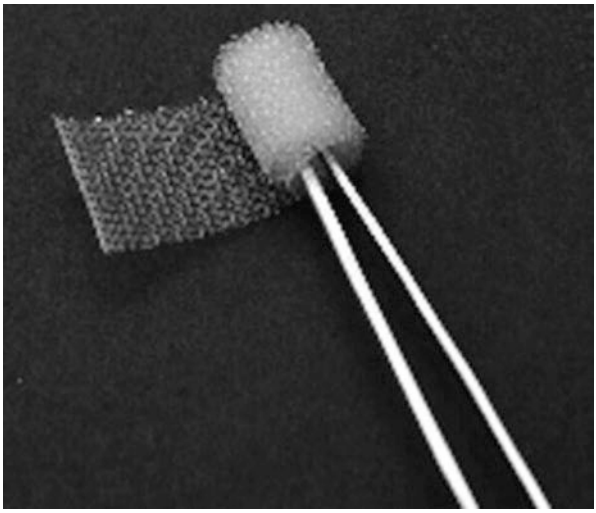

Fig. 29.14 Rolled mesh plug

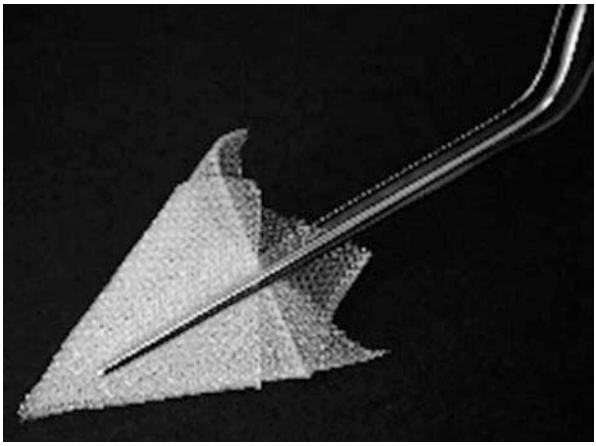

Fig. 29.15 Rutkow-Robbins hand-rolled cone

add bulk to the repair (Fig. 29.16). The plug was secured to the ring of the defect using eight to ten Vicryl sutures. Along with the plug, a 3 cm × 6 cm flat mesh was included for the patch. For small defects, including femoral defects, petals could be removed from the plug to decrease its size. Furthermore, the plug was offered in multiple sizes to customize the repair for patient habitus and defect morphology.

Rutkow and Robbins had effectively streamlined and standardized open inguinal hernia repair. They performed over 3200 mesh plug repairs, including over 1500 PerFix plug repairs. They reported a less than 1% recurrence for primary hernias and 3% recurrence for recurrent hernias. However, once multiply recurrent, they recommended alternative repairs due to a recurrence rate of 9% with the PerFix technique [17]. That said, the PerFix repair remains one of the most common inguinal hernia repairs performed today.

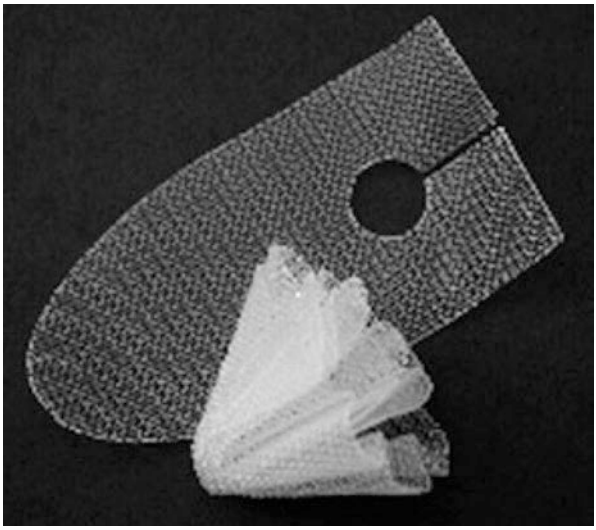

Fig. 29.16 Bard PerFix plug-and-patch

Complications of the Plug-and-Patch

Many complications have been reported with the mesh plug, partially to no fault of the device itself. Many surgeons have modified the technique that was standardized by Rutkow and Robbins, and it can be assumed that many complications are attributable to improper technique. There are multiple reports of mesh erosion and migration [18–20]. Erosion has been reported into the urinary bladder, colon, small bowel, and iliac vessels, causing significant morbidity.

The issue of mesh migration may be attributable to mesh shrinkage. During incorporation and scarring, synthetic mesh will lose approximately 20% of its surface area. When shaped as a cone, this shrinkage may result in up to a 70% reduction in plug volume [21].

Postoperative chronic groin pain is a complex entity whose etiology is difficult to elucidate. Many surgeons have attributed groin pain in some patients to the mesh material itself. However, it is our belief that the inguinal dissection and placement of the mesh is the main determinant of postoperative groin pain. For example, the protection of at-risk nerves within their investing fascia while performing a dissection with minimal tissue trauma will help protect the majority of patients from postoperative groin pain.

Post-herniorrhaphy Inguinodynia

Post-herniorrhaphy inguinodynia can be divided into nociceptive pain and neuropathic pain. Nociceptive pain is caused by tissue injury or inflammatory reaction. These signals originate at nociceptors in the tissues themselves and travel to the brain via A-delta and C-fibers. The use of local anesthesia also helps control the production of nociceptive molecules.

Neuropathic pain is caused by direct nerve injury. These injuries include myelin separation, axon crystallization, and other structural changes [22]. They can be caused by direct mesh-to-nerve contact or nerve entrapment from sutures, tacks, or folded mesh. The proper positioning of mesh and the protection of at-risk nerves within investing fascia help protect the nerves from iatrogenic injury and mesh contact, which can lower the risk of inguinodynia from 6–8% to 1% [23].

Outcomes of Open Techniques

Despite a drop in recurrence rates among tension-free repairs, concerns regarding the use of prosthetic material have been raised. Chronic groin pain (>3 months) or inguinodynia is a clinically challenging complication following hernia repair [24]. Attempts at limiting postoperative pain have been made. A self-gripping mesh, which eliminates the need for sutures or tacs, demonstrated a decrease in short-term pain (<1 year postoperatively) [25, 26]. However, an increase in recurrences following the use of self-gripping meshes has been reported [24, 27, 28].

Due to the widespread use of hernioplasty, tissue repairs have fallen by the wayside in most surgical residency programs. However, in certain settings, such as a contaminated surgical field or patient objection to mesh, the knowledge of various tissue repair techniques and their outcomes is paramount. Currently, data supports the Shouldice technique as the tissue repair of choice, compared to Bassini and McVay. The recurrence rate of a Shouldice repair has been typically reported to be in the range of 1–5% in well-selected patients [29–31]. A 2009 Cochrane review demonstrated a lower pooled recurrence rate for the Shouldice repair compared to other tissue repairs (odds ratio, 0.62; 95% CI 0.45–0.85) [31]. Comparison of the Shouldice technique to mesh repairs demonstrated a longer postoperative hospital stay (not significant) for the tissue repair and significantly reduced recurrences (3.6% vs. 0.8%) among the mesh repairs [32].

Overall, the best outcomes for a Shouldice repair are typically achieved in the hands of those well trained in the technique. Malik et al. evaluated 235,192 Ontario residents who underwent primary elective inguinal hernia repair at either a hernia specialty hospital (Shouldice Hospital) or a general hospital. Patients at the Shouldice Hospital had an age-standardized recurrence risk of 1.15% (95% CI 1.05–1.25%) in contrast to recurrence of 4.79% (95% CI 4.54–5.04%) at the highest volume general hospitals [33]. Compared to the Bassini and McVay repairs, the Shouldice technique also remains superior. The recurrence rate for Bassini repairs has been quoted as high as 21% [34]. A prospective study comparing the use of Bassini and McVay tissue repairs with a follow-up range of 10–208 months demonstrated a recurrence rate of 2.67% in the McVay group and 2.89% in the Bassini group [34]. Due to the higher recurrence rate following the Bassini and McVay repair, the Shouldice technique remains the preferred method of tissue repair [1].

Synthetics, such as polypropylene, ePTFE, and polyesters, were heralded as a major breakthrough in the tension-free repair of inguinal hernias with the promise to

limit recurrence. More recent evidence brought to light complications associated with synthetic mesh such as pain [35]. Mechanism of pain at the tissue-mesh plane has been demonstrated as nerve growth within the weaves of meshes which then become entrapped, leading to pain [36], and the possible need for mesh explantation.

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MIS Techniques: Lap TAPP and rTAPP

30

Edmundo Inga-Zapata and Fernando García

Introduction

The transabdominal preperitoneal approach (TAPP) was described more than 25 years ago by several surgeons [1], and although the main principles are kept, there are several variations and details worth mentioning [2]. Diverse technical details have emerged from formal research and surgical social media [3, 4] that are important for successful outcomes.

While the TEP technique goes directly to the preperitoneal space, the TAPP technique reaches the same preperitoneal space after first entering the peritoneal cavity. Despite TAPP being considered as more invasive and taking longer to perform than TEP [5], it is surgically straightforward when it comes to understanding and learning the anatomy and the complexity of the repair; for this reason many surgeons see it as the first choice when learning MIS hernia repair [6, 7].

Over the last three decades the TAPP technique has evolved and has been refined, with successful innovations including central aspects like fixation and mesh types, but also creative and interesting (although never widely adopted) like combined approach [8], dissection aided by water [9], preperitoneal anesthetic injection to decrease pain [10], and self-expanding mesh [11]. Therefore, we decided to include the more relevant steps proposed by many groups to reduce recurrences and minimize complications.

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Preoperative Aspects

The patient is placed supine with arms tucked. The surgeon stands on the side opposite the hernia with the monitor near the feet of the bed facing the surgeon. The TAPP repair has been performed with all the types of anesthesia: general, regional [12, 13], and even with only local anesthesia plus sedation [14]; nonetheless, the most common practice is to use general anesthesia [15] because it guarantees more relaxation of the abdominal wall (Fig. 30.1).

Laparoscopic hernia repairs are less dynamic than other abdominal major laparoscopic interventions; nonetheless, it is important to secure the patient well to the operating room table so that rotation and Trendelenburg can be used and to allow gravity to move bowel cephalad and allow for better exposure of the intra-abdominal groin region, particularly important in TAPP in comparison to TEP.

Although conservative surgeons probably favor a Foley catheter to guarantee bladder emptiness as a mean to secure and facilitate dissection of the space of Retzius, there is the counterpart emerging position toward no longer use Foley catheter by default in all patients, but only optionally in cases expected to take longer than usual [16] and simply prevent the patient to void the bladder right before surgery [17, 18].

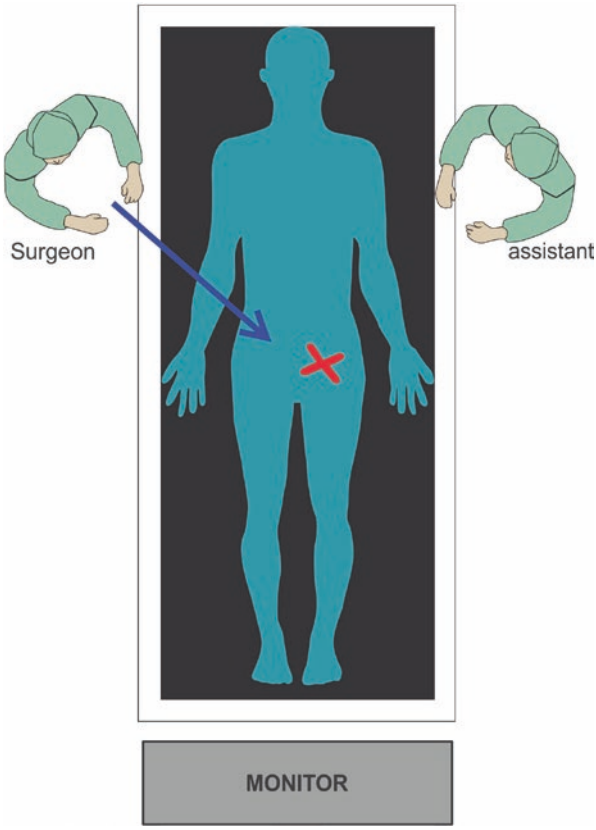

Fig. 30.1 Patient position and OR distribution. Arms tucked and surgeon contralateral to hernia site

Operative Aspects

Port position will be according to surgeon training and experience. One way to set up the ports is by looking for triangulation of the instruments, having the camera port placed at the umbilicus (to take advantage of the umbilicus) and two other lower profile ports lateral to the camera, to the right and left, for both hands.

Another common port configuration is in the classical TEP setup, in vertical midline position, having the camera at the umbilicus, and the two other ports below and in line downward. Although the surgeon will work with instruments in parallel (sacrificing triangulation), they will find it may be more ergonomic (Fig. 30.2).

The surgical gesture entails grasping, pulling, scissoring, traction, and counter-traction. The goal is a proper dissection, and most surgeons use an atraumatic grasper in the nondominant hand and scissors or an atraumatic gaper in the dominant hand. A tacker or needle driver is also used for peritoneal closure and often for mesh fixation. Minor bleeding is controlled by cauterizing and can be complemented by pressure with a gauze and better if humidified to more easily and gently wiping the film blood cloths out [19, 20]. Aspiration is barely needed, but it is convenient to have an aspirator always ready.

Development of the Peritoneal Pocket

After port placement and inspection of the contralateral groin, the peritoneum is incised, following an imaginary line starting close to the anterior iliac spine, horizontally toward the midline. Different styles for opening the peritoneum have been

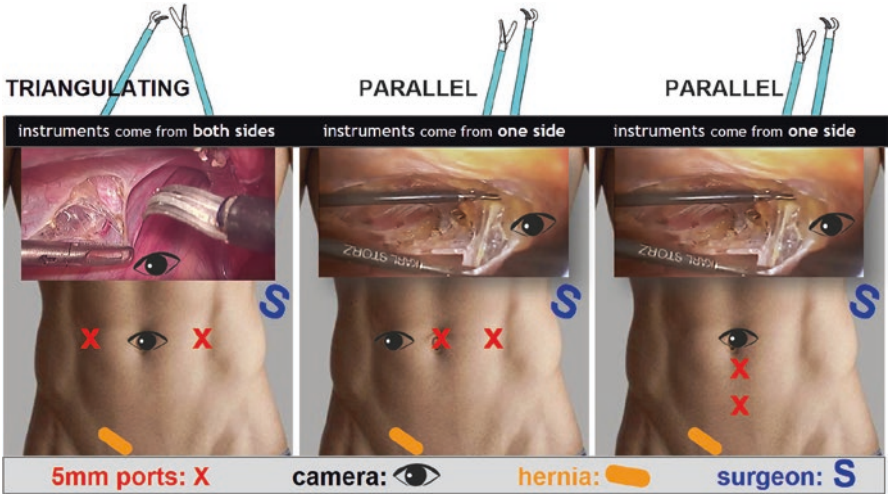

Fig. 30.2 Port positions: the classic triangulating position (*left image*) and some variants (*middle and right images*)

described: transverse, curved cephalad convex, and an "s"-shaped incision [21]. Many favor the transverse incision. The peritoneum is incised, and the peritoneal space is developed in large part with blunt dissection combined with sharp or electrocautery dissection by scissor or hook (Fig. 30.3).

As the peritoneum is opened and the preperitoneal space developed, a thorough knowledge of the anatomy is essential. The well-known critical view of safety (CVS) for cholecystectomy [22] has its sister in the critical view of the myopectineal orifice (CVMPO) [23], widely accepted and described in a previous chapter. The principles of the CVMPO were developed after years of research and academic exchange in surgical social media. Adherence to these principles ensures identification of critical anatomical landmarks and a successful endoscopic TAPP repair, whether laparoscopic or robotic (Fig. 30.4).

The development of the peritoneal flap from the anterior superior iliac spine region to the umbilical ligament region may be interrupted in the middle by the cord and its parietal peritoneum if there is an indirect sac. Because it takes time, patience, and precision to develop a peritoneal opening in a bloodless fashion, it is helpful to start the dissection laterally, where the space is more easily created by means of gentle traction and countertraction. The pubic tubercle and Cooper's ligament are

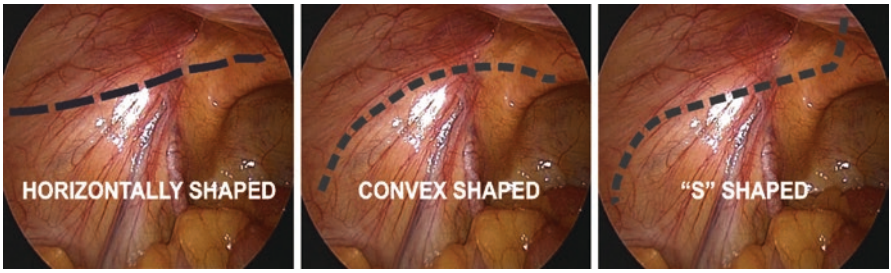

Fig. 30.3 Types of peritoneal openings: transverse (horizontally), convex shaped, and "s" shaped

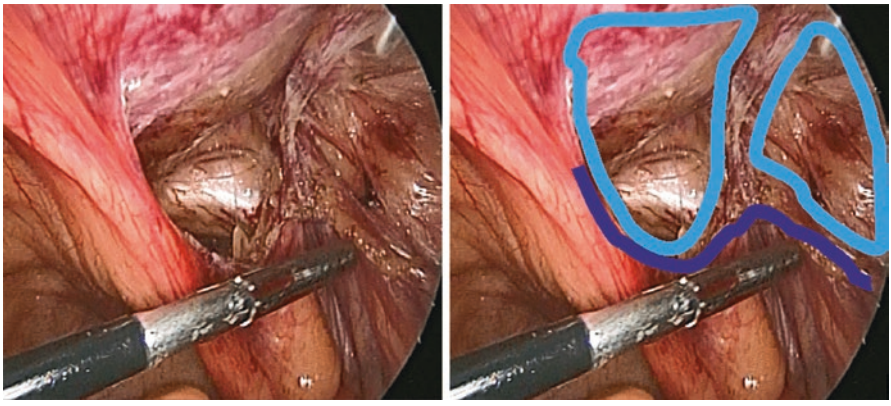

Fig. 30.4 Two spaces of dissection (blue) with a midstructure and line of peritoneal edge

found medially and used as landmarks for dissection. The first main danger zone to pay attention to is the connection between the upper and lower venous systems called the corona mortis [24]. About this anatomical landmark, it is interesting to see that the less insufflating pressure you work with, the more visible the corona mortis becomes [25].

Gentle grasping of the peritoneum to pull it away from adherent fat with concomitant sweeping of the areolar attachments and countertraction with the opposite hand/instrument is key to dissecting out the spermatic cord, vas deferens, and any indirect sac. The medial (not median) umbilical ligaments could be but do not necessarily need to be transected and are easily pushed away when dissecting. Options to treat the sac include simple peeling off of the cord until a point where our cephalad peritoneal traction does not move the cord.

For very large indirect sacs, amputation of the sac with adequate parietalization and closure of the peritoneal defect is an option. Special care needs to be given to cord lipomas whenever they arise because they might be a reason for patient discomfort or a feeling of a persistent hernia; therefore, removal is advised.

Unlike the TEP approach where the type of hernia ends up being determined only after a careful dissection during the procedure itself, the TAPP approach offers immediate and workless identification of direct and indirect hernias on both sides, being this probably its main advantage over the TEP technique. Nevertheless, this diagnostic accuracy does not readily identify the third common type of groin hernia, femoral. For this, special attention is needed with focused dissection in the area below Cooper's in the vicinity of the iliac vein where—again—we usually will find lipoma like tissue covering the femoral entrance and not necessarily a classic peritoneal sac.

In general, lipomas and lipoma-like tissues are usually found at the medial umbilical ligaments, the base of indirect sacs, deep in indirect sacs, and outside indirect sacs attached to the cord structures (Fig. 30.5).

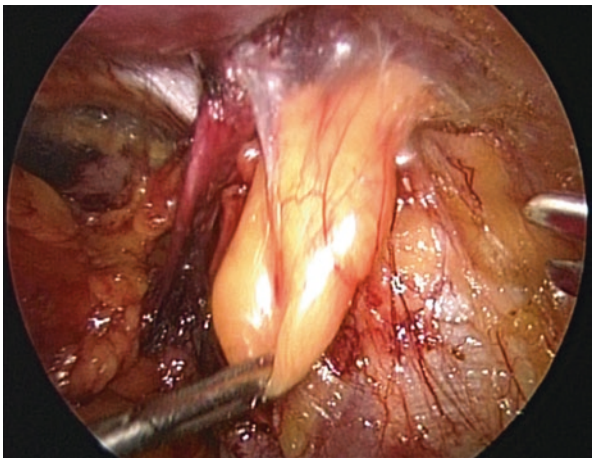

Fig. 30.5 Cord lipoma found on TAPP

The goal of the TAPP technique is the creation of a wide peritoneal pocket for mesh placement. The mesh should cover the MPO and extend to the psoas posteriorly to the rectus and transversus abdominis anteriorly and approach the anterior superior iliac spine laterally and the midline and space of Retzius medially. Care must be taken to prevent any peritoneum from slipping behind the mesh and being a cause for early recurrence. Desufflation and reinsufflation may alert the surgeon to this occurrence. Hemostasis is assured before placing the mesh, which is introduced rolled in its long axis, and grasped with an atraumatic forceps with an average size of 15 cm × 10 cm. It is upon the surgeon to tailor the size according to patient habitus. Classic plain or knitted 3D meshes seem not to make a clinical difference and both are good options.

Mesh Placement and Fixation Aspects

The mesh is placed taking care to completely cover the myopectineal orifice. Once placed with caution not to have folds at any border, the decision of fixation or not arises. Many fixation options have been proposed in the history of TAPP technique; nonetheless, based on the available level of evidence, we can say that leaving the mesh without fixation could be reasonable too as long as the following specifications are met: the defect is indirect, the defect is direct and small, or the defect is femoral [26–28].

The fixation options are invasive and noninvasive type. Invasive fixation options include tackers, staples, and stitches. Noninvasive fixation options for TAPP include vacuum suction [29] and glue-like options available today, fibrin and cyanoacrylate, the latter not yet commercially available in the USA but available in other countries. Both are suitable for TAPP repair.

One of the fixation options for TAPP, staples (i.e., *Endo Hernia*, by Medtronic), has mostly been abandoned by surgeons due to increased pain and risk of nerve entrapment. Tackers are another invasive option for TAPP and are preferred by some surgeons for mesh fixation, and many use them selectively for larger hernias, specially big direct defects. If tackers are chosen, there are many design configurations (helical and not helical) made in two types of material (permanent and absorbable) both used with quite similar clinical success in TAPP. The safest place to tack is in the Cooper's ligament over the pubic bone, in its mid- to external/lateral area, avoiding the region where the corona mortis is found.

Where to fire the tacker—aside from Cooper's ligament—remains open to discussion, but never under an imaginary line below the Cooper's ligament, and never in the triangle of doom due to risk of neurovascular damage [30]. It is helpful to use counterpressure on the abdominal wall against the tip of the tacking device when applying tacks in the soft tissue (Fig. 30.6).

Noninvasive fixation of the mesh for TAPP includes glue-like materials. In the USA fibrin glue is the most readily available (though expensive) option. In most other countries, cyanoacrylate is the adhesive option that is available and is quite inexpensive. Besides the fact that these glue-like materials show overall

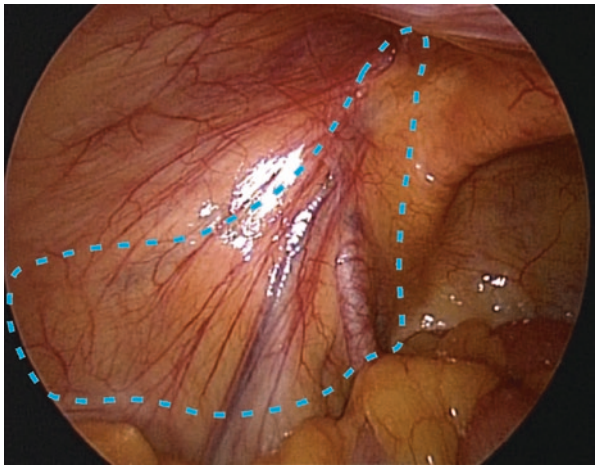

Fig. 30.6 Places not to fire tackers or staples

complications and recurrences not significantly different in comparison to conventional tacker or suture fixation, both seem to offer somehow less painful results [31–33].

For a TAPP technique, these glue-like products are instilled through a cannula inserted through one trocar, parallel to the trocar, or simply percutaneously drop by drop over the points where fixation is desired or through a spraying device [34]. Fixation by suturing can be done with similar considerations for safety as in the other methods. The added effort time needed for this task is probably the main reason it is being avoided by many surgeons.

Because all invasive fixation methods raise the concern of neurovascular damage, interest does exist for self-fixating meshes. Some are already being used in TAPP cases in many places worldwide. This self-fixating mesh is simply placed as a conventional mesh, with the advantage of saving time but not necessarily costs. Long-term data is yet needed for comparison.

The final step in the TAPP technique is the closure of peritoneal flap, and there are several ways described in almost 25 years of TAPP history: closure by conventional running suture, closure by interrupted sutures, closure by tackers, closure by staples, and closure by glue-like products. Recent efforts have been made to find whether or not it is fully necessary to close the peritoneal flap in TAPP by any of the listed means, and although preliminary results show that it may also be possible to leave the flap without closure [35], further clinical research about this is needed, being consequently the thorough closure of peritoneal incision and any big peritoneal tear the only real and formal recommendation [36]. Considering the recent onset of litigation worldwide and specially in the USA regarding mesh, many now avoid intraperitoneal mesh placement or exposure.

Probably worth mentioning—but not classically part of the TAPP technique—might be the aspiration of remanent preperitoneal gas once the flap is closed, which has been proposed as a way to reduce urinary retention and to serve as another fixating mode [37]. It can be done by inserting a cannula/aspirator through the already

closed peritoneal opening until the remanent CO2 is aspirated and deflation of the bulged peritoneum is completed [29] which may also serve to fixate the mesh in place, as previously cited.

Finally, drains are never recommended in TAPP inguinal hernia repairs. Hemostasis should be assured before placing the mesh and before closing the peritoneal flap.

Failure of the TAPP: Recurrence

A number of complications could arise from the TAPP technique including vascular, visceral organ, and nerve injuries. They are rare, and recurrence is the most frequent. Early in the history of laparoscopic TAPP repair, recurrences were reported and attributed to poor technique [38].

After 25 years of the laparoscopic TAPP approach, the same reasons for failure have been pointed out by almost every publication and surgical academic society worldwide: inadequate size of the mesh, poor closure of the peritoneal flap, and inadequate dissection for creation of the pocket. These are often related to an incomplete knowledge of the anatomy of the region due to insufficient training or inexperience.

Several recommendations can be made from accumulated worldwide experience:

1. Standardize your own steps for the technique.
2. Plan to dissect until finding all the landmarks and obtaining the CVMPO.
3. Proceed with very gentle movements in order to avoid bleeding, and then you will always have a clear view of every structure in the operative field.
4. Use a 15 × 10 cm mesh (minimum) to cover the MPO with broad overlap.
5. Fixate the mesh in every case of big direct hernias.
6. Meticulously close the peritoneum.

Robotic TAPP (rTAPP)

Performance of TAPP robotically (rTAPP) has been adopted by many surgeons. Benefits include tridimensional high-definition (3D HD) vision, wristed instruments with greater ease of suturing, and improved ergonomics for the surgeon. Lower pain scores have also been reported by some as well as improved outcomes and lower complication rates for obese patients [39]. When performed well, recurrence rates should be equivalent between open, laparoscopic, and robotic repairs.

Preoperative Considerations

Patients undergoing rTAPP should be able to undergo general anesthesia. Relative contraindications might be prior to retropubic dissection, radiation, a history of pelvic trauma, or infections. Unlike laparoscopic TAPP technique, there is a shorter

learning curve to adoption of rTAPP, probably because surgeons utilize previously acquired laparoscopic expertise. Familiarity with the anatomy of the groin region, the anterior abdominal wall, and how the preperitoneal space transitions to the retroperitoneal space are critical both for low recurrence rates and avoidance of complications. Anatomy, dissection, mesh placement, and peritoneal closure have been discussed in the preceding section.

How robotic surgery might influence the TAPP technique becomes evident when it comes to one of the pending issues of laparoscopic TAPP repair: what to do with large direct defects. The skills needed to close them as in open surgery are not an easy task by pure laparoscopy, but thanks to the 7 degree of wrist movements that robotics offers, some now finally advocate closure of these defects with far more precision than laparoscopy [40, 41].

Operative Setup

For inguinal hernias with both the DaVinci-*Si* and DaVinci-*Xi* systems, three arms are typically used. For both systems the peritoneal cavity can be accessed with an optical port, Veress technique or via an open Hasson-type entry. An 8.5 mm camera port at the umbilicus (or supraumbilical 15 cm from the pubis in patients of short stature) is common. Instrument ports are placed 8–10 cm lateral and 4–6 cm cephalad to the camera port bilaterally. Before docking, the patient is positioned supine with arms tucked and in 20° Trendelenburg. A special bed (Trumpf 7000 dV) is available for the DaVinci robot that allows for synchronized simultaneous movement of the DaVinci-*Xi* robotic arms with the patient table. In the absence of this, table movement can only be done while undocked (Fig. 30.7).

Numerous instruments are available for performing robotic TAPP hernia repairs. However, each new instrument incurs a cost. Minimizing the number of instruments results in lower cost.

Some frequently used instruments include a grasper (Cadiere forceps, fenestrated bipolar, or ProGrasp), cautery (hot scissors or hook bovie), and a sewing instrument, large needle driver, or mega suture cut. Surgeon experience and preference will guide choice. For the DaVinci-*Si* system, more time and attention has to be paid to the table used and to patient cart positioning and docking. For unilateral hernias the patient cart can be docked 45° over the side of the hernia, and this can also be used for bilateral hernias. However, for bilateral hernias some surgeons prefer pelvic docking which can also improve arm reach for very obese patients.

TAPP with other Surgical Robots

It is important to note that this brief reference to the rTAPP technique is based on the DaVinci robot (Intuitive Surgical, Inc.). There is another surgical robot used in Europe *(Senhance*, by TransEnterix, Inc.), which has recently gotten FDA clearance for the American market and similar allowance in some Asian countries as well. This new robot has different features and technical considerations when compared

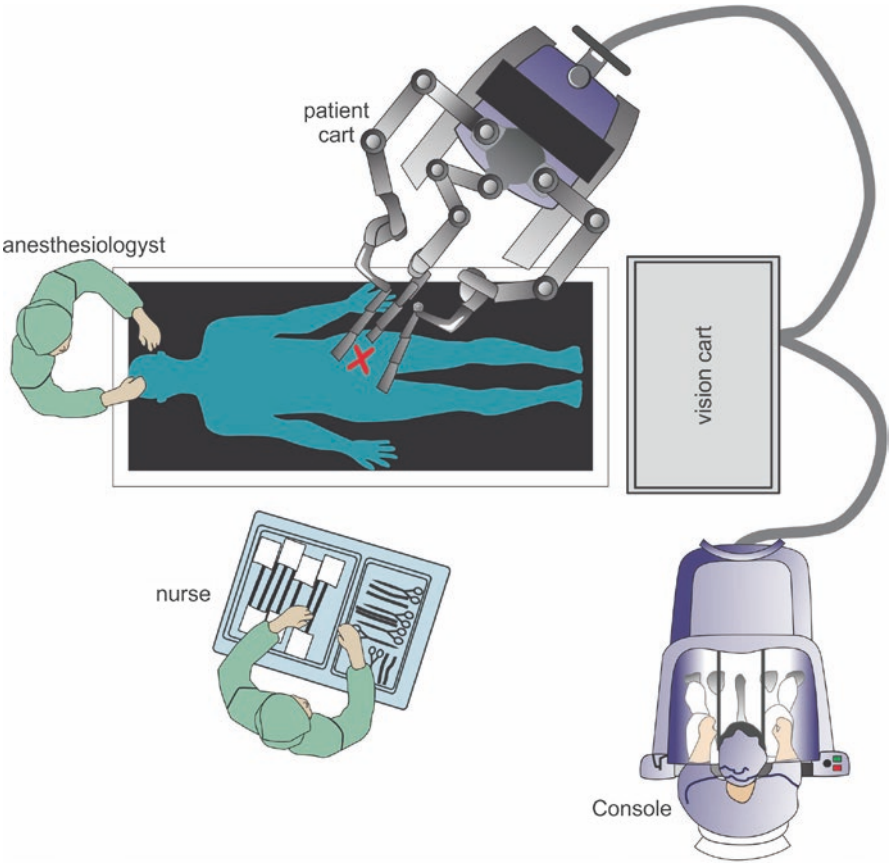

Fig. 30.7 Robotic TAPP setup (DaVinci-*Si*)

to the DaVinci robot models, essentially technically conceptualized in conventional laparoscopy. The rTAPP procedure has been successfully accomplished with the Senhance robot in Europe, but no large series has yet formally been reported to date. Other robotic platforms, multiport, and some of them single port will be soon available. It remains to be seen how robotic surgery evolves.

Conclusion

After a quarter century, the TAPP technique has kept its essence: tackling the problem posteriorly, at its origin. The evolution of the TAPP technique has led to technical recommendations to reduce complication and recurrence rates. While data from the Americas Hernia Society Quality Collaborative accrues, the benefits of laparoscopic vs. robotic TAPP will be better defined for both patients and surgeons, never forgetting that robotic costs need to approximate laparoscopic costs to foster wider adoption of robotic TAPP.

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MIS vs. Open Inguinal Hernia for Uncomplicated Unilateral Hernia

31

Fadi Balla and Ankit D. Patel

Introduction

An inguinal hernia is one of the most commonly encountered general surgical pathologies in the world. Approximately 27% of males and 3% of females will develop one in their lifetime [1]. The surgical treatment for inguinal hernias continues to evolve, with open herniorrhaphy with tension-free mesh repair (TFR) as the current gold standard across the world. With laparoscopy and now robotic surgery, minimally invasive methods have been accepted as suitable alternatives to the open repair. However, in the past, these minimally invasive methods were primarily reserved for recurrent hernias and bilateral hernias since they offered two unique benefits—working in previously unviolated anatomic planes and visualization of both inguinal areas in the same procedure. Unfortunately, more expensive equipment is needed for minimally invasive methods and may not be universally available. As a result, debate continues over the optimal repair method for uncomplicated unilateral inguinal hernias. In experienced hands, recurrence rates are similar in both open and laparoscopic repair (<2%) [2]. Therefore, the decision-making process has shifted toward consideration of other post-procedural outcomes such as postoperative pain, time to return to daily activities, and early and late complications. Previous studies have shown that inexperience with laparoscopic inguinal hernia repair was associated with higher rates of postoperative complications [3, 4]. We aim to evaluate these factors and provide recommendations for the practicing general surgeon based on current and practical data.

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Open Repair

Inguinal hernias have been recognized in medical writings as early as 1550 BC in the Papyrus Ebers. These writings describe both the appearance of inguinal hernia as well as rudimentary treatments. Greco-Roman scholars, including most notably Galen, began to lay the foundation for understanding the pathogenesis and treatment of hernia. Galen described the origin of hernias as rupture of the peritoneum and overstretching of the overlying fascia and muscles. These ancient scholars understood and described the importance of hernia sac ligation, preservation of the testis, and hemostasis which essentially laid the foundation of modern hernia repair concepts [5]. Edoardo Bassini is generally recognized as the first of many pioneers in modern hernia repair in the late 1800s. He was the first surgeon to prospectively follow his patients for postoperative outcomes including recurrence and infection. Over 5 years, he was able to prospectively gather data on 216 total patients [5]. Using the Bassini technique of "triple layer" closure (transversalis fascia, transversus abdominis muscle, and internal oblique muscle) to the inguinal ligament, he was able to achieve historically low recurrence rates (4%) and infection rates (5%). Over the next 100 years, several other methods of inguinal hernia repair were pioneered, but all were founded on the basis of tension-free repair using natural tissue planes. In the late 1980s and early 1990s, the advent of synthetic mesh changed the world of hernia repair immensely. Lichtenstein and colleagues popularized the routine use of mesh for tension-free repair of both complicated and uncomplicated hernias [6]. This has been shown in numerous studies to be superior to tissue repair with regard to most measurable data. It should be noted, however, that tissue repair at specialty centers such as the Shouldice Institute may offer similar recurrence rates to TFR [7].

The Lichtenstein repair is considered the gold standard TFR. A 5–6 cm skin incision starting from the pubic tubercle extending laterally following Langer's line should provide adequate exposure to both the pubic tubercle and internal ring. Sharp dissection is carried down through Scarpa's fascia to the external oblique aponeurosis. The external oblique aponeurosis is opened along the direction of its fibers and divided through the external inguinal ring. The hernia sac is then identified, separated from the cord structures (in the case of an indirect hernia), and reduced into the abdominal cavity along with its contents. Usually a polypropylene mesh is trimmed to cover the floor of the inguinal floor, covering both indirect and direct hernia defects. The mesh is sutured to the anterior rectus sheath 2 cm medial to the pubic tubercle, and this suture is then continued laterally securing the caudal edge of the prosthesis to either side of the pubic tubercle and the inguinal ligament to the level of the internal ring. A slit is then made at the lateral end of the mesh creating two tails. The tails are passed around the spermatic cord recreating the internal ring. The tails are sewn together allowing for adequate space for the passage of the spermatic cord. The external oblique aponeurosis is then closed in a running fashion, followed by the subcutaneous tissue.

Multiple other TFR techniques are described with excellent results and are described in detail elsewhere in this manual. For the purposes of this chapter, we will consider all TFR mesh-based repairs together when compared to minimally invasive techniques.

Laparoscopic Repair

Initial reports of laparoscopic inguinal hernia repair by Ger in 1982 described using a clip applying device to close the internal inguinal ring in dogs. Further progress in the description of laparoscopic repair described mesh "packing" into defects laparoscopically in order to fill the defect from within the peritoneal cavity. These ultimately failed as reinforcement of the abdominal wall was not achieved and did not address the inherent weakness of the orifice [8]. Today's repairs are accomplished in the preperitoneal plane through either transabdominal or totally extraperitoneal approaches.

In the transabdominal preperitoneal (TAPP) approach, the peritoneal cavity is insufflated, and the preperitoneal space is entered by incising the peritoneum and bringing down a flap. The hernia sac and its contents are reduced from within, separated from the spermatic cord (in the case of an indirect hernia), and a mesh is laid within the preperitoneal space covering indirect, direct, and femoral hernia defects. The peritoneal flap is then reapproximated with a tacking device or suture leaving the mesh within the preperitoneal space.

In the totally extraperitoneal (TEP) approach, the preperitoneal space is insufflated posterior to the rectus muscle and anterior to the posterior rectus sheath. This exposes the hernia defect without violating the peritoneal cavity. Once this has been accomplished, a similar procedure of reduction of hernia content and separation from cord structures is undertaken, and placement of mesh is used to cover the hernia defects in the preperitoneal space.

Robotic repair of inguinal hernias has increased in popularity in recent times. The principles of robotic repair mimic those of TAPP but offer the advantage of robot-driven dexterity and hand-sewn peritoneal flap closure. Cost may be increased with robot utilization, but the benefit of hand-sewn peritoneal flap closure merits consideration when choosing modality for repair. Avoidance of tacking devices may potentially avoid chronic pain syndromes and inadvertent bladder or vascular injury [9]. The use of self-gripping mesh or glue during these repairs may also provide less pain and equivalently secure placement of the preperitoneal mesh [10].

Intraperitoneal onlay mesh repair (IPOM) is also described but is not used in practice routinely given the direct interface between intraperitoneal content and mesh, potential undersizing of the mesh, and difficulty in fixing the mesh appropriately. The theoretical advantage of such a repair would be to avoid dissecting in the preperitoneal space; however, the inherent risks of IPOM repair in this area outweigh the benefit of violation of preperitoneal anatomy. It should be noted, however, that should a surgeon find themselves with inadequate peritoneum to cover a preperitoneal mesh, there are synthetic materials (e.g., Vicryl mesh) that are suitable for interface between prosthetic hernia mesh material and intraperitoneal viscera.

Repair vs. Watchful Waiting

Most patients with symptomatic inguinal hernias should be offered repair [11]. For patients with asymptomatic or minimally symptomatic inguinal hernias, the answer is less clear. Watchful waiting has been previously advised for asymptomatic or

minimally symptomatic uncomplicated inguinal hernias. However, two randomized controlled trials investigating immediate repair vs. watchful waiting show that this strategy may simply delay the inevitable repair of a hernia secondary to pain. A UK study showed 72% crossover rate into surgical repair at 7.5-year follow-up, and a North American study showed 68% crossover rate into surgical repair at 10-year follow-up [12–15]. The main symptom prompting repair in both studies was increasing pain. Furthermore, studies have shown that watchful waiting does not increase frequency of complications from repair of larger fascial defects or progression of associated comorbidities [16]. Emergent hernia surgery for strangulation carries increased risk of complications, but only a total of three patients between both studies presented with incarceration. Two of those patients had their hernias reduced and repaired electively, while the other required emergency repair. These studies also showed that those who eventually crossed over did not experience greater complications than those in the immediate repair group. These findings lay out benefits of both watchful waiting and immediate repair. Surgeons should discuss the risk-to-benefit profile for each individual patient with an asymptomatic or minimally symptomatic hernia. While the natural course of inguinal hernia seems to be progression to lifestyle-limiting pain in the majority of patients, there are a large number of patients who remain asymptomatic or minimally symptomatic even at 7–10-year follow-up [12–15]. Socioeconomic factors such as ability to return to work and cost of repair should be considered as well. Activity restrictions with known inguinal hernias may affect employment. In these trials, several risk factors have been shown to predict whether or not a patient will eventually ask for surgery due to pain. These are pain with strenuous activity, chronic constipation, married patients, patients with prostatism, and ASA classes 1–2 [17]. Recently published clinical practice guidelines from the *New England Journal of Medicine* state that "watchful waiting is an acceptable strategy" for asymptomatic or minimally symptomatic hernias despite the high likelihood of eventual need for surgery [11]. These guidelines are consistent with recommendations offered by multiple other hernia societies and surgical groups [18].

Pros and Cons of Laparoscopic vs. Open

Recurrence and the Learning Curve

Recurrence is the single most significant postoperative outcome after hernia repair. The landmark Veterans Affairs Cooperative Study questioned the benefits of laparoscopic repair for primary inguinal hernias as their recurrence rates were nearly double in the open TFR group [19]. When further examined, however, it was found that surgeons who had performed more than 250 laparoscopic repairs had recurrence rates that were not significantly different from the open group. Furthermore, perioperative complications such as pain, seroma, and surgical site infections were similar when stratified by surgeon experience. Thus, the utility of comparing laparoscopic vs. open repair with this study is limited given the mixed results upon further

analysis. Later studies have lent credence to the idea of experience-driven results. Langeveld et al. showed that more experience in laparoscopic inguinal hernia repair decreases recurrence rates as well as perioperative morbidity [20]. Numerous meta-analyses have also shown similar recurrence and perioperative morbidity rates between laparoscopic and open mesh as well as non-mesh repairs [21–25]. The question therefore becomes "when is a surgeon experienced enough to safely perform a laparoscopic repair?" This question has been addressed for TEP repairs on unilateral uncomplicated inguinal hernias. Suguita et al. showed in 2017 that operative time stabilized and plateaued after the 65th repair [26]. No complications were observed in their study after the 35th repair. This study, however, had significant limitations in that it only studied one surgeon and had limited long-term follow-up, and the surgeon studied had carried out advanced laparoscopic training prior to the period studied as a first assistant. This would seem to indicate that the true learning curve number is likely higher than 65 patients. Laparoscopic inguinal hernia repair is not frequently performed by surgical residents, and thus in all likelihood, graduating residents have not transcended the learning curve at graduation [27]. Using the robot may decrease this number, but little data exists regarding the learning curve associated with robotic inguinal hernia repair; some anecdotal information may point to an early learning curve. One study showed that operative times are significantly longer with robotic repair but decreased with surgeon experience [28]; more prospective studies are needed to assess this assertion.

Pain

For both acute and chronic pain, numerous studies have shown LIH repair to be equivalent to or better than TFR [29–33]. Chronic pain is defined as pain lasting longer than 3 months post procedure [11]. The etiology of this pain is multifactorial but can be caused by neuropathic mechanisms, scar tissue formation, reaction to foreign tissues, or chronic infection, among other things. Treatment with anti-inflammatory medications is a reasonable first-line treatment for acute pain to lessen the inflammatory component of these etiologies. Chronic unrelenting neuropathic-type pain may be treated with neurectomy or mesh excision if entrapment is the source [11]. Of all the variables to discuss when comparing LIH to open TFR, pain is consistently shown to be the most improved after LIH [9]. Furthermore, studies have shown that open TFR itself was an independent risk factor for chronic pain [31]. The European Hernia Society has stated that "when only considering chronic pain, endoscopic surgery is superior to open mesh" [34].

Early Complications

LIH repair has a higher rate of visceral and major vascular injury intraoperatively when compared to open. Although rare, this could present a strong point of consideration when deciding between open TFR and LIH repair. Major visceral and

vascular injuries are seen more often with TAPP approach vs. TEP. Higher risk to bowel and vasculature is inherent with TAPP given the surgical approach, but this does not preclude TEP from such issues [35]. Other potential early complications from TAPP repair are early bowel obstruction from adhesion to exposed mesh and mesh dislodgement from improperly placed fixation tacks. The advantage to TEP approach is avoidance of the peritoneal space which effectively eliminates potential bowel injury. Surgical site complications such as wound infection and hematoma are more frequent in open TFR [21–25].

Bilaterality and Revisional Surgery

Laparoscopic approach offers the benefit of visualizing both groin areas in the same procedure, especially with TAPP. This is an advantage of laparoscopy as in 10–22% of cases, a contralateral hernia is discovered during surgery for unilateral hernia [36, 37]. Interestingly, in up to 20% of patients, a preoperative diagnosis of bilateral inguinal hernia was found to be incorrect, and these patients were only found to have unilateral hernias when examined laparoscopically [38]. While simultaneous bilateral open repair is feasible and has historically good results, laparoscopic repair may offer the benefit of decreased operative time and quicker return to daily activities.

Previous approaches to hernia repair should influence the surgeon's modality of choice for recurrent hernia repair. If the previous repair was done in the anterior space, a laparoscopic preperitoneal approach would offer equivalent recurrence rates in an undissected plane. If the previous approach was done in the preperitoneal space laparoscopically, a conventional anterior open approach would offer the repair with the lowest complication rate.

Robot

Robot-assisted repair of inguinal hernias (rTAPP) offers greater degrees of freedom with movement and better three-dimensional visualization during repair. The ability to work with high-resolution visualization and improved dexterity offers the ability to perform more complex dissections. Using robotic assistance, inguinal hernias are repaired in a similar fashion to TAPP but with the advantage of hand-sewn closure of the peritoneal flap versus using tacks. Recent studies have shown robotic inguinal hernia repair is safe and favorable compared to LIH repair [39]. Operative time is longer for the robot, and there was a slight tendency toward higher intravenous narcotic use perioperatively. However, operative time decreased as surgeon's experience increased [28]. Like LIH repair, there is a learning curve associated with robotic inguinal hernia repair, but the exact number at which point a surgeon gains proficiency is unknown. Operative times are increased in robotic repair primarily as a result of hand-sewn closure of the peritoneal flap. This theoretically decreases the risk of chronic pain postoperatively as no fixation tacks are being used to hold the

mesh or peritoneum in place [40]. Furthermore, the avoidance of tacking devices limits the risk of inadvertent vascular or visceral injury. Disadvantages of the robot include lack of tactile feedback and mainly cost [41]. With little data to support earlier return to work or decreased postoperative pain compared to laparoscopy, the primary advantage of robotic repair may be the ability to perform more complex inguinal hernia repairs without conversion to open including large scrotal components or revisional procedures. It may also allow more surgeons to offer a MIS approach as both laparoscopic TEP and TAPP can be ergonomically challenging in certain patients. As with any new technology, however, the challenges facing the widespread use of robotic assistance with inguinal hernia repair are the need for high-quality data, cost-effective implementation, and transcendence of the learning curve [41, 42]. Many of these issues will be addressed soon as many studies are currently being performed.

Recommendations

Watchful Waiting

Adult male with asymptomatic or minimally symptomatic unilateral inguinal hernia

Open Repair

Large scrotal hernia or incarcerated hernia
Patient unable to tolerate general anesthesia or Trendelenburg positioning
Recurrent hernia when initial hernia performed laparoscopically
Increased risk for prostate cancer or need for future prostatectomy
Prior lower midline laparotomy

Laparoscopic or Robotic Repair

Uncomplicated unilateral hernia at high-volume center
Recurrent hernia when initial hernia performed open
Bilateral inguinal hernias
Women with inguinal hernias
Uncomplicated femoral hernia

Laparoscopic vs. Open Repair

Surgeon comfort with procedure
Patient preference

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TAPP vs. TEP vs. rTAPP: What Does the Evidence Show?

32

Alexandra Argiroff and Diego Camacho

Introduction

For a growing number of hernia surgeons, laparoscopic inguinal hernia repair is the go-to operation, even for primary unilateral hernias. It has similar recurrence and complication rates as the open repair [1] and less postoperative pain with faster recovery time [2]. So how do you choose the appropriate minimally invasive technique?

Laparoscopic surgery for repair of inguinal hernias with mesh has been used for over 25 years, since it was first described in 1991 by Shultz [3]. The technique originally trialed was the transabdominal preperitoneal approach or TAPP. Two years later, a second and currently commonly used technique was described by McKernan—the totally extraperitoneal (TEP) approach [4]. There is a plethora of evidence describing the two operations and comparing the laparoscopic inguinal hernia repair to the traditional open repair with mesh. The two surgical techniques, appropriate use, complications, and comparison of laparoscopic to open inguinal hernia repair are discussed in previous chapters in this book.

The newest minimally invasive technique, or the robotic transabdominal preperitoneal (rTAPP) inguinal hernia repair, also has a growing volume of data in the literature, albeit preliminary and descriptive in most cases. The rTAPP is discussed in a previous chapter as well.

Once the surgeon and patient have decided to proceed with a minimally invasive surgery to repair his or her inguinal hernia, which method is the best? Is there a clear front-runner? Or is one technique better in a particular patient or clinical scenario?

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The aim of this chapter is to look at the current data and evidence available comparing the TEP and TAPP techniques for inguinal hernia repair with mesh, as well as a comparison of the laparoscopic repairs to the rTAPP.

While there are several studies, including randomized controlled trials and meta-analyses, comparing open and laparoscopic inguinal hernia repairs, there is less data directly comparing the two laparoscopic techniques. There are even fewer studies comparing laparoscopy to the newer rTAPP. In addition to landmark papers, the most current published data will be discussed in this chapter to see what evidence is available to help choose the right minimally invasive technique for both the surgeon and patient.

TEP vs. TAPP

What Type of Evidence Is Currently Available?

First, we will present what evidence is currently published, along with overall results from those articles. Then each end point will be examined separately with data in support of TEP or TAPP.

While not numerous, there are several head-to-head studies between TEP and TAPP in the literature, with significantly more articles published in the last 10 years. The 2005 Cochrane review comparing TAPP to TEP identified one prospective randomized controlled trial (RCT) and eight comparative studies [5]. In 1996, Schrenk et al. compared TEP, TAPP, and Shouldice technique among 86 randomized patients [6]. They found less immediate postoperative pain in the TAPP group when compared to TEP; however, there were similar operation times, complications, and return to work. There was one recurrence in the TAPP group, but it was not statistically significant ($p = 0.6$). This study had low power with only 24 patients in the TEP and 28 patients in the TAPP group.

Many of the articles included in the 2005 Cochrane review occurred during the learning curve for laparoscopic hernia repair [5]. There has been a burst of new studies published since then. In fact, a 2013 meta-analysis of RCTs comparing TEP and TAPP [7] found seven total RCTs [6, 8–13] for 516 patients and 538 hernia defects to analyze. An eighth RCT was published just after the meta-analysis in the same year [14]. In the 2013 meta-analysis, Antoniou et al. found shorter recovery time but higher operative morbidity for the TEP group.

The meta-analysis also observed a high rate of morbidity in general for both laparoscopic procedures (11.9% for TEP, 24.8% for TAPP), which the authors mostly attributed to two of the seven trials. Pokorny et al. included postoperative use of analgesics as a morbidity, and when this was removed, the operative morbidity decreased drastically to a more commonly accepted rate. Dedemadi et al. also found a high rate of operative morbidity, but this study exclusively looked at repair of recurrent hernias, which carries higher risks of morbidity [15].

However, only one of the studies strictly compared TEP to TAPP [13], while the rest compared laparoscopic to open and included a subanalysis of the two

laparoscopic groups [6, 8–12]. Many of the articles had significant weaknesses, and only three of the seven trials had a Jadad score of 3–4 [7]. Overall, there were no long-term differences between TEP and TAPP. The authors concluded the current data was insufficient to recommend one over the other, and the decision should depend on the expertise of the surgeon. More rigorous randomized studies are needed to make a more definitive conclusion [7].

Two of the more recent prospective randomized trials include a much larger number of patients than the 52 patients in the 1996 Schrenk trial. In 2011, Krishna et al. published data from their one medical center from the first 100 randomized patients and compared intraoperative data, postoperative complications, pain, and recurrence during an average follow-up period of 29.5 months [13]. They found a statistically significantly lower pain score for the TEP group when compared with the TAPP group, which likely correlated with the higher satisfaction scores for the TEP group. They found no other major differences, and there were no major complications or recurrences in either cohort.

In a follow-up study in 2013, Bansal et al. evaluated data from those first 100 patients plus 3 more years of surgeries, for a total of 314 patients randomized to TEP ($n = 160$) and TAPP ($n = 154$) [14]. In addition to the primary end points from the first study, they also looked at long-term outcomes, such as chronic groin pain and quality of life. Like the first 100 patients, this study showed increased postoperative pain for the TAPP group. There were also similar rates of chronic groin pain and comparable long-term quality of life at 3 months postoperative [14].

In addition to the RCTs and the meta-analysis, there have been several comparative studies and population-based analyses published since the 2005 Cochrane review. This includes two from the Swiss Registry [16, 17] and two from the Herniamed database [15, 18], each with a large number of patients.

There is conflicting data among all of the studies, so we will look at each end point separately and evaluate the most current evidence. We will focus on evidence from the 2013 meta-analysis above and the most recent RCTs comparing TEP to TAPP for primary hernia. We also look at results from the prospectively collected data of patients who underwent laparoscopic inguinal hernia repair in the Herniamed Registry (17,587 patients) and Swiss Association of Laparoscopic and Thoracoscopic Surgery (4552 patients) [17, 19].

Complications

In the early experience with laparoscopic techniques for inguinal hernia repair, TAPP had higher rates of more severe complications, including visceral injury, vascular injury, and postoperative hernia [20]. However, that was during the beginning of the learning curve for laparoscopic inguinal hernia repairs. In the last 10 years, severe complications are now rarely reported for either technique.

For minor postoperative complications, the results are mixed. The 2013 meta-analysis found higher rates of operative complications with TEP [7], but the individual complications were not delineated in the article. Likewise, the data from the

Bansal et al. RCT and Swiss Registry population-based data reported by Gass et al. observed increased rates of short-term complications with TEP [14, 17]. In both studies, seroma was the most common complication associated with TEP.

Conversely, Köckerling et al. reported increased rates of complications for TAPP from the Herniamed Registry. Again, seroma was the most common complication by far [19]. This data corroborated similar findings from the 2005 Cochrane review that also found statistically significantly higher rates of complications with TAPP [5].

Of the more current articles, only Gass et al. make the recommendation for TAPP over TEP secondary to complication rate. As the majority of the complications reported are seromas treated conservatively, many of the authors continue to recommend that the surgeon choose the operation he or she has the most experience with.

Operative Time

The varied operative time from each study reflects the different training, experience, and comfort level of individual surgeons and centers with TEP and TAPP. For example, the Butler et al. trial observed significantly increased operating time with TEP [9], while the more recent Bansal et al. trial reported longer times for TAPP [14].

Again, the Herniamed and Swiss registries found opposite results, with the former reporting longer operating times for TAPP [19] and the latter for TEP [17]. No statistically significant difference was found between the two groups in the meta-analysis [7].

Postoperative Pain

It is widely accepted now that laparoscopic surgery has reduced early postoperative pain compared to open repair [21–24]. Is there an advantage to one laparoscopic technique over the other in regard to short-term pain? Krishna et al. found reduced acute pain the TEP group, which correlated with increased patient satisfaction scores [13]. The follow-up study by Bansal et al. confirmed that finding with a larger powered RCT [14]. The authors attributed the increased pain for the TAPP group to closure of the umbilical port fascia.

Other studies either did not report immediate postoperative pain or found the pain scores to be equivalent between TEP and TAPP [7].

Chronic Groin Pain

There are few well-structured studies on long-term outcomes comparing the two laparoscopic inguinal hernia repairs. Bansal et al. reported equal rates of chronic groin pain for TEP and TAPP with a median follow-up time of 36.5 months

(range, 3–60 months; 90.4% follow-up rate at 12 months, 23% at 4 years) [14]. Although the average follow-up time in the meta-analysis varied widely (3 months to 3 years), they also did not find a statistically significant difference [7].

Recurrence

The great "best groin hernia repair" debate ultimately is looking for the lowest risk of recurrence. The landmark "VA study" in 2004 by Neumayer et al. showed a significantly higher recurrence rate after laparoscopic repair (10.1%) versus open repair (4.9%) with an odds ratio of 2.2 [25]. This study was largely criticized for the wide range of experience of the surgeons correlating to vastly different complication and recurrence rates within the study. Systematic review and several meta-analyses have since deposed that conclusion, and in skilled hands, there is no difference in recurrence rates between open and laparoscopic repair (McCormack 2003; McCormack NICE 2004) [1].

Likewise, after the 1990s, there is no data showing a significant difference in recurrence rates between TEP and TAPP, although there is a trend for more recurrence in TAPP repairs. In RCTs, Bansal et al. reported one recurrence in the TAPP group [14], and Butler et al. reported two recurrences in the laparoscopic arm but did not specify whether they were from the TEP or TAPP repairs [9]. Interestingly, the Herniamed and Swiss registries did not report recurrences as an end point in their articles on primary hernia repair [17, 19].

Quality of Life

Only one RCT attempted to compare long-term follow-up with laparoscopic inguinal hernia patients using quality of life as a primary end point. Using the quality of life assessment proforma (SF-36), Bansal et al. evaluated 214 of the 314 randomized patients immediately preoperatively and at 3 months postoperatively. While they found an improvement in quality of life before and after surgery (with regard to mental health, social functions, physical functions, etc.), there was no statistically significant difference between TEP and TAPP [14].

Cost

The setup in the operating room for TEP and TAPP is similar with regard to consumable operating room supplies. In their trial, Butler et al. found a slightly higher cost for TEP compared to TAPP. Their technique for TEP used a balloon dissector, which at that time cost $125 and was the reason for the slightly higher cost [9]. On the other hand, Bansal et al. did not use a balloon dissector to create a preperitoneal space, and cost was the same for both groups in that trial [14]. Overall, the Antoniou et al. meta-analysis also showed equivalent costs, although operative technique differed among the RCTs [7].

TEP vs. TAPP for Recurrent Hernia

Recurrent inguinal hernias account for 10–15% inguinal hernia surgeries [25]. Laparoscopic repair for recurrent inguinal hernias is the go-to operation for repairing a recurrence from an open repair. Studies, including a meta-analysis in 2013, actually showed improved results—lower incidence of wound infection and shorter sick leave for patients—with laparoscopic technique for recurrences [26]. It even observed no difference in other complication rates or operation time between open and laparoscopic surgery. It did not differentiate between TEP and TAPP.

Most papers comparing TEP and TAPP looked exclusively at primary inguinal hernias, and recurrent hernias were excluded from the studies. However, three recent articles looked at TEP versus TAPP for recurrent hernias alone. One RCT published in 2006 by Dedemadi et al. randomized patients to TAPP (n = 24), TEP (n = 26), or Lichtenstein (n = 32) repair and confirmed the advantages of a laparoscopic approach [8]. While the analysis of the data compares each laparoscopic repair to the open group, and not TEP to TAPP directly, the comparison can be extrapolated, and there was no statistically significant difference in operative time, acute pain, recovery time, complications, or recurrence.

In population-based data, the Swiss Registry reported that although there was significantly higher intraoperative complication rate and operative time for TEP, the postoperative complications and conversion rates to open surgery were similar to TAPP [16]. There was no long-term follow-up in this group, so late recurrence or complication rates are unknown, and the authors did not recommend one operation over the other for repair of recurrent groin hernia.

The Herniamed database evaluated laparoscopic repair of recurrent inguinal hernias in 2246 patients. TAPP was associated with increased rate of postoperative seroma (odds ratio 3.1), but that did not mean a higher rate of reoperation [18]. Overall, there was no major difference between the two methods.

Robotic Transabdominal Preperitoneal (rTAPP) vs. TAPP

Although there are descriptions of robot-assisted TEP for inguinal hernia repair [27], the vast majority of robotic inguinal hernia repairs are done in a TAPP fashion. The description and outcomes for rTAPP are discussed in another chapter. Furthermore, the use of the robot for concurrent inguinal hernia repair with other procedures (prostatectomy, etc.) and those outcomes has been described by several case series; however, that will also be discussed in another chapter.

However, there are currently only two case series in the literature that directly compare traditional laparoscopic hernia repair to rTAPP. Both series retrospectively examine a single surgeon's experience at his institution for consecutive laparoscopic and rTAPP procedures.

Just published in July 2017, Kudsi et al. compared a single surgeon's experience with laparoscopic TEP vs. rTAPP. A total of 118 patients underwent a hernia repair, and the operative time and complication rates were nearly identical in both

groups [28]. One factor to consider is that robotic teams may differ in their efficiency, and surgeon's experiences may vary considerably. Nevertheless, many hernia surgeons primarily perform TEP, so data from this comparison is important. And although it is the largest series examining data from a surgeon's transition from TEP to rTAPP, they are two different operations. A more appropriate way to compare laparoscopy with robot-assisted inguinal hernia repair would be to look at TAPP vs. rTAPP.

Published in the Journal of Robotic Surgery in 2016, Herman et al. looked at 63 consecutive patients who underwent a laparoscopic TAPP (n = 24) or rTAPP (n = 39) [29] between 2012 and 2014. They showed longer operative time (77.5 vs. 60.7 min, p = 0.001), and room time was longer for the rTAPP group. Pain scores (2.5 vs. 3.8) and recovery room time were significantly less for the robotic group.

They also compared operative cost, looking at direct cost (disposables), net revenue, and contribution margin (facility net revenue minus direct costs). Direct cost and contribution margin were less for the laparoscopic TAPP; however, the authors did not find the difference significant enough to recommend one over the other without further investigation [29]. Capital costs, including the robotic system and laparoscopic towers, were not included in the cost analysis. This is a major flaw in the study as a single robotic platform can cost up to 2.5 million dollars, not including annual maintenance fees. As more robotic platforms come to market, this will likely decrease. Furthermore, the cost per case is difficult to determine based on a onetime purchase and depends on the case volume at that center.

Overall, there is a dearth of evidence in looking at rTAPP vs. laparoscopic hernia repair, and future research is needed to make a recommendation.

Conclusion

While a lot of data and results were presented in this chapter, much of it is conflicting when comparing TEP to TAPP. There is no strong or reproduced evidence looking at laparoscopic inguinal hernia repair versus rTAPP. All three operations are safe and feasible, and one may have more utility than another in a particular situation. For instance, with a larger, more difficult to reduce inguinal hernia, the TAPP adds the ability to examine the peritoneal contents. If a robot-assisted ventral hernia repair is being performed at the same time, it is safe and reasonable to repair an inguinal hernia at the same time with rTAPP. Ultimately, it still remains a case-by-case basis, and the most important factor with outcomes is surgeon comfort with an operation.

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Minimally Invasive Surgical Techniques for Inguinal Hernia Repair: The Extended-View Totally Extraperitoneal Approach (eTEP)

33

Jorge Daes

Introduction

The surgical technique used to repair an inguinal hernia should be tailored according to the surgeon's characteristics and local and regional resources as well as the characteristics of the patient and hernia [1]. We believe that surgeons should be proficient in an anterior mesh technique (Lichtenstein), a posterior open mesh technique, a non-mesh alternative, and most laparoscopic techniques to offer an individual patient the option he or she needs and selects and be able to convert from one technique to another when necessary.

Laparoscopic techniques are clearly superior with respect to decreased postoperative pain and chronic pain and a faster return to normal activities [2, 3]. Laparoscopic techniques are probably also cost-effective and very safe when performed by experienced surgeons, especially those performing high-volume surgery. Under appropriate conditions, the laparoscopic approach is a first-line approach for the repair of inguinal hernias [1].

Since 1996, we have favored the totally extraperitoneal (TEP) approach for the repair of nearly all inguinal hernias [4]. In theory, the TEP approach is the closest to the ideal technique because it avoids entry into the abdominal cavity, lessening the risk of visceral injuries and trocar site hernias and the need for opening and closing the peritoneum [5, 6]. This approach may even allow hernia repair under either local anesthesia with intravenous sedation or regional anesthesia [7, 8] and provides an optimal visualization of the hernia and surrounding structures. The TEP approach is based on the time-tested Rives-Stoppa technique. However, the classical TEP technique has several drawbacks, including a limited space for dissection and mesh placement, restricted port placement, intolerance to pneumoperitoneum, and difficulty in teaching and learning

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the technique. These disadvantages may explain the low implementation of this technique outside the circle of experts. This background inspired us to expand the space beyond the limits of the Retzius and Bogros spaces and, based on the anatomy of the abdominal wall, develop a workable extraperitoneal space from almost any point on the anterior abdominal wall. We have termed this modified protocol the enhanced or extended TEP approach (i.e., the eTEP approach). We have standardized this technique since its first publication in *Surgical Endoscopy* [9–11].

Anatomical Basis

Steady progress in the understanding of the anatomy and physiology of the abdominal wall has enabled the creation of novel and effective hernia repair procedures. Posterior component separation with transversus abdominis release (TAR), endoscopic component separation, and the eTEP technique are some recent examples.

The eTEP technique has allowed for a better understanding of the extraperitoneal space outside the boundaries of the Retzius and Bogros spaces. The extraperitoneal space can be developed from anywhere in the area of the rectus sheaths (Fig. 33.1)

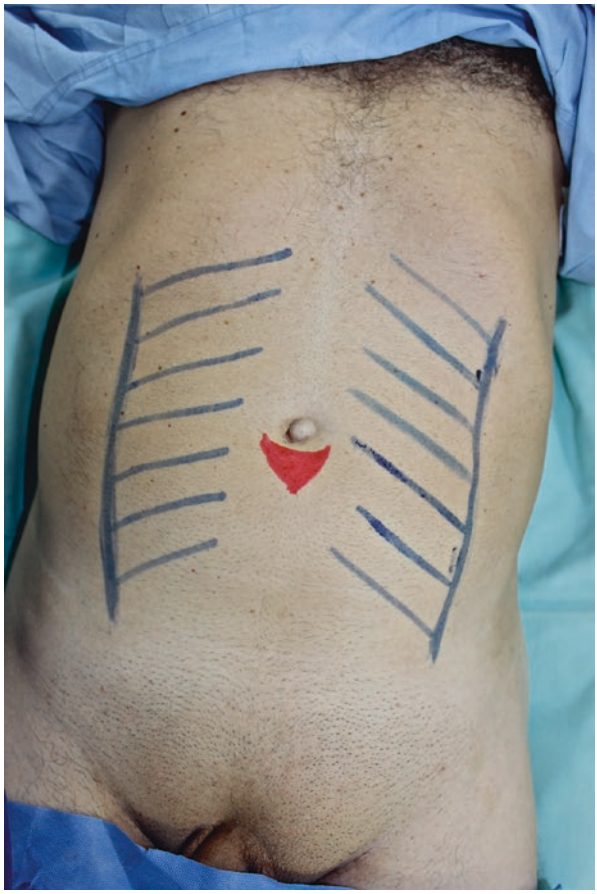

Fig. 33.1 Blue vertical lines represent semilunar lines; blue stripes represent all possible locations for initial incision in the eTEP technique

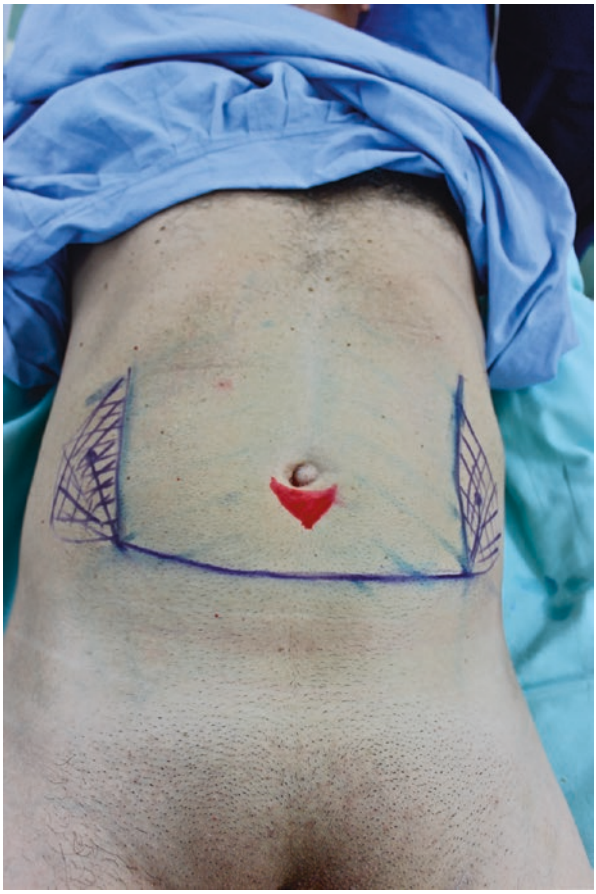

Fig. 33.2 The eTEP approach allows for direct dissection into the extraperitoneal space from outside the semilunar line, as depicted by the triangular area

or directly into the preperitoneal space from outside the semilunar lines (e.g., in eTEP lumbar neurectomy or eTEP lateral lumbar hernia repair) (Fig. 33.2). Extending the extraperitoneal view for inguinal hernia repair has many advantages as described below. The eTEP concept has also allowed for the development of other procedures such as eTEP lumbar neurectomy, eTEP lumbar hernia repair, the eTEP Rives-Stoppa technique, and eTEP TAR. Figure 33.3 shows an extensive extraperitoneal dissection involving the bilateral preperitoneal spaces, bilateral retrorectus spaces (Rives-Stoppa technique), and bilateral TAR dissection.

Salient Features

The salient features of the eTEP technique are as follows:

1. Fast and easy creation of the extraperitoneal space.
2. Creation of a large surgical field that facilitates compliance with the concept of the critical view of the myopectineal orifice (CV of the MPO).
3. Flexible port setup adaptable to many circumstances and body habitus.

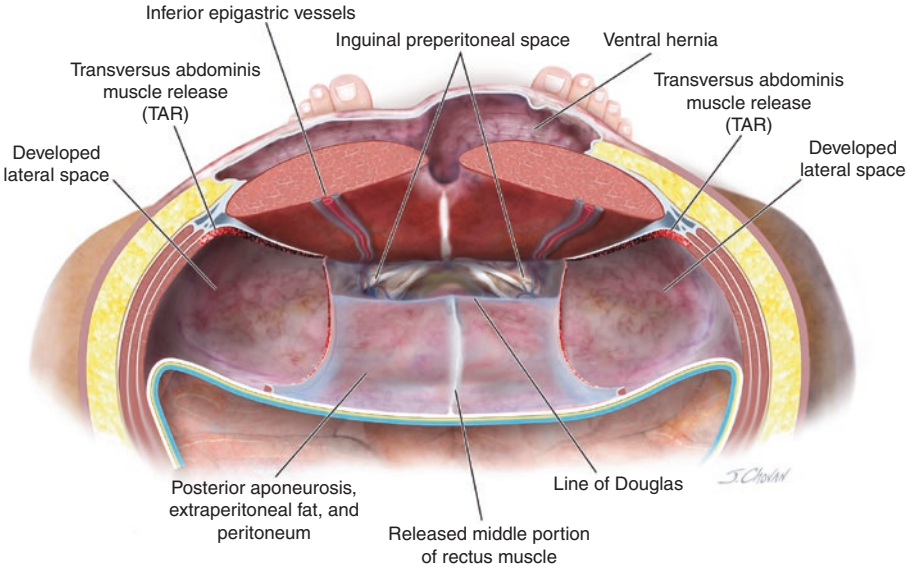

Fig. 33.3 An extensive extraperitoneal space has been developed by dissecting both inguinal regions (eTEP inguinal), both retrorectus spaces with division of the linea alba (eTEP Rives-Stoppa) and releasing the transversus abdominis muscles/internal oblique posterior fascia (eTEP bilateral TAR)

4. Tolerance to pneumoperitoneum. A larger CO_2-filled surgical space withstands better the presence of a pneumoperitoneum due to an increased tension in its walls, rarely requiring additional measures to manage it such as the use of a Veress needle or conversion.
5. Great ergonomics.

Indications

We use the eTEP technique to repair most inguinal hernias; however, there are cases for which the eTEP technique is especially useful:

1. The eTEP approach is easier to learn and master for surgeons new to the technique. Most trainees in our clinical immersion courses are surgeons who have only performed transabdominal preperitoneal (TAPP) surgeries and have no TEP experience. Notably, in follow-up surveys, most surgeons incorporated the eTEP technique into their practices.
2. For obese or post-bariatric patients, eTEP allows the surgeon to avoid the difficulties caused by the panniculus; in addition, the subcutaneous tissue is thinner as the surgeon progresses higher in the abdomen.
3. The eTEP approach is useful when the distance between the umbilicus and pubic tubercle is short.

4. The eTEP approach is useful in patients with previous pelvic surgeries.
5. With experience, the eTEP approach can be performed for more complex cases, such as patients with large inguinoscrotal, incarcerated, or sliding hernias.

In our experience, the more difficult hernias to repair with the eTEP approach are those involving a previous open radical prostatectomy (especially bilateral hernias involving a midline laparotomy), large sliding hernias, and recurrent laparoscopic hernias. Such cases should be managed by experts.

Surgeons who perform a wide dissection in using the traditional TEP technique may not see the difference at first, but they may find that the eTEP approach is an option when considering TAPP and open approaches and may appreciate the benefits derived from all procedures that have branched from the eTEP approach.

Preparation

We recommend administration of a first-generation cephalosporin during the induction of anesthesia. We do not routinely use prophylactic antithrombotic medication but instead use pneumatic compression devices in all patients. Patients should be reexamined while standing immediately before surgery, and the physical examination findings should be compared with the laparoscopic findings. This is an excellent method for ensuring that hernias are not missed.

We routinely prepare the skin, drape the patient, and set up the equipment while the patient is still awake (but sedated) so that surgery starts almost immediately after the induction of anesthesia, thereby reducing costs and facilitating a faster recovery. We recommend that patients void their bladder immediately before surgery, and we administer parenteral fluids conservatively. We consider the use of a urinary catheter for difficult cases or when we foresee a long operative time. Optimal muscle relaxation is important to ensure a fast and easy procedure, and the anesthesiologist should provide a short period of full relaxation before the start of the operation.

Technical Aspects of the eTEP Approach

Creation of the Space

Creation of the extraperitoneal space is fast and easy with minimal dissection. At the chosen location, a 12- to 15-mm incision is made, and the anterior fascia is exposed with the help of a pediatric S retractor and incised with an inverted no. 11 blade. No further retraction is necessary. Dissection continues bluntly with a finger introduced through the fascia and muscle to reach the posterior fascia, which is usually thick. The finger slides down into the retrorectus space. A lubricated balloon dissector is carefully introduced to follow the same path, while the abdominal wall is pulled up

by the other hand to maintain an appropriate angle of insertion and avoid accidental penetration into the abdominal cavity until the pubic spine is reached. Once the space is created, the balloon dissector is replaced by a blunt-tip trocar or a conventional trocar of appropriate diameter. It is possible to dissect the space without a balloon dissector, especially after the learning curve has been reached. However, studies have suggested that the use of a balloon dissector reduces the procedure duration and bleeding volume.

Pitfalls and Pearls

- Breaking the operating table at the level of the costal margin facilitates the introduction of the balloon dissector.
- Incisions close to or lateral to the semilunar lines or close to the midline should be avoided.
- The skin incision and the incision over the anterior fascia should be created in the same axis to ensure easy introduction of the balloon dissector in the proper plane.
- Creation of a subcutaneous path above the anterior fascia should be avoided.
- Placement and inflation of the balloon dissector under the symphysis pubis should be avoided to prevent bleeding and lesions in the bladder.
- In the case of an inadvertent perforation of the posterior fascia and peritoneum, with the rent close to the skin incision, the surgeon should expose the tear with an "S" retractor, grasp its inferior border, and slide the balloon dissector over it to regain the correct plane. If the rent is too far distal from the skin incision, the surgeon should return to the first steps and create a new path medial or lateral to the original path. In most cases, the extraperitoneal space is successfully created, and the rent does not interfere with the procedure.

Port Setup

Port setup is very flexible in the eTEP approach. There are two main port distributions: one involves the initial incision in the flank opposite the hernia side, which is also used in bilateral cases, and the other involves an initial cutdown in the upper quadrant on the same side as the hernia. When using the first port distribution, the initial incision is placed on the flank about 3 cm above and 5 cm lateral to the umbilicus line, which allows the dissector balloon to cross under the arcuate arch to the other side. One 5-mm working port can be placed at or next to the umbilicus, and the other can be placed inferior and lateral to the camera on the same inferior quadrant, thus achieving perfect triangulation (Fig. 33.4). This approach has the

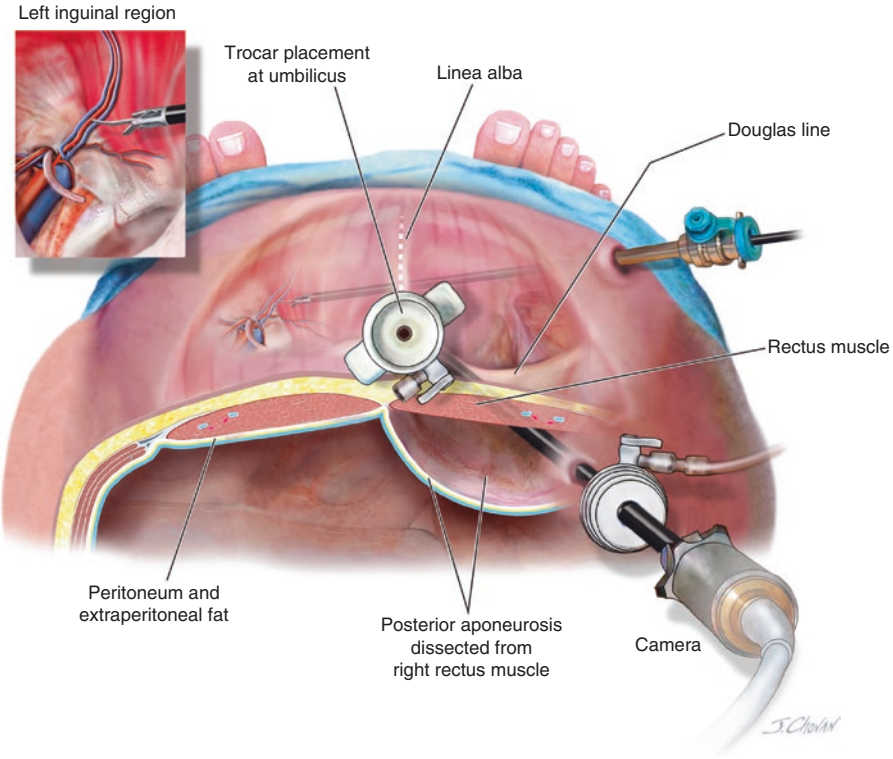

Fig. 33.4 eTEP approach established from the flank opposite the hernia side. The left working port is at the umbilicus and the right working port is placed at right lower inferior quadrant of the abdomen

advantages of a large surgical field for large or complex hernias, less arcuate arch interference, and visual triangulation. For bilateral cases, we use the same distribution but ensure that the working ports are high enough not to interfere with mesh placement, and an additional 5-mm working port is regularly placed high on the opposite inferior quadrant (Figs. 33.5 and 33.6).

In the second setup, the initial incision is placed in the upper quadrant on the same side of the hernia, usually 4–5 cm above and 5 cm lateral to the umbilicus (but sometimes higher, e.g., to avoid the panniculus in an obese or post-bariatric surgery patient). One 5-mm working port is placed at or next to the umbilicus, and the other is placed on the opposite lower inferior quadrant, where it is deemed appropriate. Using this distribution, the surgeon works with the camera at his or her side (Fig. 33.7).

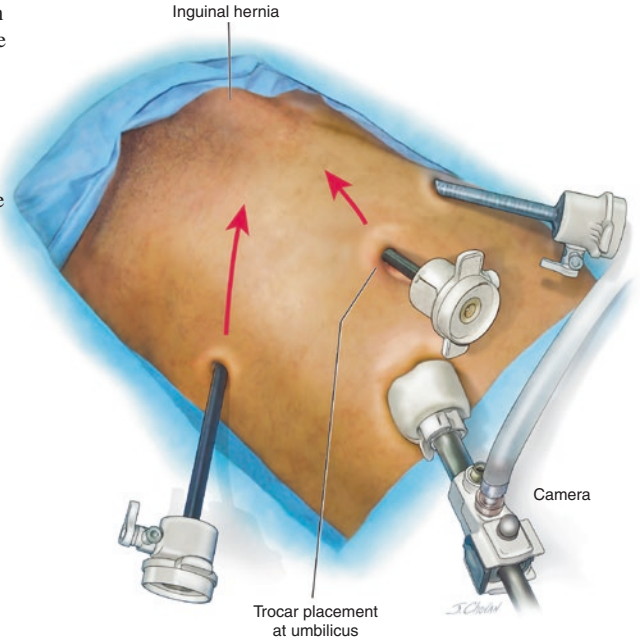

Fig. 33.5 eTEP approach for a bilateral case. For the repair of the right-side hernia, the camera port is on the left, the right working port is at the umbilicus, and the left working port is high in the left inferior quadrant; in visual triangulation, the surgeon and camera operator are opposite the hernia side

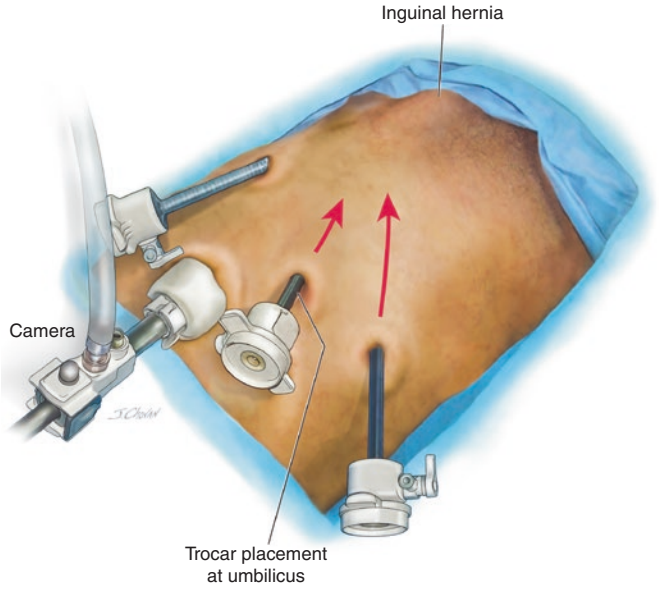

Fig. 33.6 eTEP approach for a bilateral case. For the repair of the left-side hernia, camera stays at the left flank, the port at the umbilicus now becomes the left working port, and an additional right working port is added high in the right lower quadrant to become the right working port. The surgical team is now working with a side camera. The surgeon and camera operator are opposite the hernia side

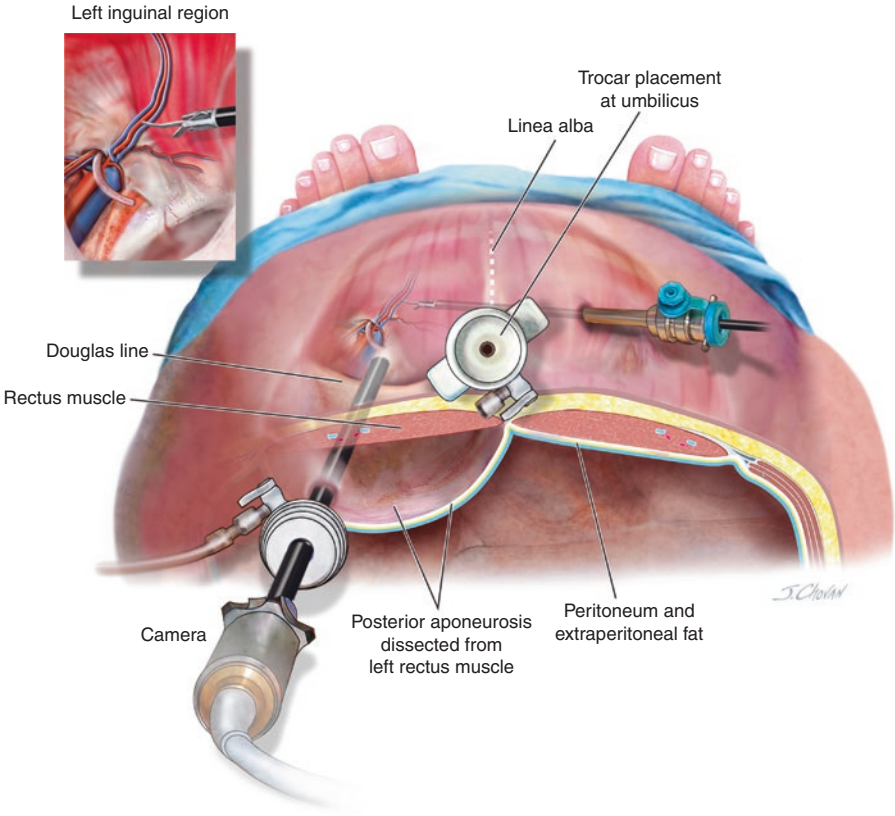

Fig. 33.7 eTEP approach for a left unilateral hernia. The initial incision/camera is at the upper lateral quadrant on the same side as the hernia. The left working port is at the umbilicus (it can be lateral to the right side), and the right working port is at the right lower quadrant

Pitfalls and Pearls

- The surgeon and camera operator work on the same side of the patient, opposite the side of the hernia. Thus, the anesthesia equipment is set accordingly, and an ether screen is not used.
- A diagnostic intraperitoneal laparoscopic evaluation may be used at the first step to confirm a diagnosis or reduce and evaluate incarcerated hernias.
- Working ports are always placed under vision with the help of irrigation from a syringe and needle.
- In very complex cases in which we foresee difficulties placing the working ports, the ports may be placed through the inflated balloon under guidance of the camera and its illumination. Of course, the balloon is rendered useless.
- For bilateral cases involving midline scars in which we suspect the preperitoneal spaces to be separated, it is possible to dissect each retrorectus space independently and develop individual preperitoneal spaces from a single midline incision

at the epigastrium or with two separate incisions at each respective upper lateral quadrant.
- Laparoscopic intraperitoneal evaluation at the end of the procedure is recommended when the peritoneum has been violated during trocar placement.

Division of the Arcuate Arch

The arcuate arch of Douglas usually extends half of the distance between the umbilicus and the pubic tubercle. Its division may be required if it interferes with visualization of the space, which is more frequent when using the camera high in the upper quadrant. When using a 10-mm camera, the arcuate line is divided with a scissors coming from the lower working port. Visualization of the scissors tip through the transparent posterior fascia indicates the appropriate extension for safe division and helps to prevent division of the peritoneum. A small cut is usually enough to substantially improve visibility. Division should take place laterally because the posterior sheath and peritoneum are sealed at the midline. When using a 5-mm camera, dissection and division of the arcuate arch and posterior sheath can be undertaken under vision. The camera is introduced through the lowest 5-mm working trocar, and the other working port is used to bluntly dissect posterior fascia free from the peritoneum from lateral to medial and then divide the arcuate arch medial to the semilunar line. This is the same maneuver performed routinely today in the eTEP-TAR's bottom-up division of the posterior fascia.

Pitfalls and Pearls

- In many cases, the peritoneum is accidentally torn during this and other maneuvers, resulting in pneumoperitoneum. This is not a problem during eTEP repair as long as a wide dissection is undertaken and no air escapes from the preperitoneal space, usually from the ports. Ensuring that the trocars are airtight is essential to avoid intermittent oscillatory movement of the peritoneum, which occurs when air escapes from the preperitoneal space and is replaced by the insufflator pump in waves.

Video 33.1 shows the detailed technical aspects of space creation, port setup, and division of the arcuate arch during the two most common eTEP arrangements.

Hernia Repair: Critical View of the Myopectineal Orifice (CV of the MPO)

No laparoscopic technique replaces the need for a thorough knowledge of the laparoscopic inguinal hernia anatomy and advanced laparoscopic skills. A detailed description of hernia repair is beyond the scope of this chapter; however, the dissection steps are common to any laparoscopic or robotic repair and are consolidated

under the concept of the CV of the MPO. The CV of the MPO is a novel concept derived from the International Hernia Collaboration (IHC) Facebook Group, to help standardize a growing variety of techniques, technology, materials, and equipment used for minimally invasive inguinal hernia repair [12]. The CV of the MPO technique is characterized by proper exposure of the anatomical area that must be attained before placing a mesh regardless of the approach, by following a list of steps. These steps, taught separately for years, are based on studies that have shown fewer complications and recurrences. The steps we follow in repairing inguinal hernias with the TEP, eTEP, and TAPP techniques are as follows [12]:

1. Identify and dissect the pubic tubercle across the midline and Cooper's ligament (CL). For large, direct hernias, extend the dissection to the contralateral CL.
2. Rule out a direct hernia. Visualize the anatomy through the inflated balloon during TEP and eTEP repairs to detect a direct hernia before dissection. Remove unusual fat in the Hesselbach's triangle.
3. Dissect at least 2 cm between the CL and bladder to facilitate flat placement of the medial and inferior edge of the mesh toward the space of Retzius, thereby avoiding mesh displacement caused by bladder distention.
4. Dissect between the CL and iliac vein to identify the femoral orifice and rule out a femoral hernia.
5. Dissect the indirect sac and peritoneum sufficiently to parietalize the cord's elements. This step is often not completed, especially in a small surgical field. To ensure compliance with this requirement, continue dissection until the cord's elements lie flat. Then visualize the psoas muscle and iliac vessels, pull the sac and peritoneum upward without triggering movement of the cord's elements, and dissect between the cord's elements to avoid missing a tail of the sac.
6. Identify and reduce cord lipomas (which may appear small and unimportant until reduced). Usually lateral to the cord's elements, they should not be confused with lymph nodes (which are generally spared). Most lipomas do not require removal but should be placed above the mesh to help prevent the mesh from rolling upward.
7. Dissect the peritoneum lateral to the cord's elements laterally beyond the anterior superior iliac spine, sweeping it back inferiorly well behind the mesh's inferior border.
8. Perform the dissection, provide mesh coverage, and ensure that mesh and mechanical fixation are placed well above an imaginary inter-anterior superior iliac spine line and any defects. This avoids recurrence and nerve injury, especially to the ilioinguinal nerve.
9. Place the mesh only when items 1–8 are completed and hemostasis has been verified. The mesh size should be at least 15–10 cm, although a larger piece of mesh is sometimes required to cover the MPO. Preferably, choose mesh that adapts to the contour of the space and the cord's elements. It should not have undue memory. Place it without creases or folds. Avoid splitting the mesh. Ensure that its lateral-inferior corner lies deep against the wall and does not roll up during space deflation (use glue or careful suturing if necessary).

Video 33.2 shows a very detailed step-by-step dissection of the space following the concept of the CV of the MPO. Implementing the CV concept through education and urging its documentation will help to standardize minimally invasive inguinal hernia repair, facilitate teaching and evaluation of techniques, reduce complications and recurrences, and ultimately improve patient care.

Conclusion

The eTEP approach is more a concept than a technique. It introduces the notion that the extraperitoneal space is limitless once the confluence of the arcuate line and semilunar line is taken down. The eTEP approach for inguinal hernia repair facilitates the performance of an anatomical and sound TEP repair, compliant with the concept of CV of the MPO, especially for residents and surgeons early in their experience. The eTEP approach also allows extension of the indications for the extraperitoneal technique to patients with a difficult body habitus, a short umbilicus-pubis distance, previous pelvic surgeries, and more complex conditions. Many procedures have branched out of the eTEP concept. Finally, the eTEP approach has a place in the armamentarium of hernia surgeons.

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Inguinal Hernia Repair with Mini-laparoscopic Instruments

34

Gustavo Carvalho, Marcelo Loureiro, Miguel Nacul, Flavio Malcher, Eduardo Moreno Paquentin, and Phillip Shadduck

Introduction

Surgical treatment of groin hernias has dramatically improved over the past century. The importance of inguinal floor repair was recognized in the 1880s, and polymer mesh repairs were introduced in the 1980s.The tension-free hernioplasty described by Lichtenstein in 1989 is now widely considered the "gold standard" to which other repairs should be compared [1]. Laparoscopic repair of inguinal hernias was established in the 1990s, and totally extraperitoneal (TEP) and transabdominal preperitoneal (TAPP) repairs remain the most widely utilized laparoscopic techniques [2]. Current TAPP/TEP techniques yield good outcomes in terms of postoperative pain, time to recovery, hernia recurrence rates, and long-term pain rates [2, 3].

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With the maturation of therapeutic laparoscopy in the last decade has come an emphasis on making minimally invasive surgery even less invasive, almost "scarless" [4]. "Reduced port surgery" (RPS) emphasizes fewer ports, smaller diameter trocars and skin incisions, and placement of incisions in occult locations [5]. Natural orifice transluminal endoscopic surgery (NOTES) and single-incision laparoscopic surgery (SILS) are two recent examples of RPS that enjoyed brief periods of popularity until a number of concerns, including unique procedure risks, longer operative times, unfavorable ergonomics, and higher costs, dampened enthusiasm. Mini-laparoscopy is a RPS option that is enjoying renewed interest.

What Is Mini-laparoscopy?

It is helpful to begin with a definition of terms [6, 7]. The term "mini-laparoscopy" (abbreviated Mini) is generally applied to laparoscopic instruments with reduced shaft diameters ranging from 1.9 to 3.5 mm (trocars of 2.2–4.2 mm), though some surgeons include instruments as large as 4 mm under the same rubric. Also, most surgeons apply the term mini-laparoscopy to procedures that utilize one 5–10 mm trocar (primarily for imaging, also for specimen extraction) as long as this site is hidden (usually intraumbilical) and as long as all other sites utilize Mini-sized instruments. In cases where more than one non-Mini trocar is used, the term "hybrid-Mini" is employed. Finally, the terms "minilaparoscopy," "mini-laparoscopy," "mini laparoscopy," "microlaparoscopy," and "needlescopic surgery" have all been utilized, leading to some confusion. Several scientific groups and professional medical societies have recently published consensus statements on terminology, with most settling on the term "mini-laparoscopy" [8].

Mini-laparoscopy was pioneered about 20 years ago [9–14]. Early adoption of Mini was inhibited by the limitations of first-generation instruments, especially functionality and durability. Newer generation Mini instruments have recently become available with improved effector tips, a choice of shaft diameters and lengths, better insulation and electrosurgery capability, improved strength and rotation, more ergonomic handles, low-friction trocar options, and improved instrument durability (Fig. 34.1). The marked improvements in Mini instrumentation have occurred contemporaneously with the increasing desire to reduce even further the invasiveness of standard laparoscopy, the waning enthusiasm for SILS and NOTES platforms, and the growing concern regarding the costs of computer-assisted (robotic) surgery. Together, these forces have contributed to somewhat of a renaissance for Mini [4, 7, 15–26].

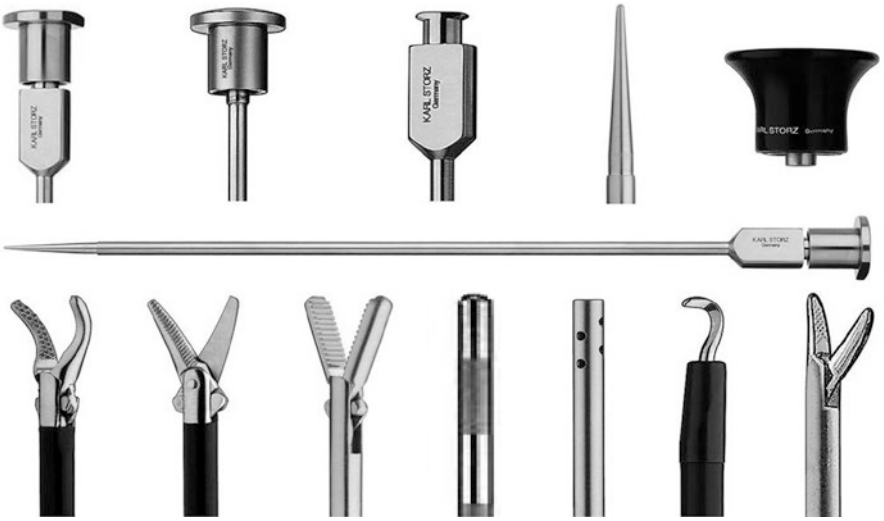

Fig. 34.1 Mini-laparoscopic instruments. Newer generation Mini instruments have recently become available with improved effector tips, a choice of shaft diameters and lengths, better shaft insulation and electrosurgery capability, improved shaft strength and rotation, more ergonomic handles, low-friction trocar options, and improved instrument durability

Why Use Mini-laparoscopy?

Mini-laparoscopy is a natural evolution of conventional laparoscopy. The port placement, instrument triangulation, and procedure conduct of standard laparoscopic procedures are preserved [27]. The optical shadow produced by Mini instruments is less than that of 5–10 mm instruments, allowing the laparoscope to come closer to the surgical target, enhancing visualization of anatomic landmarks and structures. A surgeon proficient in conventional laparoscopy can transition to mini-laparoscopy with minimal learning curve.

Mini-laparoscopy is intuitively cost-effective. No large capital expenditures for equipment purchase or maintenance are necessary. No expensive single-use, single-incision devices are required. Reusable instruments and trocars are available. Operative times are similar to standard laparoscopy.

What are the results of Mini? The science behind mini-laparoscopy was recently reviewed. Most of level I data on mini-laparoscopy address its use for cholecystectomy. Though there are many publications of mini-laparoscopic inguinal hernia repair, fundoplication, appendectomy, hysterectomy, renal surgery, sympathectomy,

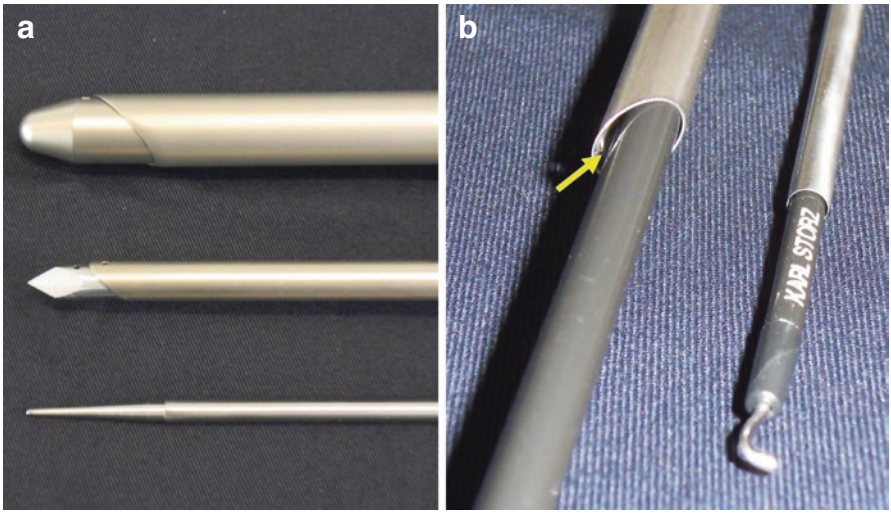

Fig. 34.2 Conventional laparoscopic and mini-laparoscopic instruments. (**a**) The comparison of trocars with diameters of 11, 6, and 3.5 mm. (**b**) The low-friction Mini trocar has been designed to precisely fit the corresponding instruments, with less gap between the instrument shaft and the trocar, allowing for a valveless, very low-friction system

and other procedures, there are limited level I data regarding these procedures. Focusing on the best quality data that we have at this time, the review of the science behind Mini concluded that "when applied to elective laparoscopic cholecystectomy, the use of mini-laparoscopic instruments results in a marginally longer operative time (3–5 min), slightly less early postoperative pain (in the first 24 h), and a better initial cosmetic result, with no other apparent significant differences" [6]. Notably, there were no apparent negative outcomes when Mini was compared to conventional laparoscopy.

One recent instrument development may advance the results of Mini: the development of a very low-friction trocar for use with Mini instruments. Current commercialized Mini trocars are miniaturized versions of traditional laparoscopic trocars which typically incorporate two seals to minimize CO_2 loss: a rubber cap and an internal mechanical valve. In order to improve the precision of movement with Mini instruments, a low-friction Mini trocar was precisely engineered (with narrow tolerances), allowing for the use of a valveless trocar [28, 29]. As compared to standard trocars, these low-friction, valveless Mini trocars are longer, have thinner walls, and have minimal gap between the trocar and the instruments (Fig. 34.2). This provides both minimal friction (instrument on trocar friction of 0.13 N vs 4.3 N) and minimal CO_2 loss (<0.1 L/min). They also have a long tapering conical blunt-tip obturator (Fig. 34.1) to minimize tissue damage during trocar insertion [30, 31] (Figs. 34.3 and 34.4). Studies have shown that the abdominal

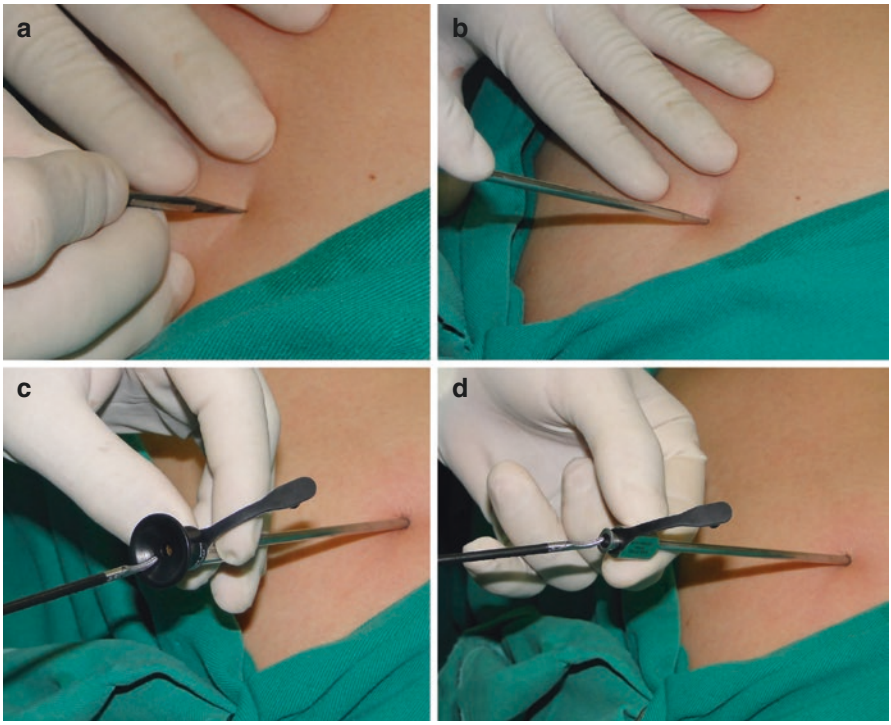

Fig. 34.3 Low-friction Mini trocar insertion. (**a**) Pinpoint skin incision is made with a scalpel. (**b**) Skin incision is dilated and the trocar with conical blunt-tip obturator is inserted. (**c**) With the funnel cap attached to the trocar inlet, instrument insertion is facilitated. (**d**) The trocar may be used without the cap, though instrument exchange may be slightly more difficult

wall tissue injury caused by different trocar sizes is proportional to the square of radius of the trocar (Table 34.1, Fig. 34.5). A 10 mm trocar generates approximately 5 times more tissue damage than a 5 mm trocar and about 25 times more damage than a 2 mm trocar. Mini instruments and low-friction Mini trocars have been evaluated in a variety of preclinical bench studies, including surgical simulators. Studies of surgical tasks being performed by medical students and surgical residents revealed improved instrument precision, particularly during dynamic and delicate tasks, with lower muscle effort and higher efficacy of movement ($p < 0.001$). Initial clinical studies of these newer, low-friction trocars are limited but encouraging ([32–35]).

Regarding Mini for inguinal hernia surgery, early adopters of the low-friction Mini trocars have noted improved surgical precision during dynamic tasks (e.g., Hernia sac dissection), lower surgeon stress, higher efficiency of movement, and fewer trocar dislocations and reinsertions [28, 29].

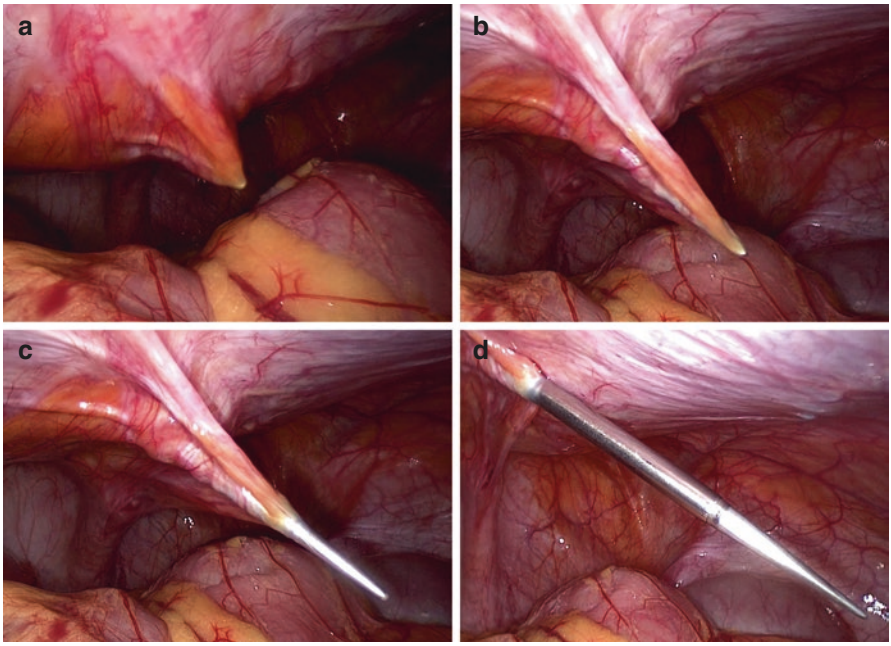

Fig. 34.4 Mini trocar insertion. Image sequence (**a**–**d**) shows insertion of the low-friction Mini trocar with conical blunt dilating tip

Table 34.1 Surgical access technique and parietal injury

Technique	Incisions	Parietal injury volume ($\pi \cdot r^2 \cdot h$)
NOTES	Pure—n**o** skin incision	~0
Hybrid NOTES	(3.5 mm × 2)	612
Hybrid NOTES	(6 mm × 1)	900
LESS (single port)	(28 mm)	19,600
LESS (single port)	(36 mm)	32,419
Mini-laparoscopy	(11 mm × 1 + 3.5 mm × 3)	3945
Std laparoscopy	(11 mm × 2 + 6 mm × 2)	7854

Mini-laparoscopy: Helpful for TAPP or TEP?

For laparoscopic repair of inguinal hernias, the two techniques most often employed are the totally extraperitoneal (TEP) and the transabdominal preperitoneal (TAPP) techniques. Both are proven with similar safety and effectiveness [36]. The decision for TAPP vs. TEP approach is subject to a surgeon's personal experience and preference [37].

The TAPP approach allows the surgeon to operate in a larger working space as compared to TEP. Advantages of TAPP include routine evaluation of intra-abdominal

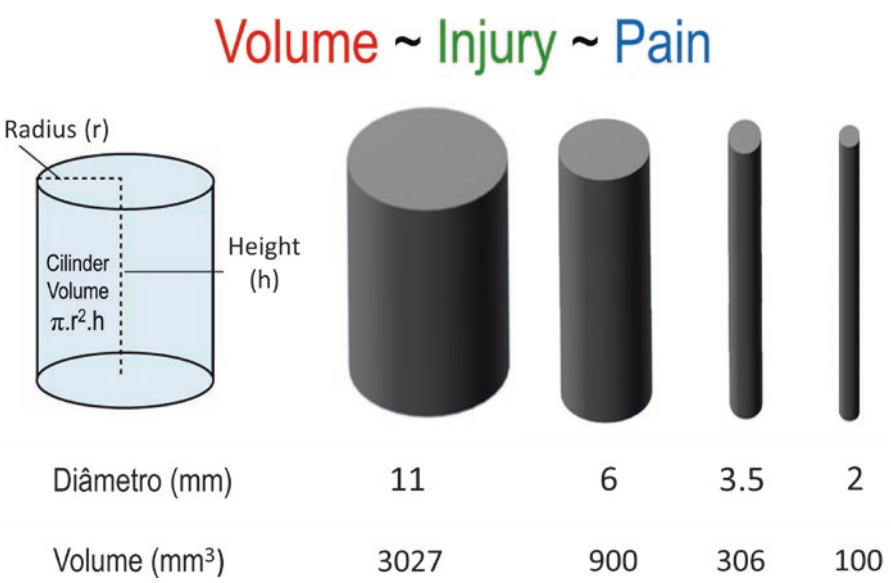

Fig. 34.5 The volume of abdominal wall tissue injury is a nonlinear function of trocar size. Because tissue injury is related to the square of the radius of the trocar, small differences in trocar diameter result in larger differences in tissue injury

organs, diagnosis and treatment of incidentally detected contralateral hernias, and evaluation of bowel viability in incarcerated hernias [38]. Disadvantages of TAPP include possible increased costs and longer procedure durations due to mesh fixation and closure of the peritoneal flap [39]. Mesh fixation has been described with staples, tacks, sutures, fibrin, and cyanoacrylate [40, 41].

Advantages of the TEP approach include simplicity and speed of execution (omitting mesh fixation saves time), possibly lower cost, and no need for opening and closing the peritoneum [38, 39, 42]. Disadvantages of TEP include a small working space with increased technical demands and an increased level of difficulty identifying anatomic landmarks [28, 29].

Almost all reports of mini-laparoscopic inguinal hernia repair refer to TEP procedures. In TAPP procedures, the surgeon uses wider movements of dissection than in TEP procedures. This may generate greater forces on the Mini instruments, increasing the potential for instrument damage, particularly with the early generation instruments. Also, because the visual space in TAPP is much larger than that in TEP, the advantage of reduced instrument size to improve visual field is less relevant. In addition, because most surgeons choose to fixate the mesh in TAPP procedures using a 5 mm diameter tacker, the use of Mini instruments in TAPP is restricted in most cases to the replacement of one 5 mm port with one 3 mm port. Thus, the advantages of a mini-laparoscopic approach for TAPP seem less than for TEP. Both options though are presented here for the reader to consider.

Mini-laparoscopic TAPP

The author's preferred technique for performing a Mini TAPP utilizes a 45°, 10 mm lens in the umbilicus and two 3.5 mm low-friction Mini trocars in the lower quadrants. This approach exploits the following advantages: (1) no need for those already familiar with TAPP to learn a new surgical technique, since it is fundamentally the same procedure as a traditional TAPP; (2) precise surgical maneuvers due to the low-friction Mini trocars, particularly helpful for hernia sac dissection and for suture closure of the peritoneum; (3) enhanced visualization due to smaller instruments casting a smaller optical shadow; and (4) good cosmetic outcome.

For Mini TAPP technique, patients are subjected to balanced general anesthesia and operated in supine position with upper extremities well-padded and tucked. Chlorhexidine is utilized for skin preparation. Incision site is routinely infiltrated with ropivacaine. The author's preference for establishment of pneumoperitoneum is an open direct trocar entry technique through the umbilicus with an 11 mm blunt-tipped trocar (Kii Balloon Blunt Tip®, Applied Medical). Pneumoperitoneum is maintained at 12–15 mmHg. A 45°, 10 mm laparoscope is utilized to perform a full abdominal cavity exploration as part of the routine protocol. Two 3.5 mm low-friction "Carvalho Mini trocars" (Storz) are inserted under direct visualization and with transillumination of the abdominal wall to avoid injury to the inferior epigastric vessels. These are placed at the border of the rectus abdominis muscle, at level of the umbilicus on each side of the patient. The operating table is tilted to 15° Trendelenburg and 15° airplane with the hernia side up. Using a mini-laparoscopic scissor, the peritoneal flap is developed from a point 1 cm medial and superior to the anterior superior iliac spine to the medial umbilical ligament in a hockey-stick fashion. A complete anatomical dissection of the extraperitoneal pelvic floor is performed, parietalizing the cord structures. The extent of dissection reaches medially 1 cm beyond the symphysis pubis, cranially 3 cm above the transversalis arch or any direct hernia defect, laterally to anterior superior iliac spine, and caudally 1 cm below the pubic bone. The complete retraction of indirect sacs is important, always avoiding critical structures and having control of hemostasis. In female patients, the round ligament is divided using a 3 mm bipolar device (Gyrus® PK Molly Bipolar forceps®, Olympus). Mesh selection depends on surgeon preference and hospital purchasing contracts. A large pore, 15 × 15 cm polypropylene mesh (Prolene mesh®, Ethicon), trimmed to fit the dissection space, is one common alternative. A heavyweight polypropylene precut mesh (3DMax®, Bard®) or a lightweight polypropylene mesh (3DMax Light®, Bard®) can also be utilized. The author prefers mesh fixation with a limited number of absorbable tacks to Cooper's ligament, rectus abdominis muscle, and transverse abdominis aponeurotic arch. In order to use a 5 mm tacker and still preserve the bilateral lower quadrant Mini trocars, the 10 mm lens is switched to a 2.7 mm laparoscope that is then introduced through one of the Mini trocars in order to free the 11 mm port for the tacker. Alternatively, after switching to the 2.7 mm lens and freeing the 11 mm port, a tube applicator for "fibrin sealant" can be utilized instead of tacks. Self-fixating mesh (ProGrip®, Medtronic) with no fixation represents another alternative. The peritoneal flap is closed using a Mini needle holder to create a continuous closure with absorbable

suture (Vicryl® 2-0, Ethicon; V Loc® 90 device, Medtronic). In order to close the peritoneal flap, the pneumoperitoneum is reduced to 8 mmHg. Extraction of working ports is always done under direct visualization. The fascia at the umbilical trocar site is closed with interrupted #0 nonabsorbable suture (Ethibond®, Ethicon). The skin incisions are closed with topical skin adhesive (2-octyl cyanoacrylate, Dermabond®, Ethicon).

The author reported his initial 25 hernia learning curve experiences with this technique [43]. Average operative time was 48 min per hernia. Mean hospital stay was 26 h. There was no conversion to standard laparoscopy or open surgery. There were no major surgical complications. Only one patient required the use of opioids in addition to ketorolac. One week post-op, no patients were taking analgesics.

What are the published data for Mini TAPP? Wada and colleagues reviewed their experience with 352 Mini TAPP procedures in 317 patients from 1996 to 2011 [44]. They performed Mini TAPP in 89% of patients presenting with inguinal hernia. They utilized a 5 mm laparoscope at the umbilicus, and surgical instruments were inserted through 5 mm and 3 mm trocars. After reduction of the hernia sac and dissection of the preperitoneal space, they placed either polyester mesh or polypropylene soft mesh with tack fixation. The peritoneum was closed with interrupted 3-0 silk sutures. The mean operative time was 103 min for unilateral hernias and 156 min for bilateral hernias. There was no conversion to open repair. Forty-three patients (13.6%) used postoperative analgesics (mean frequency of use 0.5). The authors observed one bladder injury (0.3%) and no bowel or major vessel injuries. Postoperative complications occurred in 32 patients (10.1%). One patient with a retained cord lipoma required reoperation. There was no reported chronic pain or mesh infection. The operative time for experienced surgeons (≥20 repairs) was significantly shorter than that for inexperienced surgeons (<20 repairs; $p < 0.05$). The authors concluded that Mini TAPP may have more advantages than conventional TAPP.

Chan and Hollinsky retrospectively reviewed their community hospital experience, evaluating the extent of abdominal wall surgical trauma and postoperative consequences for Mini TAPP ($n = 50$) and single-port sTAPP ($n = 35$). Intraoperative data, including length of umbilical skin incision and operative time, were recorded. A follow-up evaluation included investigation of hernia recurrence, postoperative pain, abdominal wall mobility, cosmetic satisfaction, and period of sick leave. The mean umbilical skin incision length was 13 ± 4 mm in Mini TAPP vs. 27 ± 3 mm in sTAPP ($p < 0.001$). The Mini TAPP procedure required less operating time (54.8 ± 16.9 min vs. 85.9 ± 19.7 min; $p < 0.001$). The mean immediate postoperative pain score on the visual analog scale was lower in the Mini TAPP patients (2.7 ± 2.1 vs. 4.4 ± 1.9; $p = 0.016$). Patients who underwent Mini TAPP had a shorter period of sick leave (11.2 ± 8.4 days vs. 24.1 ± 20.1 days; $p = 0.02$). Follow-up evaluation after approximately 30 months revealed no hernia recurrences and equal abdominal wall mobility and cosmetic satisfaction in both groups. The authors concluded that in patients with uncomplicated inguinal hernia, the Mini TAPP procedure resulted in less surgical trauma, had a shorter operating time, and had distinct advantages regarding immediate postoperative pain and sick leave time compared to single-incision laparoscopic repair.

Mini-laparoscopic TEP

TEP is technically more demanding than TAPP, performed inside a smaller working space with the laparoscope nearer the working instruments. Any developments that make TEP easier and that enhance visualization are welcome. Using needlescopic instruments for TEP is one very good use of mini-laparoscopy.

General anesthesia is used. The preperitoneal access begins by a periumbilical incision, ipsilateral to the hernia. After exposing the anterior rectus sheath, 1.5 cm of the sheath is opened. After dissection of the rectus muscular fibers and visualization of the posterior rectus sheath, an 11 mm reusable trocar is positioned with a U suture using #0 polypropylene. Through the 11 mm trocar, a 30° 10 mm optic is used to access the preperitoneal space. That space is progressively created by blunt telescope dissection and CO_2 insufflation at a continuous pressure of 12 mmHg. No disposable trocar or dissecting balloon is needed. Alternatively, the extraperitoneal space can be obtained by suprapubic puncture with a Veress needle and injection of CO_2 in the space of Retzius, as described by Dulucq [38]. This technique obviates the use of dissecting balloon as well. The 10 mm trocar for the rigid endoscope is then inserted into the previously distended preperitoneal space. Thereafter, under direct view, two mini-laparoscopic trocars are placed 4 cm inferior to and 4 cm lateral to the 10 mm periumbilical trocar, thereby respecting the triangulation principle (Figs. 34.6 and 34.7). Special care is taken not to injure the epigastric vessels.

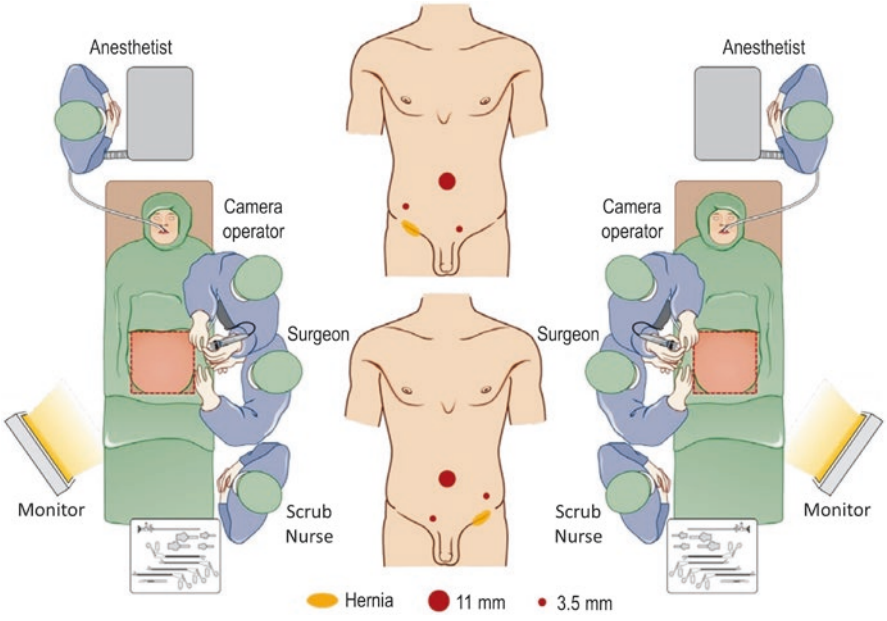

Fig. 34.6 Operating room setup and trocar positions for right and left mini-laparoscopic hernioplasty

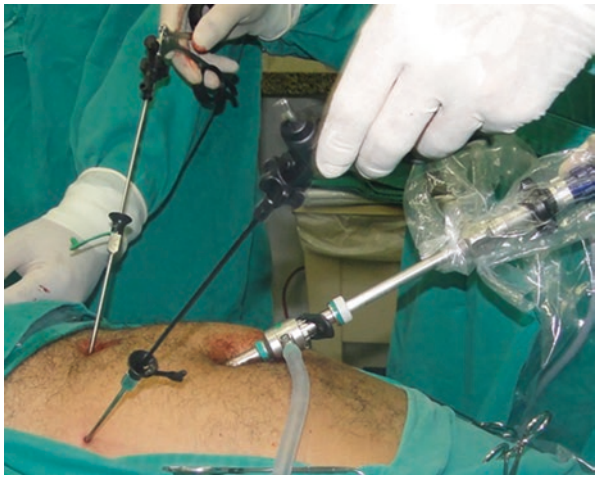

Fig. 34.7 Trocar placement for mini-laparoscopic left inguinal hernia repair. The use of a low-friction trocar reduces inadvertent trocar dislocation because undesired trocar movements during surgery are minimal

Another alternative is to place both working Mini trocars in the infraumbilical midline, a setup that allows bilateral inguinal repair with the same trocars. The dissection of direct and indirect hernias is performed in the standard fashion. Scrotal hernias are technically more difficult and sometimes require transection of the hernia sac. Once the anatomic elements are properly identified (Fig. 34.8), including dissection of the peritoneum covering the floor of the anterior pelvic wall, a 15 × 11 cm polypropylene mesh is placed without fixation, and the CO_2 is removed under vision to ensure that there are no wrinkles in the mesh.

Loureiro and colleagues reported their experience with Mini TEP in 60 patients (70 hernias) with an average operative time of 54 min, no intraoperative complications, peritoneum perforation in six patients (10%), and one conversion to open surgery due to technical difficulty (lack of proper working space) in a recurrent hernia [45]. Seroma formation was observed in ten patients (16%), and there were no immediate recurrences during the 4-week follow-up period.

With the hypothesis that combining the established advantages of TEP with the delicacy, precision, and increased visualization of Mini instruments in narrow spaces is better, Malcher et al. compared 58 patients randomized between standard 5 mm TEP and Mini 3 mm TEP (both groups without dissection balloon or mesh fixation). The authors found shorter operative time and less immediate post-op pain (at 6 h) in the Mini group [46]. Opening the extraperitoneal space without using a dissecting balloon and avoiding mesh fixation also allowed this surgical approach to be more competitive in terms of hospital costs and less likely to cause chronic pain.

Technique Combining Mini-laparoscopy, TAPP, and TEP

Laparoscopic TAPP and TEP techniques are both well established, though TEP has proven to be somewhat better than TAPP [2, 47]. Its main advantages rely on avoiding a peritoneal flap and avoiding mesh fixation, resulting in less postoperative

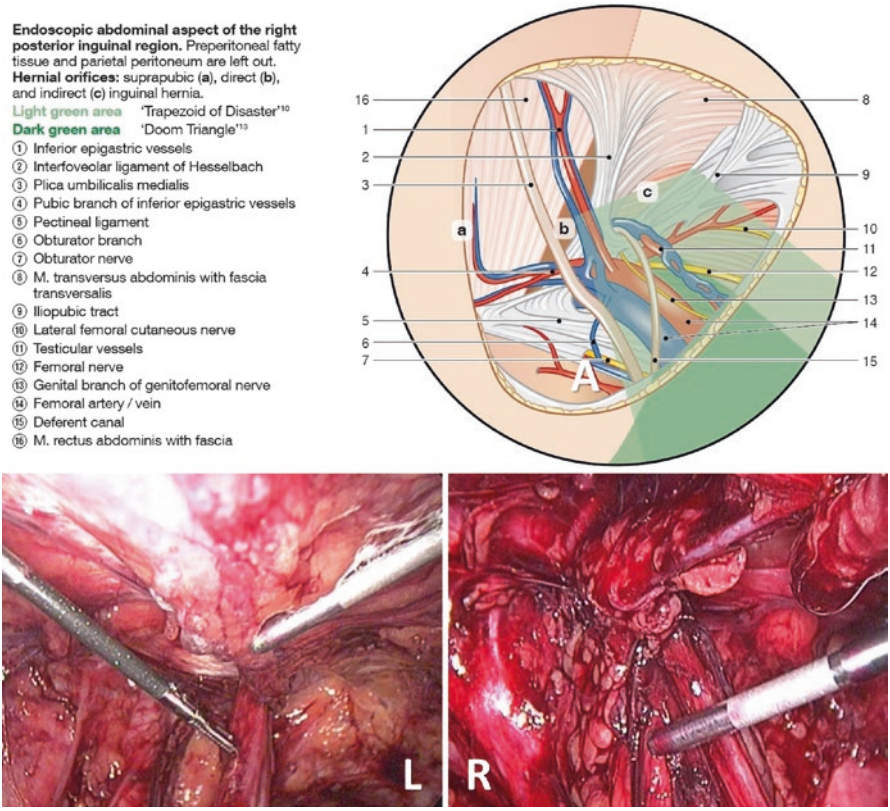

Fig. 34.8 Pelvic anatomy for Mini TEP right inguinal hernia repair. Intraoperative photos of the left and right groin anatomy

pain and faster recovery [2, 9, 15, 42]. Although advantageous in these ways, TEP has not been widely adopted because it is regarded as a more complex procedure, especially with respect to creating the preperitoneal space and understanding its anatomy. In addition, TEP does not allow intraperitoneal inspection, which is crucial for treating incarcerated hernias [2, 9, 15, 42]. By combining the advantages of TEP (no peritoneal flap and no mesh fixation), the advantages of TAPP (visualization), and the precision and cosmesis of Mini, a new technique was recently developed [28, 29].

In this combined Mini-TAPP-TEP technique, initial intraperitoneal laparoscopy (TAPP) works as a TEP facilitator. TAPP is immediately followed by TEP, and in this particular combined technique, TAPP is not being used selectively for incarcerated hernias but routinely for its specific advantages in the combined approach [48, 49]. The addition of mini-laparoscopy allows easy exchange of trocar position between the intra- and extraperitoneal spaces, which increases the versatility of this technique. Besides facilitating creation of the preperitoneal space under direct view, this

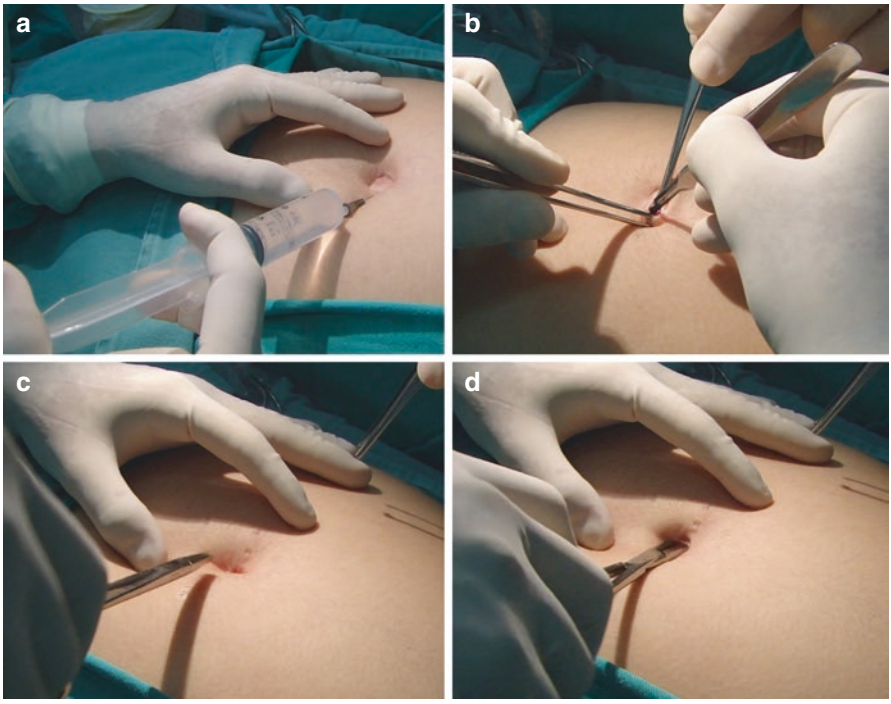

Fig. 34.9 Initial trocar insertion utilizing a direct trocar entry technique at the umbilicus. (**a**) Administration of intraumbilical anesthesia. (**b**) The intraumbilical area is exposed and skin incision is made at a hidden umbilical fold. (**c**, **d**) Blunt dilation of aponeurosis with a needle holder

combined approach also provides a number of benefits over straight TEP. Laparoscopy allows adequate evaluation of all the anatomic elements involved in hernia repair, which allows good planning of what needs to be done in the preperitoneal space. It becomes especially useful in unusual situations such as underestimated hernia size, direct coalescing bilateral hernias, displaced epigastric vessels, and abdominal contents within the hernia sac. This anatomic preview may decrease perioperative complications, which, although infrequent, are potentially serious. By facilitating TEP, this combined technique can also potentially lessen the learning curve of TEP.

The procedure starts with the author's standard laparoscopic access which is an open access. After local anesthesia infiltration (20 mL of bupivacaine 0.25%), a vertical transumbilical incision (more prominent for the infraumbilical direction) is performed (Fig. 34.9). Careful dilation of the aponeurotic umbilical orifice is made by the tip of a needle holder. A 10 mm trocar with a blunt dilating tip is gently inserted after proper dilation of this aponeurotic orifice (Fig. 34.10). The patient undergoes pneumoperitoneum using a CO_2 pressure ranging from 8 to 12 mmHg. Then, a 30° laparoscope is used for the entire procedure. Veress needle and 3 mm scope are not used here.

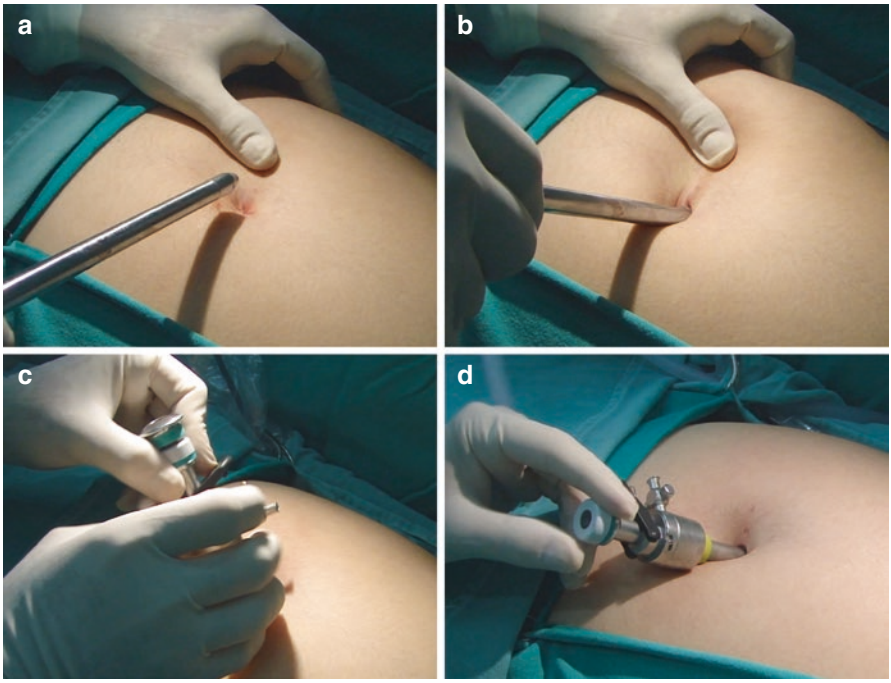

Fig. 34.10 Direct insertion of blunt-tip trocar at the umbilicus. (**a**, **b**) Sequence showing how dilation of the umbilical orifice is achieved by inserting a blunt-tip trocar. (**c**, **d**) Through the incision previously placed in a hidden umbilical fold, a blunt-tip trocar is inserted into the peritoneal cavity. No Veress needle or sutures are used

After completing the initial setup, an inspection of the abdominal cavity is carried out before starting the herniorrhaphy procedure. Potentially complicated cases are immediately converted to conventional laparoscopy by using 5 mm conventional laparoscopic trocars instead of Mini trocars. Incarcerated hernias can be reduced at this moment, after proper evaluation of the bowel, and they usually don't require conversion (Fig. 34.11).

After abdominal cavity inspection, the first 3.5 mm trocar is inserted, with transperitoneal visual control, medial to the epigastric vessels, almost at the midline, using the atraumatic 3 mm blunt dilating tip obturator and avoiding peritoneal perforation (Fig. 34.12a, b). Through this Mini trocar, dissection is made with small sideway movements between the peritoneum and the musculoaponeurotic planes under transabdominal laparoscopic vision. After removing the Mini trocar obturator, the CO_2 tubing is disconnected from the 11 mm umbilical trocar and relocated to the Mini trocar with the appropriately placed Luer lock. The preperitoneal insufflation begins at the same moment that the 11 mm intraperitoneal umbilical trocar valve is opened halfway. At this point, we directly visualize the CO_2 inflation into the preperitoneal space (Fig. 34.12c, d)

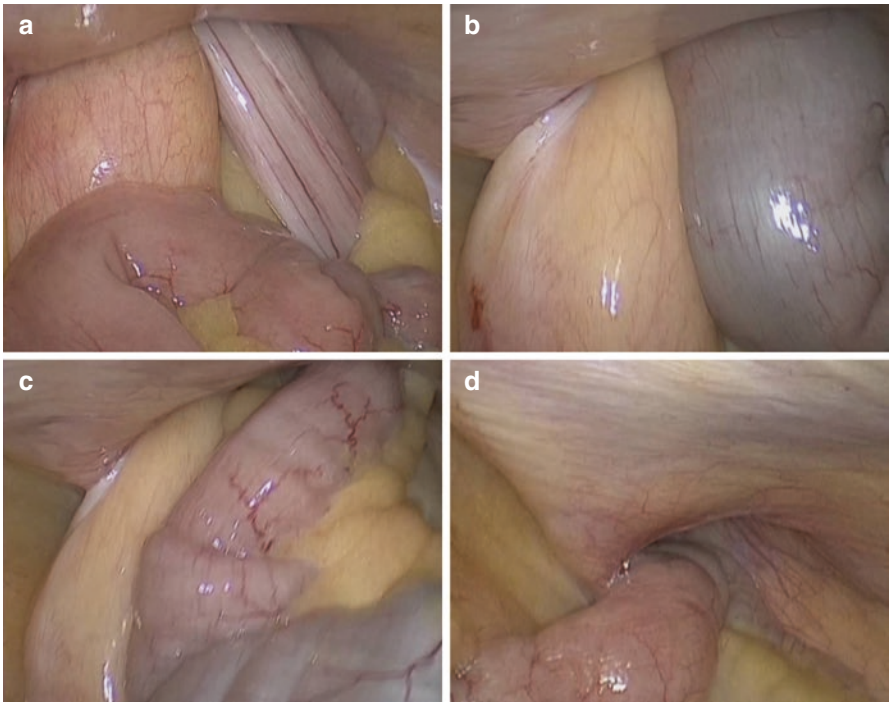

Fig. 34.11 (**a**-**d**) Reduction of incarcerated inguinal hernia. Under laparoscopic (TAPP) vision, external compression maneuvers are gently performed, and bowel can generally be reduced

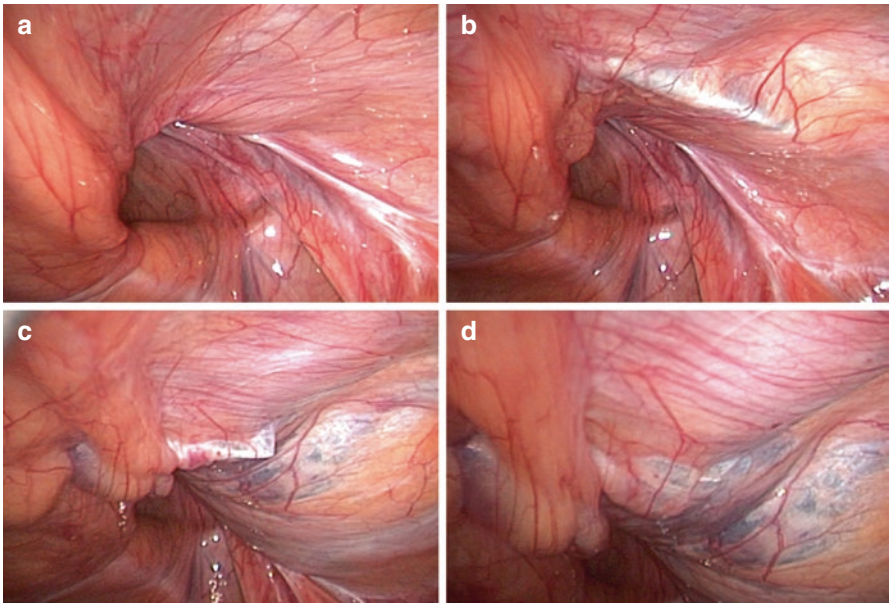

Fig. 34.12 Combined Mini-TAPP-TEP procedure. Creation of the preperitoneal space under laparoscopic view for a right inguinal hernia repair (**a**) intial view; (**b**) blunt dissection with the Mini trocar; (**c**, **d**) preperitonial insuflation under direct view

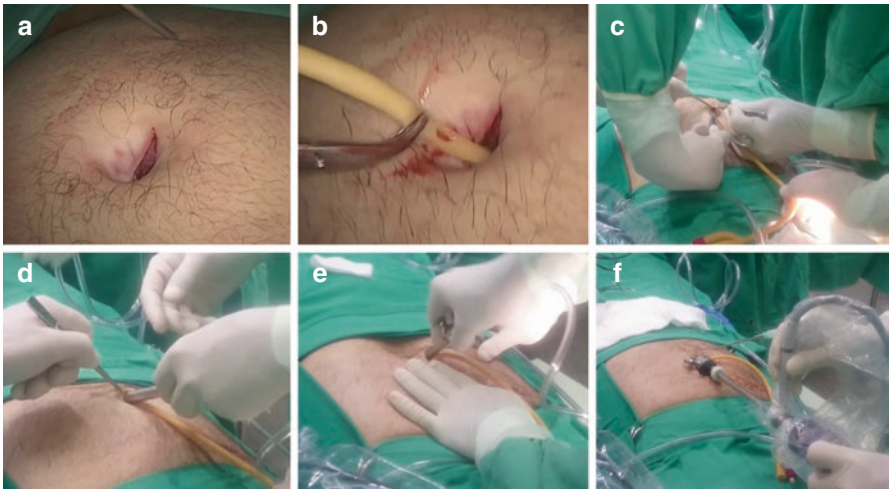

Fig. 34.13 Combined Mini-TAPP-TEP procedure. Image sequence shows how to transition from the intraperitoneal space (TAPP portion of the procedure) to the preperitoneal space (TEP portion of the procedure). (**a**) Umbilical skin incision. (**b**) Foley catheter is inserted intraperitoneal. (**c**) Subcutaneous tunnel 4 cm long is created with a blunt Kelly forceps. (**d**, **e**) Pyramidal sharp trocar is gently advanced into the subcutaneous tunnel to access the preperitoneal space 3–4 cm lower than the umbilical fascial incision. (**f**) The 10 mm scope is utilized to bluntly enlarge the preperitoneal space

After proper preperitoneal inflation, the tip of an 18–20Fr Foley catheter is placed inside the abdomen through the umbilicus to vent any intraperitoneal CO_2 that may develop either by diffusion or damage to the peritoneum during hernia sac dissection (Fig. 34.13). The 10 mm trocar is reintroduced through the umbilical skin incision and passed along a subcutaneous tunnel entering the fascia 3–4 cm below and directed in a 45° angle toward the preperitoneal space recently created, which already has enough size to start the preperitoneal dissection. It is not necessary to use a balloon dissector because the proper workspace is progressively established with the laparoscope tip and 3 mm dissection instruments introduced via the 3.5 mm trocar. At this moment, a second 3.5 mm trocar is inserted, in a good triangular position, to facilitate dissection of the preperitoneal space, now by bimanual technique. At the end of the setup, there will be (1) an umbilical transperitoneal hole, kept open by a Foley catheter; (2) an 11 mm trocar passing through the same umbilical skin incision, through a separate hole in the posterior rectus sheath, and into the preperitoneal space; and (3) two 3.5 mm Mini working trocars.

The TEP part of the procedure then proceeds under direct preperitoneal view. After acquiring adequate preperitoneal space to fully identify the inguinal anatomy using bimanual dissection, the hernia sac is properly dissected, and the preperitoneal space is expanded to accommodate a 15 × 13 cm medium or heavyweight polypropylene mesh with rounded corners (Fig. 34.14). At this point, the hernia

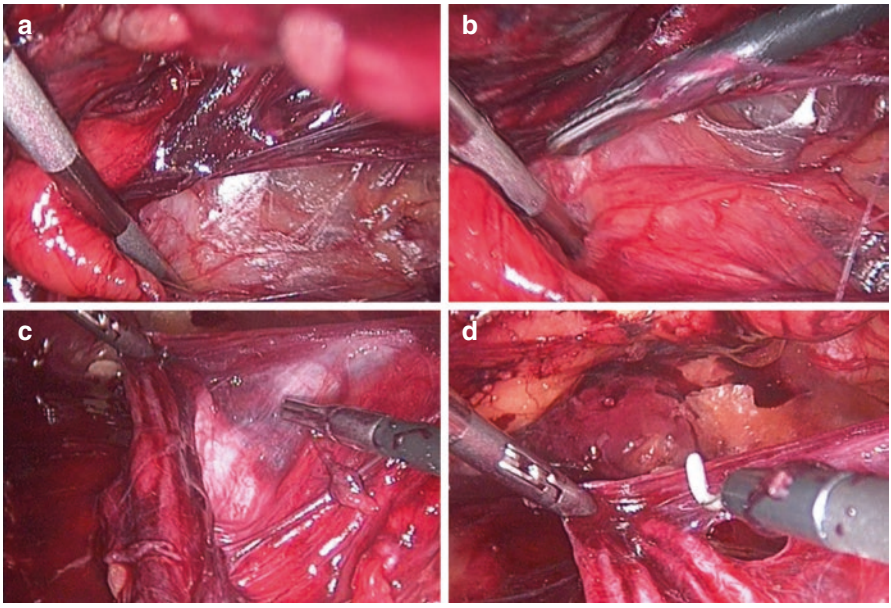

Fig. 34.14 Combined Mini-TAPP-TEP procedure. The image sequence shows adequate exposure of the preperitoneal space, which is performed by bimanual Mini dissection (**a**, **b**). Following proper identification of the hernia sac, it is progressively separated from the spermatic cord and floor structures by meticulous blunt dissection (**c**) and cautious use of electrocautery (**d**)

orifice and the inguinal anatomic landmarks (the iliopubic tract, vas deferens, gonadal vessels, epigastric vessels, urinary bladder, and Cooper's ligament) must have been well identified (Fig. 34.8).

The polypropylene mesh is tightly rolled, grasped with a 5 mm forceps, and gently and blindly inserted through the 11 mm trocar into the preperitoneal space (Fig. 34.15a). It is unrolled and positioned, completely covering the entire inguinal region, and it is usually not fixed (Fig. 34.15b). Selected large direct hernia defects should cause consideration for mesh fixation. Preperitoneal CO_2 is released allowing the peritoneum to compress the mesh, keeping it in place and exempting the need for mesh fixation in most cases. After correct mesh positioning, the 11 mm trocar is removed from the preperitoneal space and reintroduced again into the abdominal cavity, via the hole that was containing the Foley catheter. This allows the mesh to be examined from its inner aspect, confirming that it is correctly placed and without folds (Fig. 34.15c, d). If better positioning of the mesh is necessary, it can be accomplished by introducing one 3.5 mm trocar by the same skin hole into the peritoneal cavity. Subsequently, intraperitoneal CO_2 is fully evacuated. The procedure is finished by performing closure of the fascial defect at the umbilicus using a purse-string suture. The 3.5 mm skin incisions will heal without suture, being covered with surgical tape or topical skin adhesive (Fig. 34.16).

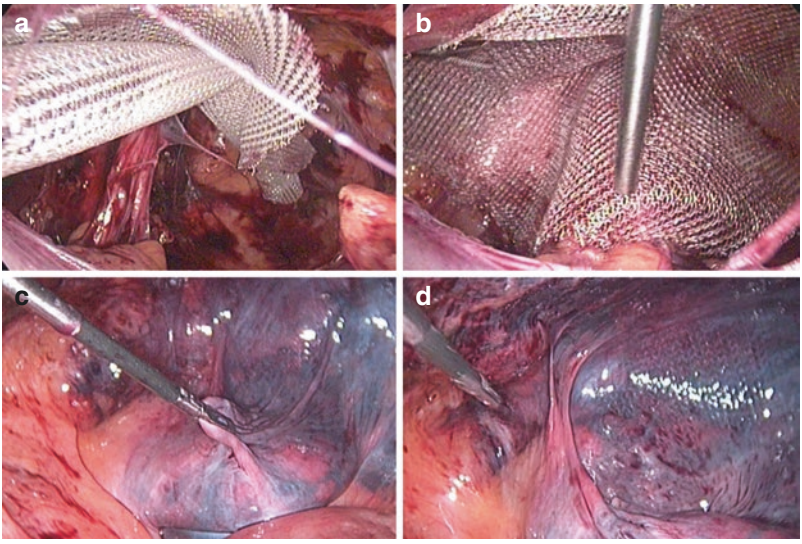

Fig. 34.15 Combined Mini-TAPP-TEP procedure. (**a**) The rolled polypropylene mesh is gently and blindly inserted through the 11 mm trocar, aiming toward the pubis. (**b**) Care is taken while spreading out the mesh completely in the preperitoneal space until it covers the entire inguinal-crural region and fits the individual anatomy. (**c**) Preperitoneal CO_2 is gradually released allowing the peritoneum to compress the mesh and keep it in place. After reinsertion of the 11 mm trocar intraperineally, it is possible to inspect the inner aspect of mesh. The surface of the mesh should give a smooth appearance without any signs of wrinkles. Note the floppiness of the well-mobilized hernia sac. (**d**) Proper implantation of the mesh is confirmed after some minor wrinkles have been smoothed out with the aid of a 3 mm forceps introduced into the peritoneal space for this purpose

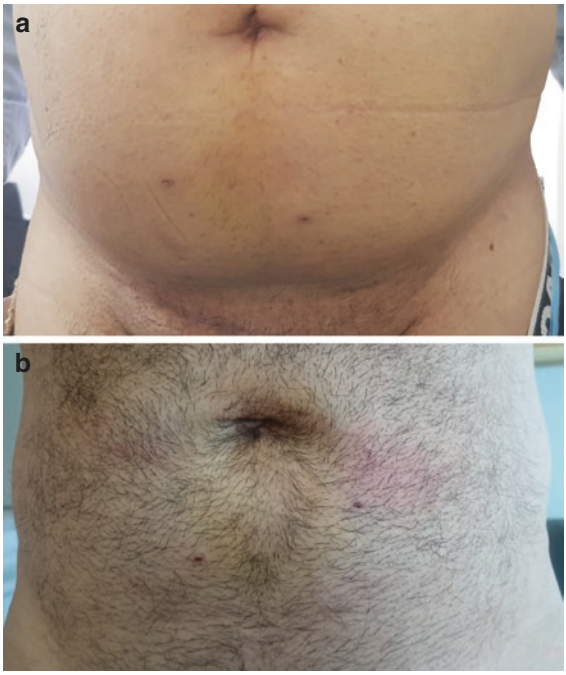

Fig. 34.16 Appearance of mini-laparoscopic skin incisions on postoperative day 5. (**a**) Mini repair of a recurrent right inguinal hernia, following two prior open repairs. (**b**) Mini repair of a left inguinal hernia

Conclusion

Mini-laparoscopy can be regarded as a natural progression and refinement of standard multiport laparoscopy. It preserves the principles of port placement, instrument triangulation, and procedure conduct. Also, if the surgeon adopts the use of low-friction Mini trocars and current generation mini instruments, increased surgical precision can be achieved. Mini requires no expensive capital expenditures, maintenance contracts, or single-use devices, an advantage over other reduced port surgery options. These factors are driving the renaissance of mini-laparoscopy.

Regarding inguinal hernia repair, mini-laparoscopy can be somewhat helpful for TAPP. It is especially helpful for TEP because TEP is executed in a constrained space. A recently developed combined Mini-TAPP-TEP technique blends together advantages of each approach, and this may become a useful option for performing almost scarless laparoscopic inguinal hernia repair, though further study is needed.

The study of mini-laparoscopy is most mature regarding its use for cholecystectomy, where level I data reveal that Mini results in less immediate postoperative pain, better short-term cosmetic outcomes, and no apparent increase in complications compared to conventional laparoscopy. While the published experience regarding mini-laparoscopy for inguinal hernia repair is less mature, the early findings appear similar—comparable safety, comparable effectiveness, and mildly improved post-op pain and cosmesis. With respect to cost, avoiding single-use disposable devices and omitting mesh fixation appear to improve cost-effectiveness.

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The Cavernous Direct Inguinal Hernia

35

Thomas Pomposelli, Grace Lassiter, and Omar Yusef Kudsi

Introduction

The "cavernous" or "giant" hernia is an informal classification given to large inguinal hernias that extend below the patient's mid-thigh upon standing [1]. A hernia of this size poses considerable problems to the patient and to the surgeon tasked with repair. Morbidities associated with giant hernias cause a significantly reduced quality of life; these include skin ulceration, infection, difficulty urinating, difficulties with mobility, and sexual dysfunction [1]. These patients are also at a greatly increased risk of morbidity and mortality following repair due to both the technical difficulties of repair and the risk incurred with potential resection of abdominal viscera which may be contained within the hernia sac. These lesions generally develop due to years of neglect; the patient population that presents with giant hernias also tends to present with a multitude of other neglected comorbidities as well [2] (Fig. 35.1).

For the surgeon, these patients present incredible challenges that are unique to their disease process. Foremost is a peculiar form of loss of abdominal domain. Because these hernias enlarge over the course of many years, the abdomen loses

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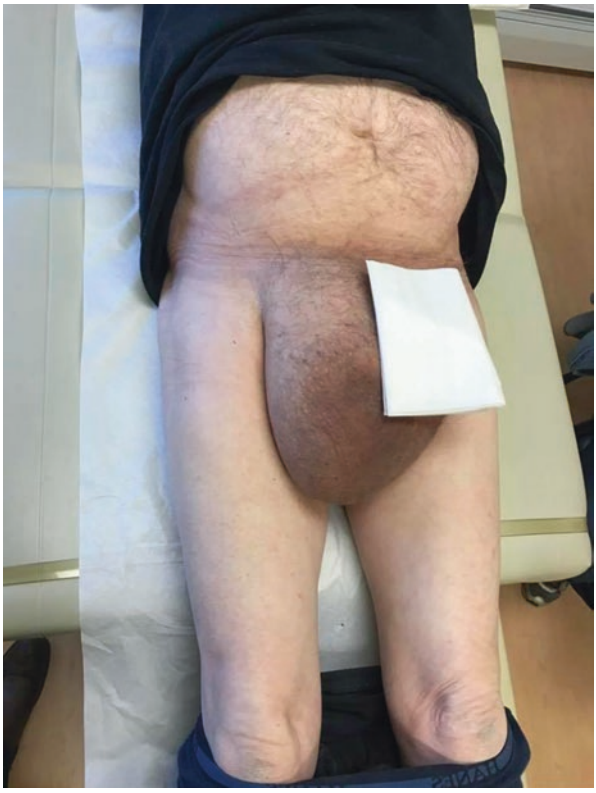

Fig. 35.1 Type III direct inguinal hernia

the anatomical accommodation it provides to the normally configured viscera. The small bowel and colon with their mesenteries as well as kidneys, ureters, and bladder have all been seen within these hernia sacs; these hernias are typically not able to be forcibly reduced [3, 4]. After surgical reduction of the herniated organs, patients are at risk for developing significant intra-abdominal hypertension in an unaccommodating abdomen, leading to respiratory failure, circulatory collapse, and cardiac arrest. Utilizing techniques to increase intra-abdominal space has become essential to managing cavernous hernias, as oftentimes extended resection of abdominal viscera will not be tolerated by this patient population [5].

Although giant hernias are a rare clinical entity, case reports are routinely published, mostly out of remote areas with little access to health care [2]. Because of the rarity of these lesions, it has not been possible to conduct large-scale comparative studies pertaining to optimal surgical management, and there remains no accepted standard of repair. Hernia specialists as well as general surgeons in underserved areas should be acquainted with the most up-to-date evidence for dealing with this challenging clinical entity.

Anatomy

A thorough understanding of the inguinal canal as well as the abdominal wall is critical in the case of giant hernias, as the intra-abdominal domain and the anatomic landmarks useful in traditional hernia repairs are often obscured. Hesselbach's triangle is the classic anatomic boundary that differentiates between direct and indirect hernias. This space is delineated by three structures: bordered medially by the lateral margin of the rectus sheath, superolaterally by the inferior epigastric vessels, and inferiorly by the inguinal ligament [6]. A hernia that arises through the internal inguinal ring is classified as an indirect hernia; a hernia that passes through the floor of the inguinal canal and medial to the inferior epigastric vessels is classified as a direct hernia [7].

The lower abdominal wall is composed of several distinct layers: (1) skin, (2) Scarpa's fascia, (3) innominate fascia, (4) intercrural fibers, (5) external oblique muscle, (6) internal oblique muscle, (7) transversus abdominis muscle, and (8) peritoneum. Although each layer is a distinct anatomic structure, they function together as a solitary unit to prevent herniation [8].

The anatomic hole located between the false pelvis and ipsilateral lower extremity is known as the myopectineal orifice. Originally described by Fruchaud [8], the myopectineal orifice is quadrangular in shape and is divided into a superior and inferior level by the inguinal ligament [9, 10]. Its role is to allow passage of the spermatic cord structures superiorly and the femoral vessels inferiorly. The boundaries of the myopectineal orifice are the arching fiber of the internal oblique superiorly, the rectus abdominis muscle medially, the anterior borders of the iliac bone inferiorly, and the iliopsoas and iliopectineal arch laterally [6, 8]. This anatomic hole can be further divided into three anatomic triangles (medial, lateral, and femoral), which are potential sites of groin herniation. Direct hernias form through the medial triangle (Hesselbach).

Epidemiology

Direct inguinal hernias represent 25–30% of groin hernias; the majority are indirect. They usually occur in men over 40 years of age [6]. Due to the rarity of giant inguinal hernias, there is no reliable data on the incidence of these lesions; however, there continues to be published case reports of these lesions on a regular basis, albeit infrequently.

Etiology/Pathogenesis

Direct hernias are generally considered to be acquired lesions. They protrude through the abdominal wall as the muscles and fascia naturally weaken with age due to normal biomechanical stresses, which is why this type of hernia is generally seen

in the middle-aged and elderly. Risk factors for direct inguinal hernia include obesity, heavy lifting, straining, coughing, or pregnancy. However, the greatest risk factor for developing a direct hernia is being male, which confers a tenfold predisposition to the lesion compared with females [6].

The current standard of care once an asymptomatic hernia is diagnosed is conservative management, as the risk of strangulation is roughly 2% per year [11]. When a hernia becomes symptomatic or interferes with the patient's activities of daily living, then operative repair is suggested. Due to the natural tendency of the abdominal wall to progressively weaken with age, direct inguinal hernias have the propensity to increase in size over time. While it is rare for hernias to attain a giant size before intervention is sought, cavernous hernias are still seen in modern practice.

An inguinal hernia is classified as "giant" when it extends below the midpoint of the thigh upon standing [12]. Trakarnsagna et al. proposed a further classification scheme based on the optimal type of operative repair: (a) Type I extending up to mid-thigh, (b) Type II extending midway between mid-thigh level and the suprapatellar line, and (c) Type III extending below the suprapatellar line [12] (Fig. 35.2). For Type I lesions, forced reduction and hernioplasty are feasible, but only with close monitoring of thoracic and abdominal pressures. For Type II cavernous hernias, some resection of hernia contents is usually required, as well as a procedure for increasing intra-abdominal volume. For Type III lesions, some resection of

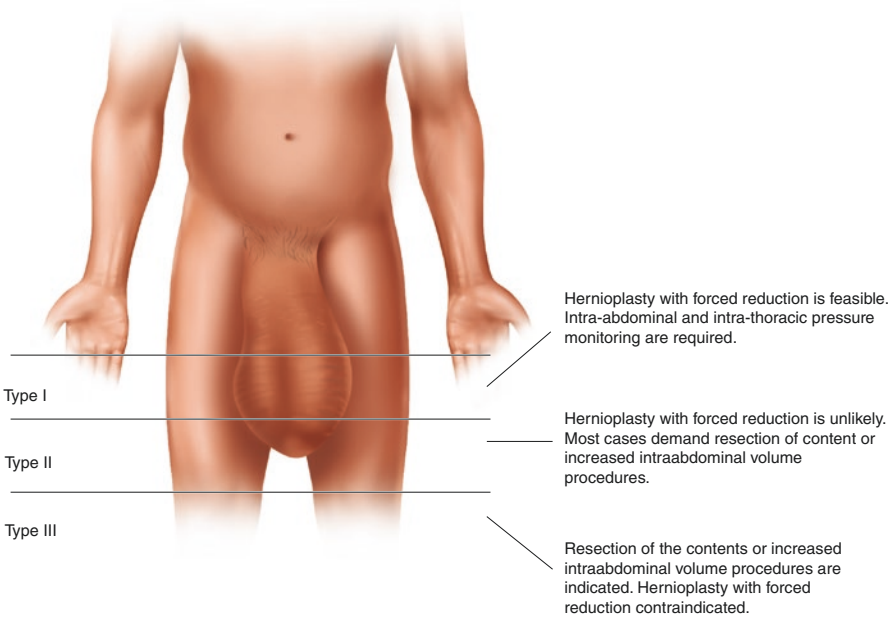

Fig. 35.2 Classification scheme for cavernous direct inguinal hernia

hernia contents is always required, and the operation must include a procedure for increasing intra-abdominal volume [12].

Often resection of hernia contents and hernioplasty are not possible in the case of giant inguinal hernias, as the content of the hernia sac is quite variable and many patients cannot tolerate extended resection of abdominal viscera. Simple forced reduction of the hernia in an attempt to spare extensive resection is usually not possible due to the risk of intra-abdominal hypertension (IAH). Due to the loss of intra-abdominal accommodation, the increased pressure in the abdomen is translated to multiple organ systems, increasing systemic vascular resistance; decreasing preload, thus affecting gut perfusion; and hindering respiration through direct pressure on the diaphragm [13]. Iatrogenic IAH may progress to multiple organ dysfunction and death quite rapidly in this already tenuous patient population who may present with poor baseline physiologic reserve. The fact that patients with giant hernias are so vulnerable to developing this syndrome was first recognized by Moreno in 1947, when he proposed increasing the abdominal space to accommodate reduction and repair of giant hernias [14]. The importance of expanding the intra-abdominal space in patients that won't tolerate resection is now recognized as an important step for repairing Type II and Type III lesions [12].

Appropriate preoperative workup is mandatory. Informed consent must cover all possible operative procedures including visceral resection. Oftentimes the final decisions are made intraoperatively, and so we favor the wording of "hernia repair, proceed as indicated." All potential decisions and outcomes must be adequately explained to the patient as well as their family members beforehand [12]. A thorough delineation of the hernia contents should also be performed in the preoperative period utilizing a contrast-enhanced CT scan [15]. There is a high likelihood that the hernia contains portions of the colon with the necessity of resection during repair [2, 11]. A thorough bowel prep should also be considered in all cases, especially in patients where the hernia sac extends beyond the imaginary line between superior borders of patellar bone [12].

Repair of Cavernous Direct Hernias

There is no gold standard for the surgical management of cavernous direct hernias; these lesions are rare and highly heterogenous in presentation. Because of the high risk of recurrence (up to 30%) as well as the risks of intra-abdominal hypertension with respiratory failure and circulatory collapse, operative strategy must be carefully considered on a case-by-case basis [6]. Currently, there exist two strategies described that surgeons have used with success: resecting the hernia contents and/or increasing intra-abdominal capacity.

Because these hernias are typically diseases of neglect, patients often present with a multitude of other comorbidities. Although performing visceral resection would typically be the safest strategy to minimize the risk of recurrence, this patient

population often lacks the physiologic reserve necessary to tolerate this type of repair. Most hernia specialists advocate a procedure to expand intra-abdominal volume as a critical component [16].

One method of repair of the Type III hernia was described by Kovachev et al., who elected to perform their repair in a staged manner by first introducing progressive pneumoperitoneum to increase intra-abdominal space [12]. Using local anesthesia, a catheter with a stop cock was inserted in the right lower quadrant, and a total of 20,000 mL of air was then instilled gradually over the course of a week. The authors instilled approximately 6000 mL of air every 3 days. After the final insufflation, the catheter was removed. All procedures were performed in the operating room using sterile technique. After this maneuver to increase intra-abdominal accommodation, they were able to successfully reduce the hernia contents back into the abdomen. The repair was performed utilizing the Stoppa technique, in which a large piece of synthetic mesh was sutured as a retromuscular sublay that covered the entire myopectineal orifice. Once the hernia contents were reduced, an incision was made in the peritoneum and a plane developed between the posterior sheath and the rectus abdominis. This dissection was carried lateral to medial until the epigastric perforator vessels were encountered, and care was taken to preserve this blood supply. The mesh was then placed in this plane, and the posterior sheath was closed primarily [12, 17]. This extended procedure, while successful, requires the patient to be hospitalized for a week preoperatively.

Merrett et al. reported repair of giant inguinal hernia via rotational musculocutaneous flaps. Preoperative progressive pneumoperitoneum was undertaken. The peritoneum was initially entered through a midline abdominal incision, and the abdomen was found to be almost completely devoid of bowel. They were able to reduce the hernia, which contained the entire small bowel and right colon. After redelivery of the bowel, the defect was repaired by suturing a Marlex mesh between the posterior edge of the inguinal ligament and the conjoint tendon, but once the repair was complete, they were unable to close the laparotomy. Inguinoscrotal skin flaps were raised, rotated to cover the midline defect, and sutured in place. The patient did well and returned 3 months later for resection of redundant skin. The authors reported no further complications from the procedure [16].

Hamad et al. presented their hybrid technique utilizing laparoscopic component separation to increase abdominal domain [5]. Their patient's hernia contained most of the colon and small bowel with only the rectum, proximal jejunum, and duodenum lying within the abdomen. After a midline laparotomy, the hernia was reduced with great difficulty, requiring division of the lower end of the left rectus abdominis. The hernia defect was then repaired extraperitoneally using a large polypropylene mesh extending from the anterior superior iliac spine to the symphysis pubis. Both the inguinal ligament and rectus abdominis muscle were repaired. Subsequently, a laparoscopic bilateral component separation was performed, with mass closure of the laparotomy incision [5].

Laparoscopic Robotic-Assisted Transabdominal Preperitoneal (TAPP) Approach

Our group has utilized a laparoscopic robotic-assisted transabdominal preperitoneal (TAPP) approach with success [8, 13, 15]. Pneumoperitoneum is achieved via Veress needle placement in the left upper quadrant (Palmer's point). Three 8.5-mm trocars are introduced in a horizontal line 4 cm above the umbilicus; each lateral trocar is positioned in the midclavicular line, and the center trocar is positioned just off the midline. All trocars are separated by at least 8 cm. The patient is then placed in the Trendelenburg position (30°), and the robot is docked at the patient's side at 30°. To avoid visceral injury in cavernous direct irreducible hernias, neither adhesiolysis nor reduction is performed at the beginning of the case; rather, these procedural steps are taken during preperitoneal dissection and mobilization of the hernia contents.

A peritoneal incision is made 4–6 cm above the inguinal canal from the anterior superior iliac spine to the median umbilical ligament, and the flap is developed with dissection in the preperitoneal space. The medial extent of dissection is carried out roughly 2–4 cm beyond the symphysis pubis to the contralateral side. The cranial extent of the dissection is carried out 4 cm above the transversalis arch. The lateral extent is the anterior superior iliac spine. The caudal extent is 4 cm below the iliopubic tract at the level of the psoas muscle and 2 cm below Cooper's ligament. The peritoneal hernia sac and associated adipose tissue from the hernia (pre-, extra-, and retroperitoneal fat tissue) are reduced toward the middle of the psoas muscle (parietalization) (Fig. 35.3), taking into consideration the importance of preserving the spermatic fascia and lumbar fascia to protect the vas deferens, nerves, and vessels. Repairing these types of hernias without addressing the cavity often leads to seroma

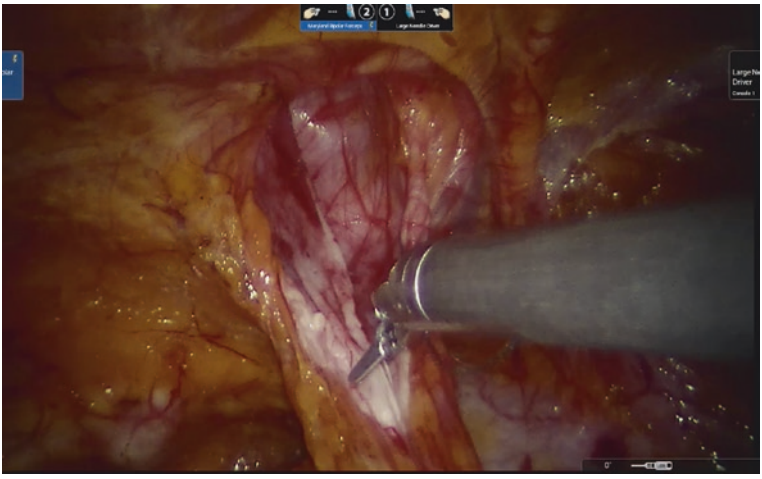

Fig. 35.3 Direct defect containing hernia sac

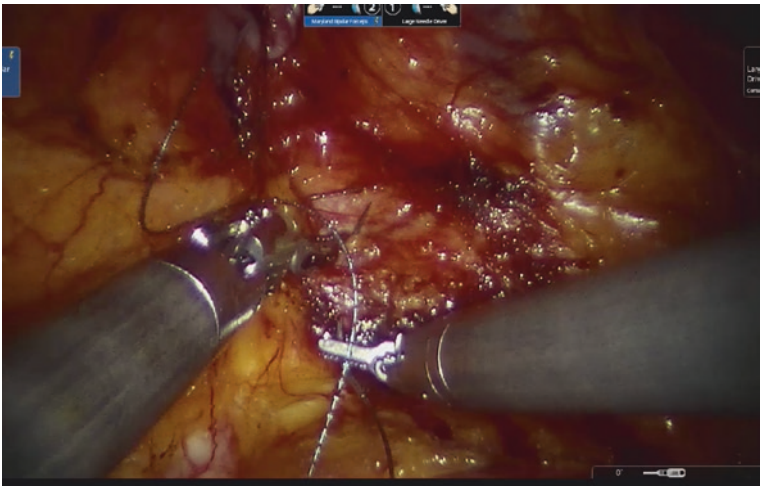

Fig. 35.4 Placing sutures in Cooper's ligament

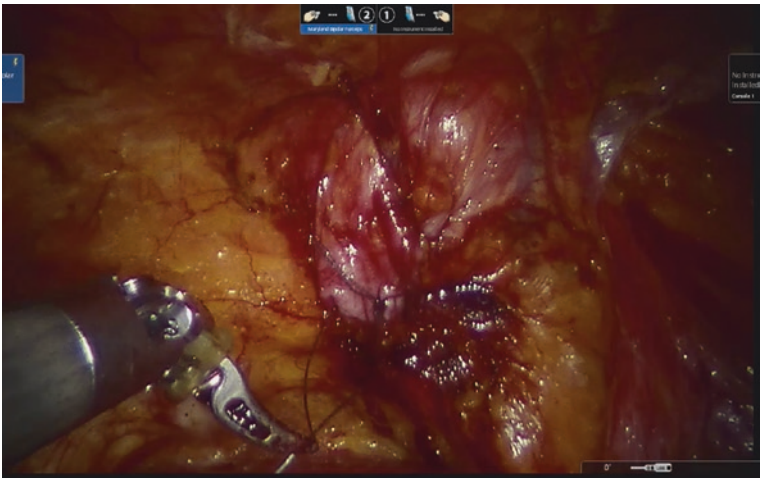

Fig. 35.5 Transversalis fascia to Cooper's ligament

formation which could impact the recovery period [1, 18]. We favor suturing the weakened transversalis fascia to Cooper's ligament via running 3-0 absorbable sutures in order to address the dead space (Figs. 35.4 and 35.5). This is to decrease postoperative seroma, as well as to have the mesh placed against the tissue rather than the cavity. It is important to avoid approaches to direct defect closure utilizing repair under tension, as this could harbor a chance of chronic groin pain due to the possibility of nerve entrapment [13] (Fig. 35.6).

We have thus far performed a total of 82 direct hernia repairs as described above with no groin pain. Complete dissection of the pelvic floor ensured flat placement of the mesh, which covered the entire myopectineal orifice without folding. We believe that

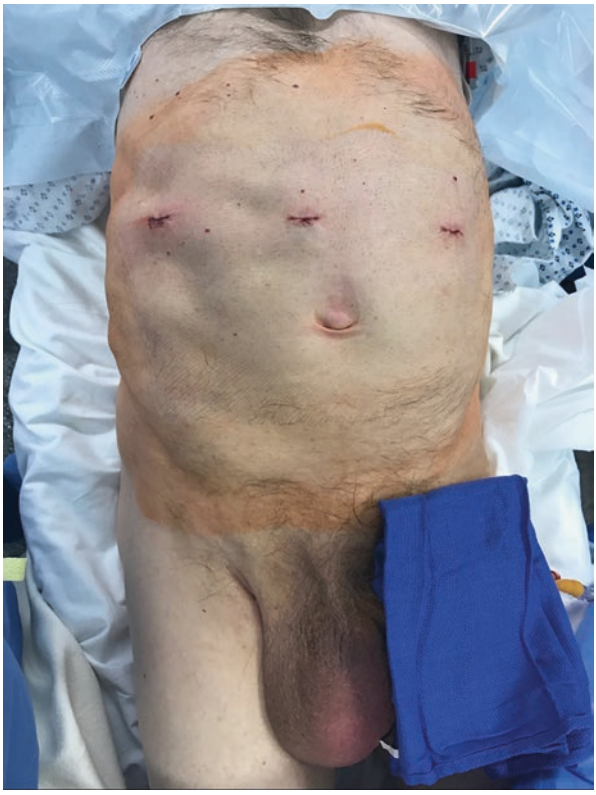

Fig. 35.6 Immediately post-op following TAPP repair

ProGrip™ laparoscopic self-fixating mesh (Covidien, New Haven, CT, USA) is advantageous due to the benefits of fixation across the whole surface. One could potentially also consider medium-weight mesh with either suturing or surgical glue on the medial side at numerous points such as Cooper's ligament and medial to the inferior epigastric vessels. Depending on the size of the hernia, we commonly use 12 × 16 cm mesh or 15 × 20 cm. Our practice is to place the mesh in the peritoneal flap without using tacks or sutures, as in our experience, we have seen an improvement in postoperative pain. After adequate positioning of the mesh is ensured, the peritoneal flap is closed using a 3-0 absorbable, barbed suture. Local anesthetic (1% bupivacaine hydrochloride, Marcaine) is infiltrated at the trocar sites prior to skin closure. We generally utilized four robotic instruments in dealing with large cavernous hernias: bipolar non-crushing grasper, non-crushing grasper, monopolar scissors, and needle driver (Fig. 35.7).

Laparoscopic Totally Extraperitoneal Inguinal Hernia Repair

What follows is a description of the laparoscopic totally extraperitoneal (L-TEP) approach that our group has also utilized with success [19]. A fascial incision is made into the anterior rectus sheath, and the rectus muscle is retracted laterally to gain entry to the preperitoneal space. A 12-mm blunt-tip trocar is placed with an

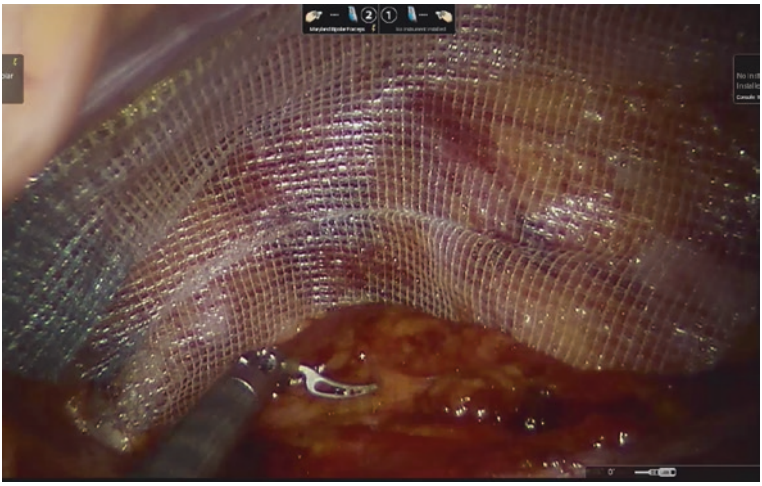

Fig. 35.7 Mesh covering myopectineal orifice with adequate medial overlap

oval dissection balloon to help delineate the anatomy of the inguinal space and dissect within the preperitoneal space. Two 5-mm trocars are then placed in the same vertical line, taking care to prevent peritoneal entry. We ensure that dissection extends superiorly to the level of the umbilical area, inferiorly to the space of Retzius, inferolaterally to the psoas muscle and the space of Bogros until the anterior superior iliac spine is reached, and medially at least 2 cm beyond the midline. In a similar fashion to the R-TAPP repair, complete exposure of the myopectineal orifice of Fruchaud is achieved. The direct hernia is reduced to the level of the psoas muscle; complete parietalization of the vas deferens and the testicular vessels is then achieved; and complete dissection of the pelvic floor is carried out to ensure flat placement of the mesh without folding or curling.

Reduction of the hernia sac occasionally presents a significant challenge, and the surgeon may not be able to properly assess the intraperitoneal organs. With this being the case, our group favors placing a 5-mm port at the conclusion of the case to evaluate the peritoneum. The transversalis is sutured to Cooper's ligament, and the mesh is placed in a similar fashion as described above.

The 12-mm balloon trocar incision is closed with a figure of 8-0 absorbable braided suture. Skin closure is performed only at the 5-mm ports. Local anesthetic (1% bupivacaine hydrochloride, Marcaine) is infiltrated at the trocar sites. In cases of peritoneal entry, we attempt to close the peritoneum with a 5-mm metallic clip, and in cases where this is unsuccessful, we place a left upper quadrant 5-mm port to decompress the peritoneal cavity, thus facilitating the completion of the L-TEP repair.

Conclusion

Cavernous direct inguinal hernias are an increasingly rare entity in modern times but when encountered present significant challenges to the surgeon as well as to the patient. As with all hernia repairs, a thorough knowledge of the anatomy and

the appropriate preoperative workup is essential. Recently, some guidance has emerged in the form of stratifying these hernias by size and correlating the safest methods of repair. Many authors have also advocated the importance of monitoring and avoiding the development of intra-abdominal hypertension, due to the unaccommodating abdomen that many of these patients present with. In terms of repair, it has been our group's practice to suture the transversalis fascia to Cooper's ligament to close the dead space and minimize the risk of seroma formation. While rare, all hernia and general surgeons should be comfortable in dealing with this challenging clinical entity.

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Femoral Hernia and Other Hidden Hernias: Options and Strategies

36

Shirin Towfigh

Femoral Hernias

The most common hidden hernia is the femoral hernia. These are uncommon hernias, represented in only 2.6% of all patients with hernias [1]. Femoral hernias are more common among women, ranging from 22 to 53% of all diagnosed groin hernias, vs. 1–8% of all groin hernias among men [2, 3]. Femoral hernia repairs are more common among women by a factor of 2:1 versus men [1–3].

Among patients that undergo femoral hernia repair, only 15.5% have a known pre-existing diagnosis of such hernia [4]. Femoral hernias can be missed at the time of first hernia surgery and are a known common cause for reoperation among women (41.6%) versus men (4.6%) [5].

At least 1/3 of all femoral hernia repairs are treated as an emergency, often due to intestinal obstruction or strangulation [3]. This is in disproportion to inguinal hernias, where less than 5% of patients require emergency operations. In the most recent population study, 14% of elective and 48% of emergency hernia repairs in women were for femoral hernias; in contrast, 0.5% of elective and 5% of emergency hernia repairs in men were for femoral hernias [6]. The need for intestinal resection is higher in patients with femoral hernias, the patients are more likely to be critically ill, and mortality is higher than the baseline elective population, by a factor of 7 [3].

Given the higher prevalence of femoral hernias among women and synchronous occurrence of femoral hernias with inguinal hernias, the International Endohernia Society and the European Hernia Society recommend that all females be surveyed and treated for femoral hernias at the time of any inguinal hernia repair [7, 8].

Though elective femoral hernia surgery is considered to be as safe as other groin operations, emergency surgery is associated with higher risk of intestinal resection, complications, and death (Koch et al. 2005; [4]). As a result, watchful waiting is not

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considered appropriate for most patients with incidentally diagnosed femoral hernias. The European Hernia Society advocates for elective repair of femoral hernias even if symptoms are "vague or absent" [8].

The gold standard approach for femoral hernia repair has been recently changed to be via laparoscopy [9]. This is significant as there are no randomized controlled trials to support this recommendation [10]. Population studies have shown higher than expected recurrence rates after femoral hernia repair, especially among women (Koch et al. 2005). Most of these are performed in open fashion. It is important to note that open repairs included retroperitoneal approaches [6]. Modern studies show consistent reduction in recurrence rates and postoperative pain after laparoscopic repair with mesh [6, 11, 12].

The laparoscopic approach for femoral hernias is no different than those typically used for incarcerated or strangulated inguinal hernias. A transabdominal or TAPP approach is the first step, allowing for reduction of the contents and surveying for ischemia and/or need for intestinal resection. Once this is completed, then an extraperitoneal mesh repair can be pursued. As with any TAPP or TEP, the entire myopectineal orifice must be covered by the mesh implant. In my practice, I permanently fixate the mesh in situations where there is a femoral hernia, as I believe the risk of mesh migration—which will result in hernia recurrence—is highest in this population. I place my permanent fixation into Cooper's ligament just inferior to the femoral space. A robotic-assisted approach would be similar.

In situations where there is contamination, such as with a strangulated femoral hernia requiring intestinal resection, I recommend a staged approach. There is strong evidence that mesh repair is superior to non-mesh for femoral hernias, so I prefer not to resort to a tissue repair. It is also not my routine to implant synthetic mesh if there is intestinal ischemia, though there are reports of safety of synthetic mesh implantation in the setting of contamination. Thus, I recommend a staged approach: Address the primary acute problem, such as with intestinal resection. Then, return for a definitive laparoscopic TEP or TAPP repair with mesh at a later date, typically no earlier than several days after the original operation. If there is concern for re-incarceration in the femoral hernia prior to the second-stage surgery, you may choose to temporarily plug the defect with an absorbable hemostatic product.

Alternative approaches to femoral hernia repair may be considered if laparoscopy is contraindicated. This includes the open infra-inguinal approach, the open trans-inguinal approach, and the open retroperitoneal approach, all with or without mesh [Fig. 36.1] [13]. The open approaches may all be performed under local anesthesia with sedation, without the need for general anesthesia. These open techniques tend to be best served in patients with relative contraindications for general anesthesia and/or in centers where there is more experience with the open as opposed to the laparoscopic techniques.

The infra-inguinal approach offers the least invasive procedure, with the least amount of exposure. It is appropriate for the least complex type of femoral hernia. It is most convenient if the hernia is palpable, in a thin patient, and is fat-containing only. The incision is made below the level of the inguinal ligament, sometimes at or

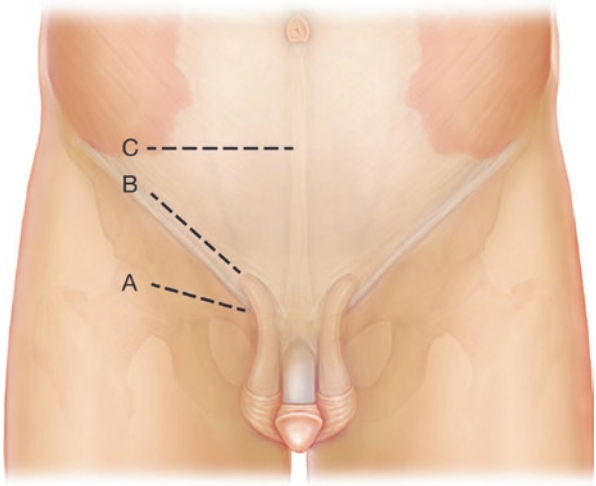

Fig. 36.1 Incisions for infra-inguinal (*A*), trans-inguinal (*B*), and open retroperitoneal (*C*) approaches (from: Towfigh S (2013) Incarcerated Femoral Hernia. In: DB Jones DB (Ed). Master Techniques in Surgery: Hernia Surgery. Lippincott, Williams, and Wilkins, Philadelphia)

above the groin crease. Too low of an incision may result in difficulty with this approach. Anatomy is important to review; otherwise, the surgeon risks injury to the femoral vein laterally or the aberrant obturator artery, found retroperitoneally along the inferior border of the femoral space in 1/3 of patients. If the hernia cannot be reduced, the lacunar ligament of Gimbernat can be incised medially, or the inguinal ligament can be transected superiorly, in order to open the space.

Repair of the defect from the infra-inguinal approach is best performed via a cigarette plug of mesh. Lichtenstein and Shore [14] first described this technique. It allows for a small space-occupying roll of mesh, cut to a short length so that it only traverses the femoral canal (i.e., 1–2.5 cm). If the plug is too long, it may impinge on the psoas muscle or the femoral nerve, resulting in postoperative pain and complications. The mesh is sewn to the inguinal ligament superiorly, lacunar ligament medially, and pectineus fascia inferiorly. No suture is placed laterally.

Primary closure of the femoral hernia has been described by Marcy and Bassini [13]. The Marcy purse-string approach involves a three-point suture through the ilioinguinal ligament, lacunar ligament, and pectineus fascia. The Bassini repair involves interrupted suture approximating the ilioinguinal ligament to the pectineus fascia. Neither technique is favorable, as both involve suturing taut ligamentous structures together. They should be considered only if the defect is no more than 5 mm. The repairs are high in tension and result in a chronic postoperative pain and high recurrence rates.

The trans-inguinal approach is the most common open technique for femoral hernia repair with mesh. Using mesh allows for a tension-free approach to patch a defect that is difficult to close primarily. The mesh options include using a flat mesh that is sewn down to Cooper's ligament to cover the femoral space while continuing as a typical Lichtenstein onlay-type repair for the rest of the inguinal floor. The mesh must be tailored so that there is a lip of mesh that extends down inferior to the inguinal ligament [13]. A sandwich-type mesh, with an onlay and underlay layer,

can also be used in this setting. The underlay component would need to be wide enough to cover the femoral space. I recommend it be sutured to Cooper's ligament to assure adequate coverage, without slippage.

Non-mesh trans-inguinal approaches can also be pursued. This would be in the setting of contamination or other relative contraindications to synthetic implant. The most well known is the McVay or Cooper's ligament repair. It involves opening the inguinal floor; any synchronous inguinal hernia should be repaired at the same setting. The conjoint tendon is sutured down to Cooper's ligament. Care must be taken not to narrow the femoral vein with this technique. A relaxing incision at the anterior rectus fascia may help reduce the tension on this repair.

Lesser known trans-inguinal non-mesh techniques include the Lytle purse-string and the Ruggi repairs [13]. The Lytle purse-string repair is essentially a posterior approach to the infra-inguinal Marcy purse-string technique. The Ruggi repair involves the approximation of the iliopubic tract to the Cooper's ligament. This increases the risk of direct hernia, so the Moschcowitz modification adds an inguinal hernia tissue repair on top of the Ruggi repair.

The open retroperitoneal approach is best performed with mesh. The major benefit of this approach is that it is essentially a low transverse laparotomy. It provides adequate exposure to address any intraperitoneal issue, such as intestinal ischemia and/or the need for intestinal resection. Meanwhile, it is low enough to approach the femoral space for hernia repair. The incision is made two fingerbreadths cephalad to the inguinal ligament. Tissue and mesh approaches have been reported by many different surgeons, including Cheatle, Henry, McEvedy, Nyhus, Stoppa, and Kugel [13]. The key is to develop the retroperitoneal space, similar to a TEP approach. If necessary, the peritoneum can be invaded and the intraperitoneal contents examined, the hernia reduced, and any other intraperitoneal procedures performed. The peritoneum is then closed and the tissue or mesh repair can be pursued. Isolated primary tissue repair can be performed à la Ruggi technique, approximating the iliopubic tract to the Cooper's ligament. For better results, a mesh repair is preferred. This can involve implantation of a large mesh, as described by Nyhus, Kugel, and others, and is very similar to the laparoscopic approach.

In summary, the femoral hernia is difficult to diagnose. Many do not know they have one until they present with a complication, such as intestinal obstruction or strangulation. Once diagnosed, watchful waiting is not recommended, and early, elective repair is considered the safest approach. Mesh options, specifically laparoscopic repair with mesh, are the gold standard. In situations where mesh may be relatively contraindicated, consider staging the repair, as non-mesh options are fraught with tension, chronic pain, and high recurrence rates.

Hidden Inguinal Hernias

The concept of the hidden inguinal hernia was first reported in the literature in the 1970s [15, 16]. Found mostly in females, the patients presented with activity-induced pain localized in the groin region yet without a "palpable clinical impulse"

on examination. They were found in 8% of their patients. Inguinal hernia repair resulted in cure of their symptoms and return to normal lifestyle.

In modern day, the hidden inguinal hernia remains a concept poorly understood and frequently misdiagnosed and undertreated. Perhaps one reason is because the majority of patients with hidden hernias are females and inguinal hernias are not often associated with females, while other pelvic pathologies are considered.

Anatomically, the female pelvis is broader, the inguinal canal is narrower, and it travels a more oblique path than in the male pelvis. As a result, a much smaller content within the canal can result in pain and pressure, without demonstrating a notable bulge. In contrast, in the narrow pelvis of males, with a wider and less angled inguinal canal, hernia contents are more likely to descend, resulting in a bulging mass or impulse on examination as their first presentation. Pain is a less common complaint among males and a later presentation of their inguinal hernia than the bulge.

A detailed history can help include a hidden inguinal hernia in the differential diagnosis of groin, lower quadrant, or pelvic pain. Pain is often at a single point, corresponding to the internal ring. The pain may radiate, which I see in half of my patients [17]. It can radiate around the back, into the vagina/testicle, down the front of the leg, or to the upper inner thigh. The pain is never below the level of the knee. There may be a neuropathic component to the pain, following the ilioinguinal or genital branch of the genitofemoral nerve, in up to 2/3 of patients [19],. The pain may be dull, sharp, and burning or feel like a "hot poker." The pain is worse with activities and best when lying flat. Activities that increase abdominal pressure, such as coughing, bending, and straining, may cause pain. Sexual intercourse and/or orgasm may be painful. In women, the pain may be worse during the menses, which I see in 15% of my patients [18]. This is considered to be due to the fluctuation of hormones, in particular the plummeting of estrogen level that triggers menses.

On examination, patients with hidden hernias will have no visible bulge or groin asymmetry. Examination while standing, with Valsalva, may help elicit a positive impulse. A very careful gentle examination may even demonstrate a vague fullness along the inguinal canal in half of the patients. Almost all patients (96–100%) will have point tenderness over the internal ring (Fig. 36.2) [19, 20]. This is considered to be the most sensitive examination finding for hidden inguinal hernias.

In my experience, I have also noted that patients with hidden hernias have pelvic floor spasm. The exact mechanism is unknown, though pain is considered to be a contributor. As a result, pelvic examination may be painful, and pelvic floor physical therapy is not helpful. Once the hernia is repaired, the pelvic floor spasm resolves. In rare cases, the patients present with severe urinary frequency due to pelvic floor spasm. Once the hernia is repaired, the frequency is cured, presumably because the spasm is resolved.

Imaging is often necessary to secure the diagnosis, as history may be suggestive of an inguinal hernia, but examination is not necessarily diagnostic. The typical imaging modalities of ultrasound, computed tomography (CT), and magnetic resonance imaging (MRI) can be helpful. It is important to note that each examination

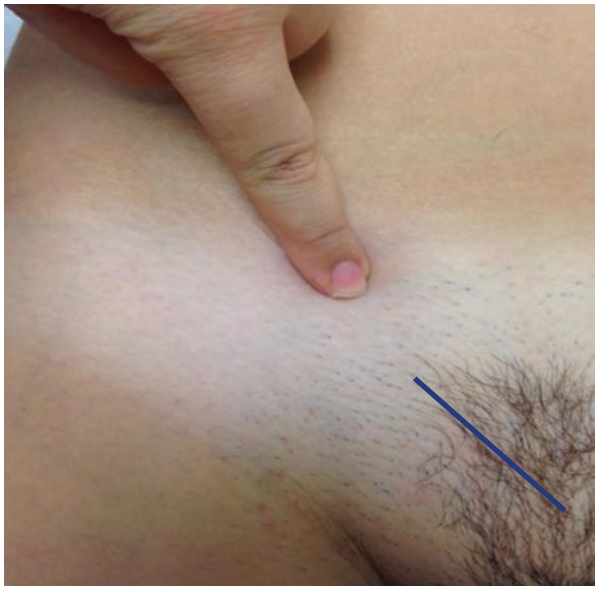

Fig. 36.2 On examination for hidden inguinal hernias, maximal point tenderness is found over the internal ring, which is approximately halfway between a line from the anterior superior iliac spine and the pubic tubercle

Study	Sensitivity	Specificity	Predictive Value	
			Positive	Negative
Ultrasonography	0.33	0	1.00	0
Computed tomography	0.54	0.25	0.86	0.06
Magnetic resonance imaging	0.91	0.92	0.95	0.85

Fig. 36.3 Sensitivity and specificity of imaging modalities for evaluation of hidden inguinal hernias (from: Miller J, Cho J, Michael MJ et al. (2014) Role of imaging in the diagnosis of occult hernias. JAMA Surg 149 (10):1077–1080)

has its pitfalls and it is not uncommon to undergo imaging with negative findings, often falsely negative.

Ultrasound is a low-cost and excellent modality for diagnosis of most hernias. It has a 100% positive predictive value (Fig. 36.3). However, the imaging must be performed with maneuverings, including Valsalva, standing, etc., in order to optimize its sensitivity. Though CT scan is widely used for evaluation of abdominal pain, it is poor for diagnosis of hidden inguinal hernias [8]. It can be performed with Valsalva to help improve its sensitivity. Nevertheless, for hidden inguinal hernias, we have shown it has only 25% specificity [21]. The most sensitive and specific imaging for hidden inguinal hernias is the MRI (91%, 92%, respectively). In our experience, the addition of Valsalva to the images provides even more positive predictive value. If ultrasound and CT scan are negative for hernia in a patient with high clinical suspicion for inguinal hernia, then MRI should be considered before taking inguinal hernia off the differential diagnosis (Fig. 36.4).

Inguinal hernia repair for hidden hernias follows the same decision-making as for any other indirect inguinal hernias. Since the majority of these patients are

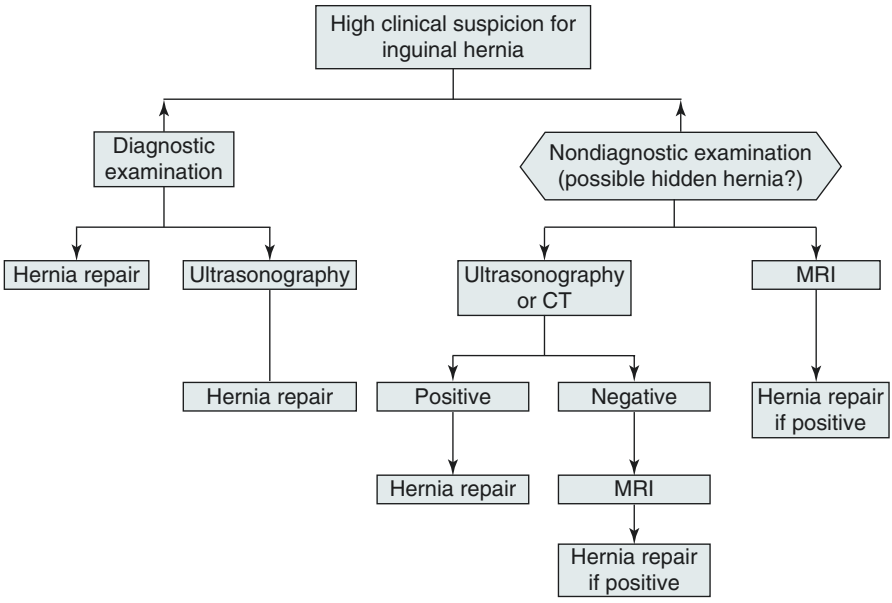

Fig. 36.4 Treatment algorithm for patients with hidden hernia (from: Miller J, Cho J, Michael MJ et al. (2014) Role of imaging in the diagnosis of occult hernias. JAMA Surg 149 (10):1077–1080)

female, laparoscopy may be considered more often. Laparoscopy is also a nice way to survey for hidden hernias without committing to a repair.

It's important to note that the majority of patients with hidden hernias only have retroperitoneal fat in the inguinal canal. There is little to no peritoneal extension into the hernia; that may be found at later stages of these hernias. Since pain is the first indication of a hernia, the amount of content and extension into the inguinal canal may be minimal. Thus, exploratory laparoscopy or TAPP approach may initially show a normal flat inguinal region, without invagination of the peritoneum into the internal ring. For appropriate evaluation for inguinal hernia, the peritoneum and associated retroperitoneal fat must be dissected off the abdominal wall, exposing the internal ring at the level of the muscle. If there is any content within the ring, in the clinical scenario of a hidden inguinal hernia, then emptying the canal of all its content and repairing the hernia are appropriate.

In my experience, in some females, the smallest amount of content may result in a disproportionately high level of pain. The size of hernia does not correlate directly with symptoms; in fact, in most cases, there is an inverse relationship. Hernia repair can result in cure of the pain in at least 87% of patients.

In summary, hidden inguinal hernias are a known but underdiagnosed entity. It is found more commonly in females. The hernia content is usually of retroperitoneal fat, with minimal peritoneal extension. History is key, often describing an activity-related pain that can radiate. Examination may only demonstrate point tenderness over the internal ring, but that is a highly sensitive finding. Imaging can help

confirm the diagnosis, understanding that ultrasound and CT scan have very low specificity. When these studies are negative, MRI should be considered, preferably with Valsalva. Repair should be tailored to the needs of the patient and will result in a high rate of cure of the original pain.

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Strangulated Inguinal Hernia: Options and Strategies

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Kara A. Vande Walle and Jacob A. Greenberg

Strangulated inguinal hernias represent a surgical emergency that are dealt with frequently over the course of a surgical career. The efficient diagnosis and appropriate management of strangulated inguinal hernias are of critical importance to ensure good patient outcomes. In this chapter, we will review the options and strategies for repair of strangulated inguinal hernias.

Incidence

Inguinal hernia repair is one of the most common operations performed in general surgery. Despite the high incidence of hernia formation, the risk of bowel strangulation from an inguinal hernia is relatively low. Only 3.8% of inguinal hernia repairs are done on an emergent basis, and not all of these are for strangulation [1]. The overall incidence for emergent repair is 0.0076 per 100 person-years compared to 0.2 per 100 person-years for elective inguinal hernia repair [1]. The incidence of emergent inguinal hernia repair has been decreasing over the past 20 years for both men and women based on a study done by Mayo Clinic [1]. Multiple randomized clinical trials have further supported the low incidence of strangulation [2, 3]. In a North American trial of men with asymptomatic or minimally symptomatic inguinal hernias managed by watchful waiting with approximately 10 years follow-up, only 2.4% underwent emergent surgery for a bowel obstruction or strangulation from the hernia with an incidence of 0.2 per 100 person-years [2]. The low rate of strangulation has led to the acceptance of watchful waiting as a management option for asymptomatic and minimally symptomatic inguinal hernias, although most patients will develop symptoms necessitating operative intervention [2].

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There are multiple risk factors that increase the chance for strangulation of an inguinal hernia. Age >70, underweight, overweight, ASA class ≥3, femoral hernias, recurrent hernias, and females are all associated with increased risks of incarceration and strangulation [1]. In these patients, consideration should be given to elective hernia repair instead of watchful waiting given the increased incidence of strangulation.

Presentation and Diagnosis

A hernia becomes strangulated when there is compromise of the blood supply to the incarcerated structures. Any structure located in the pelvis can become strangulated, but the most common structures involved are omentum and bowel. Strangulation occurs when the incarcerated contents are encircled by a tight hernia defect causing tissue edema. The edema causes venous stasis and decreased perfusion to the incarcerated contents. Ischemia follows and can lead to necrosis and perforation. A patient may present at any time during this course.

In the early stages, it may be difficult to differentiate an incarcerated hernia from a strangulated hernia. Patients typically present with acute onset of pain and a tense bulge at the hernia site. There may also be overlying skin erythema. In the case of a strangulated femoral hernia, the bulge may be difficult to feel if it is small. Patients will also often present with signs of obstruction including nausea, vomiting, and obstipation. As ischemia progresses, the patient may develop diffuse abdominal pain and fever. Distributive shock and peritonitis may develop if the strangulated bowel perforates.

The diagnosis of a strangulated inguinal hernia can usually be made based on a thorough history and physical exam. Most patients will have a history of a reducible groin bulge that became irreducible in the recent past. Laboratory values may show an elevated white blood cell count as well as an elevated lactate. While imaging is frequently not necessary and may delay definitive management, imaging may be helpful in certain cases. Plain abdominal films may show dilated bowel consistent with obstruction, pneumatosis consistent with ischemia, and/or pneumoperitoneum consistent with bowel perforation. Computed tomography will accurately make the diagnosis by showing the incarcerated contents in the hernia. There may be signs of bowel ischemia including pneumatosis intestinalis, pneumatosis portalis, bowel wall thickening, and changes in bowel wall enhancement and/or evidence of bowel perforation with pneumoperitoneum.

In the event of a recently incarcerated hernia without any signs or symptoms of possible bowel ischemia, reduction may be attempted within a few hours of incarceration. However, hernia reduction should not be attempted preoperatively if there is suspicion of a strangulated hernia. This may reduce threatened or necrotic bowel and cause diffuse peritonitis and an increased inflammatory response. It will also require the surgeon to perform laparoscopy or laparotomy to evaluate the reduced bowel for viability.

Operative Management

Strangulated inguinal hernias require emergent operative intervention for resolution. The most important aspect of management of strangulated inguinal hernia is minimizing the time from the onset of symptoms to beginning the operation since strangulated bowel may undergo necrosis in as little as 6 hours of symptom onset. There are several operative approaches for strangulated inguinal hernia, and selecting the appropriate approach is dependent on the presentation of the patient, prior operations, and surgeon comfort. Options include open repair with or without mesh and minimally invasive repair including laparoscopic totally extraperitoneal (TEP) and laparoscopic or robotic transabdominal preperitoneal (TAPP) repair.

Open Repair

Open repair is the classical approach to repair of a strangulated hernia and is most commonly performed via an anterior approach. In an open anterior repair, an incision is made in the groin over the strangulated inguinal hernia. The hernia sac is then identified and opened. The bowel should be inspected for necrosis or signs of ischemia. Bowel resection should be performed if necrosis or ischemia is present and can generally be performed through the groin incision. In the event that the bowel appears healthy, it may be reduced into the peritoneal cavity. Repair of the hernia defect may then be performed through a tissue-based repair or mesh repair.

There are several tissue-based techniques for open inguinal hernia repair. The Bassini repair involves suturing the conjoint tendon (formed by transversus abdominis and internal oblique) to the inguinal ligament. This was a popular method to electively repair primary inguinal hernias in the past but is now infrequently used. In the McVay repair, interrupted sutures are placed from the transversalis fascia to Cooper's ligament starting medially. Once the femoral sheath is reached, Cooper's ligament is sutured to the iliopubic tract to close the femoral canal. As the repair continues laterally, sutures are placed from the transversalis fascia to the iliopubic tract. A relaxing incision is then made at the lateral border of the anterior rectus sheath starting just above the pubic tubercle and extended superiorly to reduce the tension on the closure of the canal floor. The rectus muscle protects against herniation through the new defect. This is the only tissue-based repair that repairs both inguinal and femoral defects. The Shouldice technique is currently the most popular tissue-based repair as it is associated with the lowest recurrence rates of the tissue-based repairs. The Shouldice repair involves the use of two separate continuous running sutures to close the floor of the inguinal canal in four layers. Surgeons who perform the Shouldice technique require significant expertise and experience to obtain low recurrence rates.

The most common open mesh repair is the Lichtenstein repair. The Lichtenstein repair is an anterior, tension-free repair that uses mesh to recreate the floor of the inguinal canal as well as the internal ring. This method involves using a piece of polypropylene mesh fitted to the floor of the inguinal canal to prevent direct recurrences. The mesh contains a slit made in the superior portion to allow passage of the

spermatic cord and to recreate an internal ring and prevent indirect recurrences. The mesh is sutured to the aponeurosis of the pubic tubercle and then to the shelving edge of the inguinal ligament laterally and the conjoint tendon medially. The two tails are sutured together to recreate the internal ring. Care must be taken to identify the ilioinguinal nerve, iliohypogastric nerve, and genital branch of the genitofemoral nerve to ensure that they are not incorporated into the sutures used to secure the mesh. Another option for tension-free mesh repair is the plug and patch. A cone-shaped plug is inserted into the internal ring and deployed to close the defect. The plug is then sutured in place, and a mesh patch overlies the plug and the inguinal canal. The patch is generally secured in a similar fashion to a Lichtenstein repair.

While an anterior approach is the most common technique for inguinal hernia repair, another option is a posterior preperitoneal repair. In this technique, a transverse incision is made 2 cm above the inguinal ligament slightly more medial than an anterior approach. The anterior rectus sheath, external oblique, and internal oblique muscles are incised. The transversalis fascia is then incised along the edge of the rectus in order to enter the preperitoneal space. The hernia sac is then exposed and opened. The hernia sac contents are inspected and reduced. If there is ischemic or necrotic bowel, it is resected at this time. The hernia sac is then closed, and the hernia defect is repaired with either a tissue-based (McVay or iliopubic tract) or prosthetic mesh repair. A randomized controlled trial performed by Karatepe et al. [4] compared preperitoneal repair with prosthetic mesh to Lichtenstein repair for 38 patients with incarcerated or strangulated hernias. They reported no mesh infections or recurrences in either group with a mean follow-up of almost 2 years [4]. They argue that a preperitoneal approach is safe and effective in incarcerated and strangulated hernias and has several advantages including easier exposure of the hernia defects and more proximal control of incarcerated contents with improved access to the peritoneum if bowel resection is required.

Induction of general anesthesia causes an incarcerated hernia to reduce approximately 1% of the time [5]. When this occurs, the abdominal cavity must be visualized to assess the viability of the bowel. This may also be necessary if the bowel cannot be adequately evaluated from the groin incision. Inspection of the bowel may be done with laparoscopy, laparotomy, or hernioscopy. If persistently ischemic or necrotic bowel is found, bowel resection of the affected segments should be performed (Figs. 37.1 and 37.2) [6]. Hernioscopy may be performed during an open approach to hernia repair. During hernioscopy, the hernia sac is identified and opened, and a purse-string suture is placed at the apex of the hernia sac. A laparoscopic port is placed through the opening in the hernia sac and secured by tying down the purse-string suture. Pneumoperitoneum is then obtained by connecting the carbon dioxide insufflation, and a laparoscope is inserted through the port to allow for inspection of the bowel. Additional 5 mm ports may be placed in the abdomen under direct visualization to manipulate the bowel for closer evaluation. Once inspection is completed, the laparoscope is removed as well as any ports that were used. The hernia can then be repaired in any of the manners listed above. This procedure is relatively simple to complete and useful for those surgeons less familiar with laparoscopy [5].

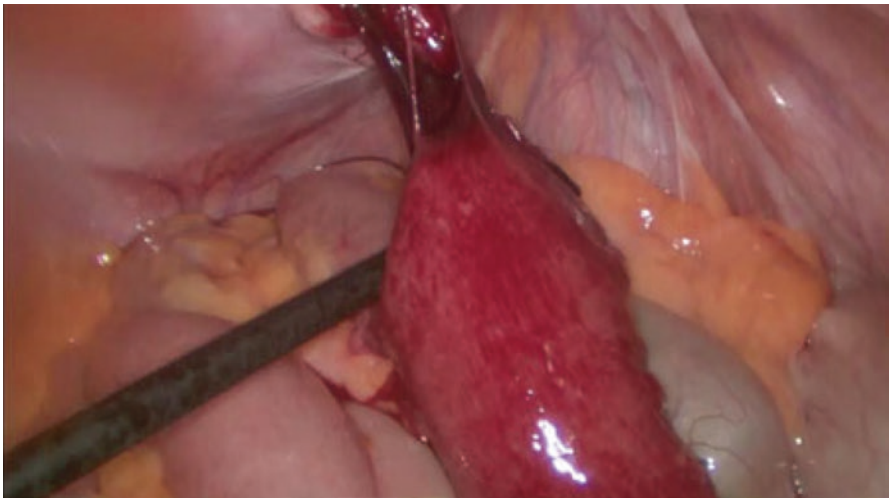

Fig. 37.1 Characteristics of ischemic but ultimately viable bowel from a strangulated inguinal hernia. Note the uniform *red* discoloration. This bowel also demonstrated peristalsis on inspection (From Pearl and Ritter [6] with permission of Springer)

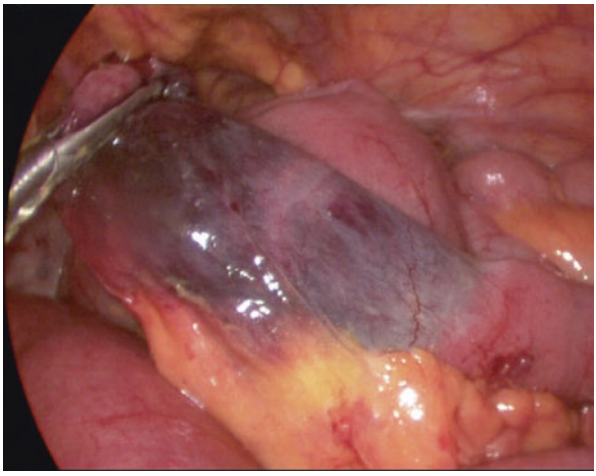

Fig. 37.2 Example of necrotic small bowel from a strangulated inguinal hernia. Note the areas of *deep purple* discoloration and the areas of blanching serosa. The grasper on the *left* is controlling spillage from an area of perforation (From Pearl and Ritter [6] with permission of Springer)

Mesh in Open Repair

There remains controversy over the use of mesh in strangulated hernias due to concern of an increased risk of wound and mesh infection from bacterial translocation. The advantage of a mesh-based repair is a decrease in recurrence, which has led to the European Hernia Society recommendation that a mesh repair be used over a non-mesh repair in clean inguinal hernias [7]. Additionally, it is generally accepted that mesh repair should not be performed when the patient has

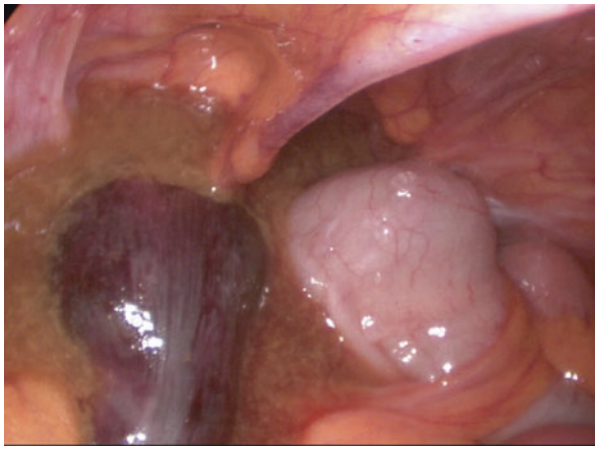

Fig. 37.3 Gross contamination from small bowel perforation secondary to a strangulated obturator hernia. Prosthetic mesh is best avoided in this situation (From Pearl and Ritter [6] with permission of Springer)

generalized peritonitis or there is gross contamination of the surgical field (Fig. 37.3) [6]. There have been a number of studies investigating the use of mesh in repair of acutely strangulated and incarcerated hernias in patients that did not have generalized peritonitis or gross contamination. A recent study done by Bessa et al. [8] included 234 patients from a single center with acutely incarcerated or strangulated hernias that were repaired with the Lichtenstein tension-free repair using monofilament polypropylene mesh and had a mean follow-up time of 62.5 months [8]. Bowel resection for ischemic or necrotic bowel was performed in 13.7% of patients. Mesh infection occurred in 0.5% of patients with subsequent removal of the mesh. Wound infection occurred in 6% of patients, all of which were obese patients who were adequately treated with antibiotics. There was no difference in wound infection between those who underwent bowel resection and those who did not. Recurrence occurred in 0.9% of patients, and the mortality rate was 2.1%. Multiple earlier studies investigating the use of mesh in acutely strangulated and incarcerated inguinal hernias with 11 months as the shortest follow-up time showed a mesh infection of 0%, wound infection rates of 0–10.3%, and recurrence rates of 0–5% [9–17]. Chronic mesh infections may take years to develop and may not be accounted for in these studies.

A systematic review with meta-analysis published by Hentati et al. [18] compared mesh repair versus non-mesh repair for strangulated inguinal hernias [18]. There was no significant difference in wound infection between the mesh and non-mesh groups. There was a significant difference in recurrence rates with 2.2% in the mesh repair group compared to 4.6% in the non-mesh repair group. This analysis was limited in that only two of the nine studies were randomized controlled trials resulting in possible selection bias. In a retrospective study done by Nieuwenhuizen et al. [19] of incarcerated and strangulated abdominal wall hernias (37% inguinal), there was an increased rate of wound infection in patients who required a bowel resection compared to those that did not require a bowel resection (OR 3.53) [19].

It is clear that mesh-based repairs have a lower recurrence rate than tissue-based repairs in emergent inguinal hernia operations. This decreased recurrence rate should

be balanced with the possibility of mesh and wound infections. As a result, mesh should not be used in patients with diffuse peritonitis or gross contamination due to the high risk for infection, and these patients should preferentially undergo a tissue-based repair. The Shouldice repair has the lowest rate of recurrence of the tissue-based repairs and should be performed in this situation if the surgeon possesses the expertise and experience to perform the procedure. In the event that a tissue-based repair is unable to be completed, the hernia can be repaired at a later time, or biologic or synthetic absorbable mesh may be used to repair the defect. In the absence of diffuse peritonitis and gross contamination, many studies have reported a low rate of mesh infection and wound infection with mesh use in acutely incarcerated and strangulated hernias. This data suggests it is safe to use mesh in emergent hernia operations. However, there remains conflicting data on the use of mesh with concomitant bowel resection, and thus mesh use in these patients should be decided on a case-by-case basis at the discretion of the surgeon. If mesh is used, lightweight, macroporous materials should be utilized to repair the defect. In addition, all patients with incarcerated and strangulated hernias should be given preoperative antibiotics which are continued for 24 h to 4 days postoperatively depending on the presence of ischemic or necrotic bowel requiring resection in order to prevent mesh and wound infections.

Laparoscopic Repair

The two most prevalent laparoscopic repairs for acutely incarcerated or strangulated hernias are the totally extraperitoneal (TEP) and transabdominal preperitoneal (TAPP) repairs. When performing TEP for suspected strangulated hernia, the peritoneal cavity should be visualized to inspect the bowel since the peritoneum is typically not entered in this approach. This can be done by placing a transperitoneal laparoscopic port at the umbilicus or in the subcostal region with additional ports placed as needed for bowel manipulation. The hernia can be reduced at this point. After the bowel is evaluated, the abdomen is desufflated, and TEP repair can then be performed. An infraumbilical incision is made, and the anterior rectus sheath is incised. After retracting the rectus muscle laterally, the space posterior to the rectus is developed, and a balloon dissector is inserted down to the pubic symphysis. The preperitoneal space is insufflated, and two more ports are placed in the lower midline. Cooper's ligament is cleared medially, and the space is opened laterally to the anterior superior iliac spine. The iliopubic tract is identified, and the cord structures are dissected free of the peritoneum. Once the hernia sac has been reduced, a piece of mesh is placed between the transversalis fascia and the peritoneum.

To perform a TAPP repair, the peritoneal cavity is accessed with an infraumbilical incision. Two more ports are placed laterally with one on each side of the umbilicus. Next, the hernia is reduced with the assistance of manual compression and/or enlargement of the hernia defect. The bowel is inspected for evidence of ischemia or necrosis. The peritoneum is then incised at the medial umbilical fold and carried laterally to the anterior superior iliac spine superior to the hernia defect. This peritoneal flap is reflected inferiorly to expose Cooper's ligament, the iliopubic tract,

and the epigastric vessels. The hernia sac is reduced as the cord is freed of peritoneal attachments. Once this is complete, a piece of mesh is placed between the transversalis fascia and the peritoneum. The mesh may be fixated with sutures, tacks, fibrin glue, and self-adhesing materials or placed in the space without fixation. The reflected peritoneal flap is then replaced over the mesh and tacked or sutured in place. If ischemic or necrotic bowel remains, resection is performed at this time either completely laparoscopically or laparoscopic-assisted.

In the event that the hernia is not easily reduced during hernia repair, there are different strategies for reduction depending on the type of hernia. For an indirect hernia, the epigastric vessels can be divided, and/or a releasing incision can be made in the internal ring at 12 o'clock toward the external ring to improve hernia sac dissection (Fig. 37.4) [20]. For a direct hernia, a releasing incision can be made at the anteromedial aspect of the defect to avoid vascular injury (Fig. 37.5) [20]. For a femoral hernia, a releasing incision can be made at the medial femoral ring at the iliopubic tract insertion into Cooper's ligament (Fig. 37.6) [20].

Another option is to perform a two-stage laparoscopic repair of the hernia. In this approach, a diagnostic laparoscopy is performed on presentation in order to reduce the hernia and resect bowel if needed. The hernia is left unrepaired with a plan to return to the OR in the near future for definitive repair. At that time, a second operation is performed to repair the hernia with the TEP method. The authors theorize that this approach may decrease the rate of mesh infection as the mesh placement is delayed and that this may have application in elderly patients who would benefit from decreased operative time and possibility of mesh infection in the acute setting [21].

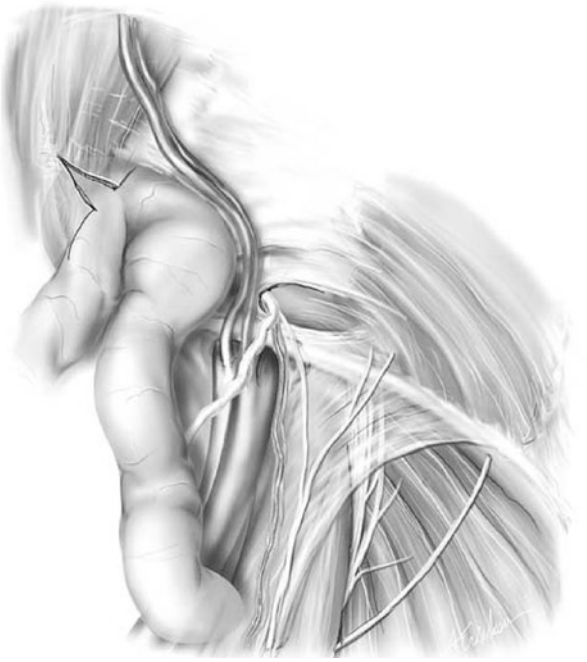

Fig. 37.4 Site of releasing for indirect hernia (From Ferzli et al. [20] with permission of Springer)

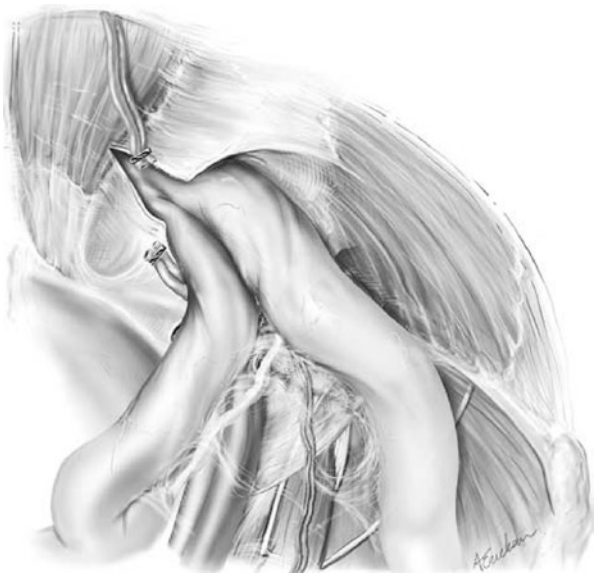

Fig. 37.5 Site of releasing incision for direct hernia (From Ferzli et al. [20] with permission of Springer)

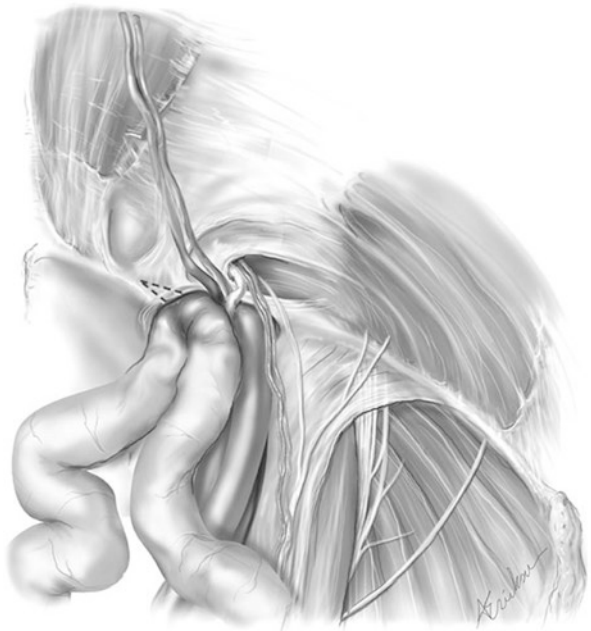

Fig. 37.6 Site of releasing incision for femoral hernia (From Ferzli et al. [20] with permission of Springer)

The utilization of laparoscopy in the repair of elective inguinal hernias has been rising in recent decades [1]. A Cochrane review from 2003 showed that there was no difference in recurrence between laparoscopic mesh repairs and open mesh repairs [22]. Laparoscopic cases take longer and have a higher risk of rare serious complications (bladder, vascular) but have a quicker recovery as well as

less pain and numbness over time [22]. Laparoscopy has also been used in acutely incarcerated and strangulated inguinal hernia repair since the early 1990s. A retrospective analysis of 188 patients performed by Yang et al. [23] compared emergency open inguinal hernia repair with laparoscopic repair using either TEP or TAPP. The mean length of stay was 4.39 days in the laparoscopic group and 7.34 days in the open group, but this was not statistically significant. There were no mesh infections in either group, but there was an increased rate of wound infection in the open group. Additionally, the laparoscopic repair group had fewer bowel resections [23]. This study, as well as others, have shown that laparoscopic repair of acutely incarcerated and strangulated hernias is feasible and can be performed with low complication rates [20, 24, 25]. A systemic review was performed by Deeba et al. [26] on the use of laparoscopy in inguinal hernia emergencies [26]. A total of 7 studies (4 TAPP, 3 TEP) were included with a total of 328 patients. Bowel resection was performed completely laparoscopically or laparoscopic-assisted in 17 patients (5.2%). They reported six conversions (1.8%) for iatrogenic bowel injury, omentectomy, bowel distention, extensive intra-abdominal adhesions, and obturator hernia. There were 34 total complications (10.4%) reported with 25 of them considered minor. Complications included a Veress needle injury to the left colon, cecal injury and subsequent mesh infection with salvage of the mesh through reoperation and irrigation, two reoperations for salvage of infected mesh by drain placement, vas deferens injury, and reoperation for distended abdomen with negative results [26].

Advantages of the laparoscopic approach include the ability to evaluate the viability of the small bowel without laparotomy, evaluation for occult hernias, decreased rates of wound infection, and quicker recovery. Additionally, laparoscopic repair may make reduction of the hernia easier by increasing the size of the hernia defect from insufflation. However, laparoscopic repair of acutely incarcerated or strangulated hernias is technically demanding and should not be performed unless the surgeon has significant experience with elective laparoscopic repairs. The bowel is generally dilated and edematous which limits the working space inside the abdomen. Additionally, the bowel must be carefully handled to prevent perforation. Laparoscopic repair should be avoided in patients with hemodynamic instability, a hostile abdomen, or when the surgical expertise is not available. In addition, in the event a bowel resection needs to be performed, consideration should be given to an open tissue repair so that mesh is not present in a clean contaminated field as there is limited data on the occurrence of mesh infection in laparoscopic repairs of strangulated inguinal hernias with bowel resection.

It remains unclear whether TEP or TAPP is preferred in emergency hernia surgery. A potential advantage of TEP for surgeons concerned about mesh infection is that the mesh is placed in a field outside of the peritoneum, which may reduce contamination. When performing TEP, the transperitoneal trocar must be kept away from the TEP operative field to prevent a peritoneal hole, which will possibly lead to seeding of the mesh with bacteria. The decision to perform TAPP or TEP should be based on surgeon experience and comfort.

Conclusion

Strangulated inguinal hernias are surgical emergencies. In the presence of diffuse peritonitis or gross contamination, a tissue-based repair should be performed. Shouldice repair has the lowest rate of recurrence and should be performed in this situation if the surgical expertise is present. When a strangulated hernia requires bowel resection, there is mixed data in whether mesh should be used in an open repair and limited data in laparoscopic repair, and as a result an open tissue-based repair should be considered. In an acutely incarcerated or strangulated inguinal hernia where all the bowel is viable, an open mesh repair or laparoscopic mesh repair may be used depending on surgeon experience and the patient's prior surgical history.

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Groin Pain Syndromes in Athletes: "Sports Hernia"

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Brian S. Zuckerbraun and Craig S. Mauro

Introduction

Groin pain syndromes are frequently present among amateur and professional athletes. However, there are few entities that are as poorly understood by health-care professionals as the spectrum of diagnoses that contribute to groin pain. In the absence of groin hernias or hip joint pathologies, groin pain is perplexing to most general practitioners and surgeons. This is not surprising, as the etiologies of groin pain can be difficult to discern on exam and imaging studies may or may not show definitive findings that account for the individual's symptoms. The literature consists mainly of case series and opinions that describe groin pain in athletes using varied nomenclature. These reports have lacked clarity and only recently have been coming to agreements on how to classify and describe the constellation of symptoms, exam findings, imaging results, and operative findings. Thus there has been minimal progress in educating more physicians about the diagnosis as well as surgeons regarding management. There is a lack of literature to draw clear consensus on many issues regarding groin pain syndromes, and the surgical community needs to agree upon a common language and necessary aspects of assessment, so that the beginnings of meaningful comparisons can be made.

This chapter will attempt to classify groin pain syndromes and describe common findings in these patients. The aspects that need to be included in the assessment of

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individuals with chronic groin pain will be addressed. Finally, the anatomy, hypothesized pathophysiology, and treatments, including various surgical approaches, will be described.

Nomenclature

The groin pain syndromes that we are referring to in this chapter are essentially nonhernia and non-ball-and-socket hip joint causes of groin pain. These causes of groin pain have been found primarily in athletes and physically active individuals. Thus common names have included sports hernia, sportsman's groin, athletic pubalgia, Gilmore's groin, incipient hernia, core muscle injury, inguinal disruption, and several others [1–4]. Using the term hernia is misleading. Some names are broadly descriptive but do not aptly describe the clinical entity. Thus, we favor the noncommittal but highly descriptive and inclusive term *groin pain syndromes*.

Anatomy

It is imperative to consider the anatomy of the groin to conceptualize these disease processes. This includes the bony anatomy, the muscles and forces applied, and the ligaments that converge upon the pelvis, both from the abdominal wall and the thigh.

The bones of the pelvis include the hip bones, the sacrum, and the coccyx. Anterior medially, at the pubic symphysis, the two hip bones meet and are joined by a fibrocartilaginous disc. The femoral heads sit within the acetabulum of the hip bones to form the hip joints.

The muscular anatomy and the forces applied to the pelvis are critical to understand. Meyers and colleagues have framed the relevant anatomy and the torque upon the pubic bone and symphysis in the terms of what they have called the "pubic joint" [2, 5, 6]. This group has categorized the forces into three main compartments, the anterior, posterior, and medial compartments (Fig. 38.1a). The anterior compartment of the abdomen is made up of the abdominal muscles. The anterior compartment in the thigh is made up of muscles and ligaments including the sartorius, iliacus, psoas, pectineus, vastus lateralis, vastus medialis, vastus intermedius, and rectus femoris. The medial thigh compartment consists of the adductor muscles, the gracilis, and the obturator externus. The posterior compartment muscles include the hamstrings and a portion of the adductor magnus. The muscles and ligaments can also be grossly categorized in functional terms. These are the abdominal muscles (flexors), the adductors, the thigh flexors, and the hip rotators. These opposing muscles result in the anterior or anteromedial tilt of the pelvis bone.

Muscles apply the forces but are also the shock absorbers. During sport there is a tremendous amount of torque that is applied to the pubic joint from these muscles and a significant strain to the muscles and ligaments themselves. Meyers and others argue that these muscles stabilize the pubic joint and that it is imbalances in the forces that lead to symptoms. These imbalances can be from relative differential

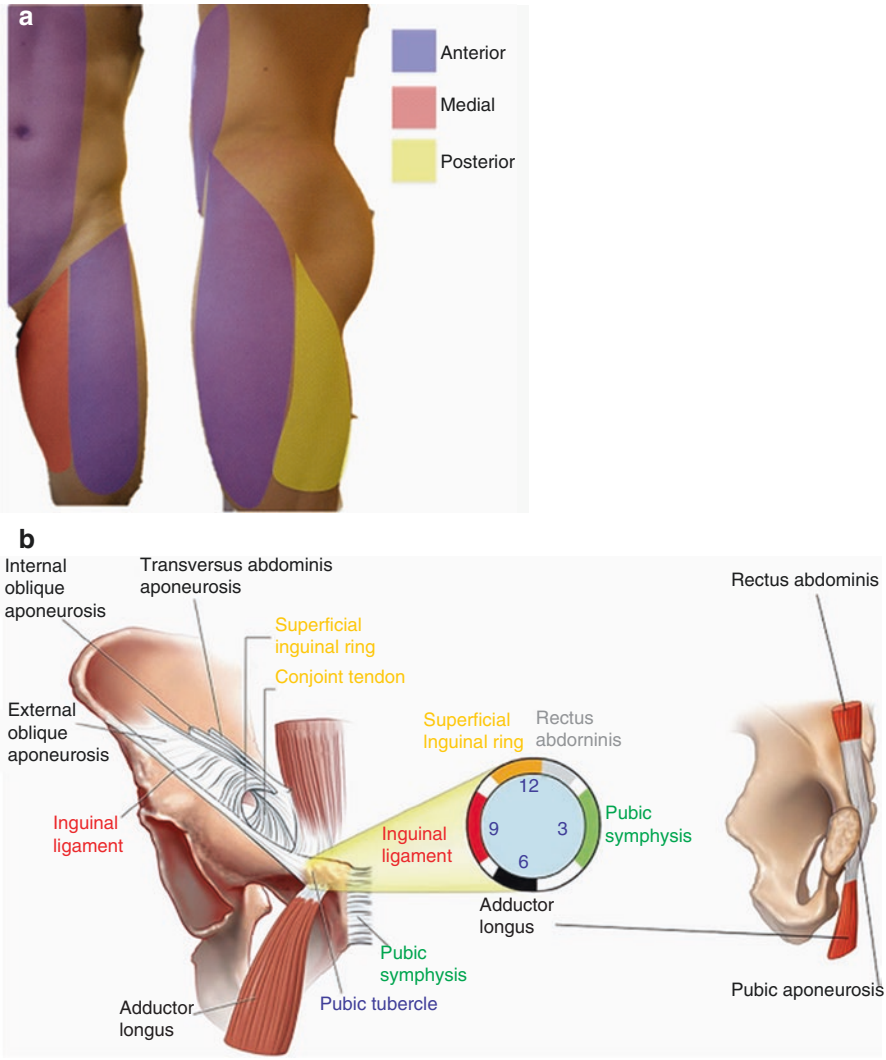

Fig. 38.1 *Anatomy of the pubic joint*. (**a**) The anterior muscular compartments of the torso and thigh (blue), the medial compartment (red), and the posterior compartment (yellow). (**b**) The anatomy of the inguinal canal and insertion of muscles, tendons, and ligaments on the pubic bone. The "pubic clock" represents the different forces pulling on the pubic bone and thus the pubic joint. Also pointed out is the pubic aponeurotic plate that connects the rectus abdominis from above to the adductor longus below [7]

strengths of the opposing forces from above and below. Additionally, a key concept is the hypothesis that injuries are initiated by a temporary loss of core control and a resultant imbalance of force during exertion. The rectus abdominis, the adductor longus, and the psoas are responsible for a major component of the torque that is applied to the pubic joint, and they also take the most strain.

A further anatomical concern is that the relatively soft anterior labrum of the hip joint is susceptible to injury from the tremendous forces applied by these muscles. MRI findings of labral injuries can be present without being a source of pain; however, both hip and non-hip pathologies are often present in athletes. Again, detailed history and physical exam can often tease out what is responsible for the symptoms, but due to overlapping sensory innervation, this can be challenging. This stresses the need for a multidisciplinary care team.

Symptoms/Signs of Groin Pain Syndromes

Obviously, the presenting complaint is pain in the region of the groin. In some, the pain starts insidiously in nature, while in others it starts after a defined event. These events are often characterized by a sensation of an acute pulling, popping, or tearing. People will often have pain and tenderness on the pubic tubercle, pain at the adductor longus tendon near the insertion on the pubic bone, and/or pain at the lower portion of the rectus abdominis muscle immediately above the pubic bone [8–10]. Some will have a dull, diffuse pain along the extension of the inguinal ligament, pain that radiates to the perineum, and/or pain that radiates across the midline toward the pubic symphysis. In athletes, pain is often more pronounced with lateral movements, twisting, or sprinting. Those with adductor pain may have exacerbations with passive abduction of the hip joint or active adduction [11, 12]. Many individuals will describe the pain to be aggravated by sitting for extended periods, such as driving in a car. People will sometimes report pain with daily activities such as getting out of bed or swinging their leg into a car. A component of some people's pain syndrome will include inguinal neuralgia symptoms [13]. This can manifest as a sharp, burning, stabbing, or electrical pain in the groin. Patients may report these symptoms being exacerbated by coughing or sneezing.

The intensity of the pain is highly variable, ranging from slightly bothersome to debilitating. The frequency of symptoms is unpredictable, with some having pain only during or after sport, while others have constant pain. Some have pain that actually improves during warm-up or at the beginning of the sporting activity, only to return after prolonged activity, after completion, or the following day.

Physical exam findings will often include tenderness at the pubic tubercle or over the external ring. There may be tenderness on the adductor longus tendon or the lower rectus muscle. A complete exam includes inspection and palpation for inguinal or femoral hernias, passive and active range of motion of the hip joint and thigh, active muscular contraction of the hip adductors and lower rectus abdominis (resisted sit-ups), as well as passive and active stretching of the hip and pubic joints. It is useful to observe the patient walking, as well as getting up from lying down and sitting. Additionally, ask the individual to demonstrate the positions that bring on the pain. Table 38.1 includes important aspects in the evaluation of groin pain.

Differentiating pain stemming from the bones and surrounding soft tissue layers of the hip joint from pain stemming from the more superficial muscular and neural layers overlying the hip joint is extremely important to ensure the appropriate

Table 38.1 Proposed common documentation of evaluation and treatment of patients with groin pain syndromes using "SPORTS" outline

Starting events/ symptoms	– Sport played – Inciting event or insidious?
Pain characteristics	– Point of maximum pain (mark on photo or anatomical schema) – Characteristics of pain (sharp/dull/burning, etc.) – Timing of pain (constant, during sport, after sport, etc.) – Exacerbating positions, movements, activity, sitting – Pain with coughing, sneezing, getting out of bed – Radiation (into testicle, thigh, across midline) – Contralateral side
Objective exam	– Standing hernia exams – Palpation of the adductors, rectus, inguinal ligament, direct space, pubic bone, pubic symphysis – Passive and active range of motion of the hip – Passive and active adduction and abduction – Sit-up and resisted sit-up – Thigh flexion and extension – Gait/balance – Straight leg raise
Radiology findings	– Ultrasound – CT – MRI
Technique/treatments	– Physical therapy – Steroid injections (location) – Platelet-rich plasma injection (location) – Radiofrequency denervation – Surgical technique
Sports return/ satisfaction	– Timing to return to sport – Ongoing symptoms

Modification of "SPORTS" pneumonic proposed by Brian P. Jacob, MD, on the International Hernia Collaborative. This was proposed to fulfill the need for a common evaluation schema to facilitate meaningful communication and improve care

diagnosis and subsequent implementation of an effective treatment [14]. Pain stemming from the hip joint most often is referred to the groin but also may radiate in a "C-shaped" pattern to the lateral hip. Patients with hip joint pathology often describe sitting pain or pain going from sitting to standing or when getting in/out of a car. They may also describe a mechanical clicking or catching with hip joint motion or a sense of stiffness with motion in the hip.

Physical examination maneuvers which are most sensitive for identifying hip joint pathology include measurements of range of motion and a few basic provocative tests. Asymmetric internal or external rotation (measured with the hip flexed to 90°) or pain through the range of motion should raise suspicion that the hip joint may be involved in the pain syndrome. Log roll (internal and external rotation with patient supine) pain and pain with hip FADIR (flexion, adduction, and internal rotation) or FABER (flexion, abduction, external rotation) are the most sensitive tests for hip joint pathology but are not necessarily specific for any one diagnosis. Suspicion of hip joint pathology from the history or physical examination findings

should warrant referral to an orthopedic hip surgeon for evaluation. Often radiographs, advanced imaging, or diagnostic hip joint injections also may be useful in identifying whether the hip joint is a pain generator. Hip joint pathology and groin pain syndromes may exist concurrently, and in some cases the groin pain syndrome may be the end result of compensatory mechanics stemming from a mechanical hip joint problem [15].

Differential Diagnosis

The differential diagnosis of groin pain is broad; however, a thoughtful history and physical exam can often narrow this expansive list to diagnoses that fall within the spectrum of groin pain syndromes. We attempt to grossly classify the differential diagnoses of groin pain in Table 38.2. Although some of these diagnoses are distinct clinical entities, athletes with groin pain syndromes may have multiple diagnoses, as femoroacetabular disease may coincide with other musculoskeletal causes of groin pain syndromes. In multiple series, including our own, 10–30% of individuals have been treated surgically for both acetabular and groin pain syndromes either at the same time or in a staged fashion. Furthermore, many of these injuries in athletes will result in a constellation of symptoms that combine features of several diagnoses.

Groin Pain Syndrome Pathophysiology

Groin pain is a symptom and is associated with multiple different anatomical or imaging findings. Common to most of the pathophysiology hypotheses that have been proposed to explain chronic groin pain in athletes is the existence of an imbalance of forces and strain on the pubic joint/bone/tendons. Furthermore, most therapies (both nonsurgical and surgical) are aimed at restoring balance.

The prevailing hypotheses of the pathophysiology that contributes to the development of groin pain syndromes generally fall into several gross categories. These categories include inguinal canal pathology/inguinal disruption, rectus abdominis pathology/tendinopathy, adductor pathology/tendinopathy, or pubic bone and symphysis pathology.

Inguinal canal pathology/inguinal disruption/groin disruption. This attributed pathophysiology is probably the most popular based upon commonly described operative findings. The original nomer of “sports hernia” was supported by operative findings of inguinal floor weakness within the transversalis fascia in the absence of a true direct inguinal hernia. It should be noted, however, that many authors report a true hernia at the time of operative exploration that was not appreciable on

Table 38.2 Differential diagnoses of chronic groin pain

Category	Specific etiology
Groin hernias	Inguinal hernias Femoral hernias Obturator hernias Spigelian hernias
Hip associated	Acetabular labral tear Femoroacetabular impingement Osteoarthritis Snapping hip syndrome Iliopsoas tendonitis Avascular necrosis Iliotibial band syndrome Septic arthritis Osteomyelitis
Bone lesions	Growth plate stress injury or fracture Legg-Calvé-Perthes disease Developmental dysplasia Slipped capital femoral epiphysis Osteoid osteoma Stress fractures Avulsion fractures
Genitourinary associated	Prostatitis Epididymitis Orchitis Testicular torsion Testicular carcinoma Ovarian disease Endometriosis Pelvic inflammatory disease
Neurologic	Nerve entrapment (groin or pelvic surgery) Nerve compressions Sacroiliitis Referred pain
Visceral	Inflammatory bowel disease Diverticulitis
Groin pain syndromes	Inguinal canal pathology Posterior canal weakness Conjoint tendon tears External ring tears Inguinal ligament disruption or strain Transversalis fascia lesions External oblique muscle or aponeurosis tears Rectus abdominis pathology/tendinopathy Adductor pathology/tendinopathy Pubic osteoarthropathy Pubic joint instability

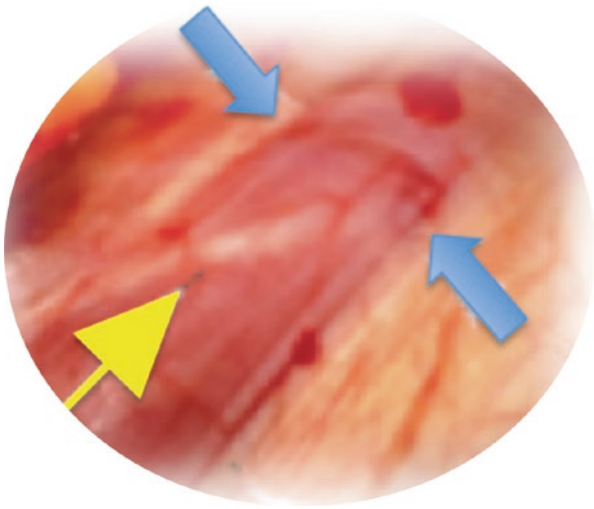

Fig. 38.2 *Common operative finding of external oblique tear with the ilioinguinal nerve running underneath*. The edges of the external oblique (*blue arrows*) with the ilioinguinal nerve (*yellow arrow*) are highlighted. These tears can cause bowstringing or compression of the nerve

physical exam. This category also includes injury to the conjoint tendon, inguinal ligament insertion on the pubic bone, dilation or tearing of the external ring (Fig. 38.2), or tears in the fascia of the external oblique [3, 16–19].

Rectus abdominis pathology/tendinopathy. The rectus abdominis muscles come anterior to pelvis, and the tendons of these muscles insert on the pubis at the central aspect of the hip bone. These tendons share a common aponeurosis with the adductor longus tendons coming from the thigh. Although there may be a complete disruption and tear of the muscle above the pubis, more often there is a strain or inflammation of the tendon near its insertion site. In more extreme cases, the tendon is avulsed, or there is an avulsion fracture with bone fragments [2].

Adductor pathology/tendinopathy. People will often manifest some degree of symptoms of pain or tenderness on the adductors or pain with adductor contraction. This can be an insertional tendinopathy of the adductor longus on the pubic bone or a muscle-tendon junction tendinopathy [12]. Because of the common aponeurosis, adductor and rectus pathology may be hard to distinguish.

Adductor compartment issues occasionally cause symptoms of obturator nerve entrapment or compression [20]. An additional specific anatomic finding within the adductors has been termed baseball pitcher-hockey goalie syndrome, in which there is an actual tear in the fascia (epimysia) overlying the adductor muscles with herniation of the muscle through the fascia, with or without an avulsion injury of the adductor longus or magnus at the pubic bone insertion [5].

Pubic symphysis pathology. Pubic symphysis pathology can include hypermobility of the pubic symphysis joint. This is not common in athletes but may be more common in postpartum women. Pubic osteoarthropathy of the symphysis and adjacent bone is often seen on imaging studies and by many are not considered to be the primary pathology but rather the result of imbalanced torque and chronic microtrauma.

Inguinal neuralgia. Although usually attributable to inguinal canal pathology, inflammation or compression around the inguinal sensory nerves (ilioinguinal, iliohypogastric, and genital branch of the genitofemoral nerves) is hypothesized to contribute significantly to the groin pain syndromes [13]. For sure, inguinal canal pathology/inguinal disruption can lead to direct compression or bowstringing of these nerves on the fascia (Fig. 38.2). Addressing nerve compression has been a part of many of the different surgical approaches.

Miscellaneous. Any of the muscles or tendons that insert or interdigitate in the region of the groin can account for pain. Iliopsoas muscle pathology, snapping psoas syndrome, and rectus femoris muscles are some of the additional lesions to name a few. However, the above highlighted categories are what the remainder of the chapter will focus upon.

Imaging/Diagnostic Adjuncts

The two major imaging modalities that are used include magnetic resonance imaging (MRI) and dynamic ultrasound. Although no imaging study is needed to make a recommendation and determine surgical management when the history and exam is highly suggestive, MRI is almost unavoidable in high-performance athletes and individuals with any findings that may be attributed to the hip joint. There are multiple findings commonly seen on MRI, which include diffuse edema or edema of the subcortical bone and rectus-adductor plate or enthesis, adductor tears, osteitis pubis, bone marrow edema, or fluid in the symphysis pubis. A detailed review of the relevant MRI protocols and findings is highlighted in a review from Khan et al. [21]. Significant MRI findings can be found in the absence of symptoms (and in asymptomatic post-op patients), and people that are highly symptomatic do not always have associated MRI changes. However, MRI is a useful test to examine for hip pathology and acetabular damage. Dynamic ultrasound may show bulging or ballooning of the inguinal floor in the direct space with Valsalva. Additionally, ultrasound is sensitive for ruling in inguinal and femoral hernias. Of note, neither imaging exam usually identifies injuries or tears to the muscles and fascia of the inguinal canal in patients with chronic groin pain.

Therapeutic Approach

It is imperative to state that patients with groin pain syndromes should be approached in a multidisciplinary manner. This should include a surgeon that focuses on the soft tissue anatomy of the inguinal canal and adductors (in the United States, this is usually a general surgeon), an orthopedic surgeon that ideally has expertise in sports-related hip pathology, a physical therapist with knowledge of groin pain syndromes, and perhaps a procedural pain specialist. This team approach best serves the patient, as there is often a constellation of findings with overlapping symptoms. Coordinated care with team-based recommendations hopefully leads to streamlined management and better outcomes.

Nonoperative Therapies

Once the etiology of pain is determined to be within the realm of a groin pain syndrome, treatment for the pain can be initiated. The timeline of therapy and decision for surgical management is often accelerated in professional or collegiate athletes. These decisions often depend upon the timing in which these individuals present in relationship to their sport season, where the individual may be motivated to move acutely to surgical therapy to allow return to sport as soon as possible without a trial of nonoperative management. For almost every nonprofessional athlete, a trial of physical therapy and focused rehabilitation should be undertaken prior to consideration of surgery.

Acute pain associated with a defined injury event can often be treated with a period of initial rest (2–8 weeks) and nonsteroidal anti-inflammatory drugs [1]. Although some will present to surgeons with acute pain, most patients do not present to surgeons or sports medicine physicians until pain has become a chronic issue. Many primary care and other practitioners are not aware of the diagnosis of groin pain syndromes, and patients often will have had multiple physician consultations to rule out hernia, hip, or other pathologies. These individuals are often frustrated and beleaguered.

Physical rehabilitation. For most patients presenting with chronic groin pain, once the diagnosis of a groin pain syndrome is made, the initial therapy is focused physical rehabilitation. Most studies suggest it to be beneficial [22]. In our experience, we have seen multiple patients with chronic pain improve or resolve their symptoms through nonoperative therapy. Rehabilitation should include evaluation of core muscle stability, strength, and imbalances/compensations. Additionally assessment of hip strength and flexibility is critical. Therapy should focus on strengthening, neuromuscular reeducation during activity, and functional motions. Adjunctive manual therapies can be added for soft tissue and fascial manipulations. A good overview of initial therapy and postoperative therapy is available from Ellsworth et al. [23]. We believe that all nonprofessional athletes should have a trial of rehabilitation over 6 weeks, as the neuromuscular reeducation and core strengthening and balancing will aid in postoperative recovery if the nonoperative approach is unsuccessful.

Some have suggested that pain present for more than 2 months will not resolve without surgery [3]. Muschaweck has recommended earlier operation to avoid chronic regional pain syndromes [18]. Others have suggested that certain changes on MRI, including secondary pubic bone changes such as double cleft signs, osteoarthropathy, and marrow edema, are associated with a failure of nonoperative management and are indications for a recommendation of surgery. We do not see these as absolute recommendations for surgery but are issues to consider when personalizing the therapeutic recommendation.

Adjuncts to nonoperative management. Adjunctive therapies to rest and physical rehabilitation have included oral nonsteroidal anti-inflammatory drugs, oral steroids, as well as steroid or platelet-rich plasma injections into the pubic symphysis or rectus-adductor aponeurotic plate. Although there is little data, the use of

nonsteroidal anti-inflammatory drugs in addition to rest following acute injury is commonly accepted practice. Oral steroids for patients with groin pain are not studied, and we do not advocate this route. Injection of steroid, usually with a local anesthetic (i.e., bupivacaine), has been adopted by many but is also poorly studied. The longevity of this approach is unlikely but may help decrease pain in the short term and allow more active participation in physical rehabilitation. Local anesthetic and steroid injection to target ilioinguinal nerve symptoms is also unlikely to be successful in the long term but may serve as a diagnostic adjunct to help guide subsequent therapy [13].

Platelet-rich plasma (PRP) has received a fair amount of attention in the treatment of musculoskeletal injuries [24]. The hypothesis is that PRP will create a local environment to promote healing. There are several reports using this for groin pain in athletes; however, these are usually acute injuries that may have resolved with rest and physical rehabilitation. At this point we do not advocate the use of PRP in most athletes with this problem, with the exception being acute injuries in high-level athletes that have limited and focal findings on imaging studies. However, some have argued that PRP can cause fibrosis that can complicate subsequent surgery if nonoperative management fails.

An additional approach to chronic groin pain has been radiofrequency denervation of the inguinal sensory nerves. As inguinal nerve compression and inflammation often correspond with symptoms, strategies aimed at targeted denervation have been proposed and utilized. A study from Comin et al. from [13] examined radiofrequency denervation of the inguinal ligament in patients that had an absence of structural findings by MRI or in patients that had continued symptoms following a surgery [13]. In this small series, this therapy had a good outcome at 6 months in both patient populations. This therapy is promising, and further research is needed comparing to surgical approaches.

Operative Therapies

Several operative approaches and variations have been used over the years. Although there have been several larger series, there have been no good trials comparing these operative approaches, only meta-analyses [8, 25]. Consensus regarding operative approach has yet to be achieved. The Manchester Consensus Conference from 2014 stated "The surgery itself relies on identifying pathology, releasing any abnormal tension and restoring anatomy with suture or mesh reinforcement. There is no evidence from [randomized controlled trials]… to support the superiority of any type of operation" [3]. Some operative techniques take a minimal approach, while others address multiple facets of the pathophysiology. Even though several approaches have been popularized, they arguably all have a common goal: to relieve or change tension and unequal torque on the pubic joint, with or without decompression of nerves or neurectomy. We highlight the common surgical approaches with proposed pro and con arguments for each.

Open repairs without mesh. Open repairs for chronic groin pain usually involve an inguinal incision similar to that of an inguinal hernia. This allows access to the inguinal canal, inspection for inguinal or femoral hernias, as well as exposure of the adductor longus tendon insertion on the pubic bone if desired.

Multiple groups have utilized variations of open repairs without mesh. The early work of Nesovic used a modified Bassini suture repair [26]. This repair would hypothetically relieve pressure on nerves, reinforce the inguinal floor, as well as change the vector of pull of the conjoint tendon, internal oblique, transversus abdominis, inguinal ligament, and thus the pubic bone. A potential downside of this repair is the greater degree of tension that requires a longer recovery.

Gilmore had popularized an approach to this problem that is a variation of the above [17]. He expressed that common operative findings include a shredding or tearing of the external oblique, as well as disruption of the conjoint tendon and inguinal ligament, resulting in loss of strength of the floor of the inguinal canal and nerve compression. Gilmore describes repairing a defect in the transversus abdominis or internal oblique with an absorbable suture, followed by a nylon suture repair of the internal oblique to the inguinal ligament. Of note, about 20% of patients in his series had an adductor longus tenotomy as well. This operation should repair muscular defects, reinforce the floor, change the vector of pull from these muscles and ligament, and decompress the nerves. Similar to the work by Nesovic, the repair would be under some tension.

Meyers in the United States has a large series but provides limited detail in describing his operative approach [2]. We surmise the following general approach. A sutured repair in two layers of the rectus abdominis muscular fascia to the pubis and medial aspect of the inguinal ligament. The branches of the superficial nerves of the inguinal canal are divided. The epimysia overlying the adductor longus tendon insertion onto the pubic bone is opened over the muscle and tendon. The superior aspect of the fascia is sutured cranially to the pubic bone and buttresses the reinforced rectus repair. Small longitudinal incisions are made in the adductor tendon to promote revascularization. This repair reinforces the rectus and changes the vector of pull and hypothetically releases increased pressure within the adductors with possible lengthening as well. There is some unclear extent of denervation. There is no significant reinforcement of the inguinal floor, but the repair likely has less tension than the previous two open repairs.

Ulrike Muschaweck has popularized what she calls a "minimal repair" [18]. Common findings described include weakness of the inguinal floor and medial displacement of the rectus abdominis muscle. Her repair involves opening the transversalis fascia and repairing in a "vest-over-pants" fashion in two layers to reinforce the floor and reduce weakness. The stiches extend to slightly lateralize the rectus muscle to the pubic tubercle. The genitofemoral nerve is transected in up to 10% of cases. This approach achieves reinforcement of the floor, lateralization of the rectus with change of the vector of pull on the pubic bone, and nerve decompression. There is minimal tension allowing earlier return to activity (2–4 weeks).

A schematic summary of these operative approaches is highlighted in Fig. 38.3. All of these operations result in some degree of change in tension/torque on the pubic joint and decompression or denervation of inguinal sensory nerves. Similarly, these repairs are suture-based repairs without mesh, which one could argue avoid

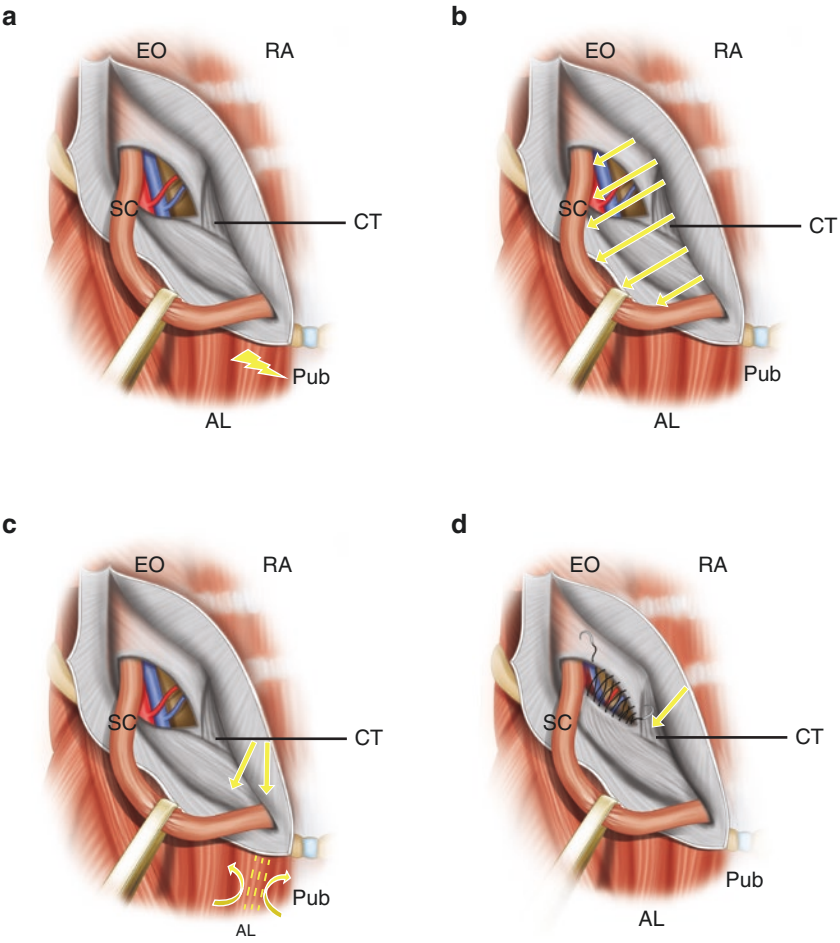

Fig. 38.3 *Schematic summary of open, non-mesh operative techniques*. (**a**) Representative of adductor longus tenotomy. A full tenotomy involves opening the overlying epimysia and then cutting the tendon and lateral muscular portion attaching to the pubic bone. (**b**) Representation of a modified Bassini or Gilmore type of repairs. These are sutured tissue repairs that reinforce the inguinal floor and the direct space. (**c**) Representation of a Meyers repair. The rectus muscle is reinforce to the pubic bone and slightly lateralized on the inguinal ligament. Additionally, there is a complete epimysiotomy and freeing of the adductor longus tendon without tenotomy (curved arrows). Multiple small vertical slits are made to promote neovascularization and minimal lengthening. (**d**) A representation of a minimal repair of Muschaweck. A weakness in the inguinal canal floor is repaired with minimal tension by opening the transversalis fascia and performing a sutured repair. This decompresses the genitofemoral nerve. The rectus abdominis is also slightly lateralized. *EO* external oblique, *AL* adductor longus, *SC* spermatic cord, *CT* conjoint tendon, *Pub* pubic bone

mesh-related complications, allow continued stretching, give off the layers of the abdominal wall, and focus on "fixing" the defects that are found.

Mesh repairs. Mesh repairs can be performed in an open or minimally invasive fashion. Open repairs with mesh are most often a variation of a Lichtenstein type of repair. Several series and experiences have been reported.

Campanelli is one surgeon who has advocated for an open mesh repair [27]. He and his group believe there is hypertrophy of the rectus and adductor longus muscles, weakness in the inguinal floor, and compression of the nerves. They will perform a partial tenotomy of the rectus and adductors, cut all three inguinal sensory nerves, and use a lightweight mesh to reinforce the inguinal floor. This achieves changing the tension, relieves nerve compression or entrapment, and reinforces the floor. There is minimal to no tension created as part of this repair.

Minimally invasive repairs utilize either a transabdominal preperitoneal (TAPP) or a totally extraperitoneal (TEP) approach. The common aspects of these repairs include reinforcing any defect or weakness and hypothetical distribution of tension across the inguinal canal and pubic bone. These repairs do not directly address nerve compression, but reinforcement would prevent pressure on the nerve caused by bowing within Hesselbach's triangle.

Paajanen reported one of the first series in 2004 in 41 patients [28]. They described no visible abnormality in over 50% of the patients, conjoint tendon tears in about 25%, and muscle asymmetry in about 17%. A TEP repair was performed with mesh. Adductor tenotomy was added in two patients. Outcomes were good with short-term follow-up. Others since have reported similar outcomes with TAPP or TEP repairs with or without adductor longus tenotomy. In a series by Edelman, porcine intestinal submucosa biological mesh was utilized, with the understanding that there would be remodeling and reinforcement without the permanent synthetic mesh [29].

An additional minimally invasive approach is proposed by Lloyd [30]. He expresses that the pathophysiology results in tension of the inguinal ligament on the pubic bone. His operation has been termed "Lloyd's release" as he utilizes a TAPP approach and laparoscopically releases the inguinal ligament from the pubic tubercle and then reinforces with a synthetic mesh.

A shortcoming of these minimally invasive repairs is that they take longer to learn, utilize some form of mesh, have low but slightly higher complication rates than open, require general anesthesia, and do not allow for evaluation of all associated anatomical changes [8]. However, in meta-analyses, outcomes have been reported to be as good as open repairs with an overall earlier return to sport. Our experience with minimally invasive approaches has shown success in many but a combined early and late failure rate in 10–15% of patients. In several patients that have failed, we have performed a subsequent open approach in which we have found evidence of ilioinguinal nerve compression or entrapment, most often with bowstringing on an attenuated or torn external oblique fascia or external ring. As a result, if patients have any neuralgia symptoms on history or physical exam, we do not offer a minimally invasive approach. If we do a minimally invasive approach, which we now do only if symptoms are mild and without any signs of neuralgia, we typically perform a TEP and will add an adductor longus tenotomy if the patient has adductor symptoms (Fig. 38.4).

Adductor longus surgery. Adductor tendinopathy contributes to pain in many athletes. As highlighted above, many believe that the adductors contribute significantly to the pathophysiology of groin pain syndromes through the relative

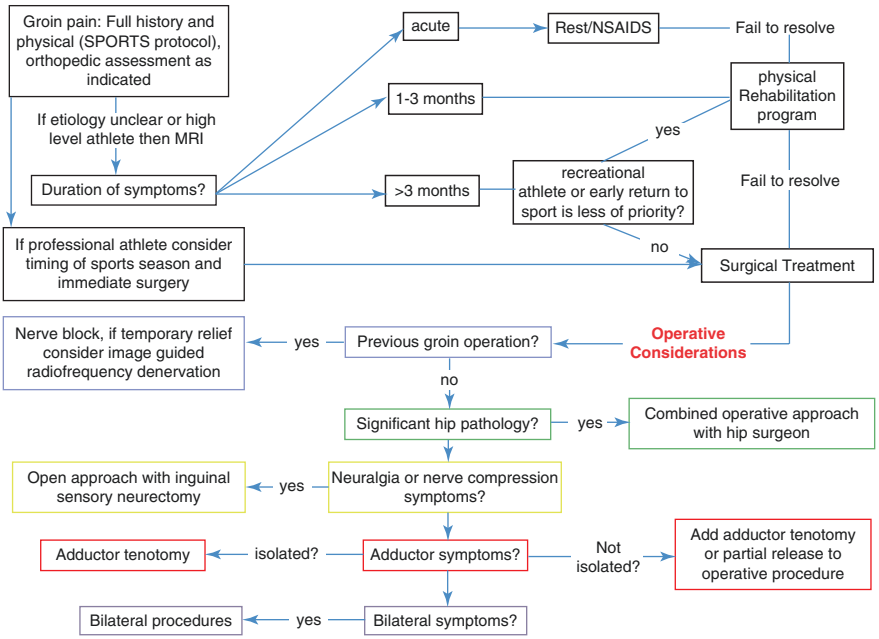

Fig. 38.4 Algorithm and considerations for patients with groin pain syndromes

imbalance of strength between the adductors (relatively stronger) and the rectus muscles (relatively weaker) [12]. Adductor longus tenotomy been used alone or as an adjunct to the above approaches when MRI demonstrates pathology and history and physical demonstrate adductor symptoms. The adductor longus can be approached through an open inguinal incision when an open technique to the inguinal region is being utilized or a separate incision directly over the adductor longus tendon about 1 cm below the groin crease. The epimysia (fascia) overlying the tendon and muscle is opened, and the adductor tendon and the lateral muscular attachments can be isolated with a right angle clamp. It can be divided by electrocautery. Some have advocated for a partial tenotomy to "lengthen" the tendon, and as mentioned above, Meyers often performs multiple small longitudinal slits after an epimysiotomy [2]. Series of isolated adductor longus tenotomy have reported good outcomes in many cases but presumably have been utilized more frequently as an approach in patients with isolated adductor symptoms. Adductor longus tenotomy achieves changing the vector of pull on the pubic bone, relieves pressure within the adductor compartment, and can decompress the obturator nerve [20]. Isolated tenotomy obviously fails to address any lesions within the inguinal canal or floor. Some small series of adductor longus tendon repairs to the pubic bone in the setting of full thickness injuries using suture anchors have been reported as well.

Surgical outcomes. Larger series report success rates ranging from 85 to 100% [8, 25]. Success has been defined as return to sport or improvement in symptoms. The duration of follow-up varies, with some series reporting only 6 weeks of

follow-up with others having up to 5 years of follow-up. Longer follow-up is necessary to be meaningful, as we have seen several patients with good initial results followed by recurrence of symptoms after 1 year. Of note, this has mainly been with the laparoscopic approach in our series. Most recommend postoperative rehabilitation that escalates over a 5- to 7-week period.

Summary

We propose the following treatment guideline in the management of patients (Fig. 38.4). It is necessary to consider career and career goals in collegiate or professional athletes when making recommendations. Of note, this is our current approach and considerations, which we are constantly striving to nuance with each success and, more importantly, any failures. We have utilized many of the approaches outlined above. The approach we currently utilize most frequently is neurectomy of entrapped nerves (most often sparing the iliohypogastric), reinforcement and lateralization of the rectus abdominis, and a full thickness adductor tenotomy in the presence of adductor symptoms. However, we will alter this depending on the patient's symptoms and temporal issues.

A greater understanding of the pathology and treatment options of groin pain syndromes is imperative. Many patients struggle with symptoms without recognition of pathology or access to treating practitioners that can offer therapy. Consensus of nomenclature and standardized evaluation is necessary. Furthermore, critical evaluation of both successes and failures of specific surgical approaches in the context of the patients' symptoms, imaging, and operative findings would help advance the care of patients with groin pain syndromes.

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Chronic Pain After Inguinal Repair

39

David K. Nguyen and David C. Chen

Introduction

Chronic postoperative inguinal pain (CPIP) is a known complication of inguinal hernia surgery and one that should always be discussed during the initial consultation. Patients often consider inguinal hernia repair a simple and routine procedure with minimal long-term complications [1]. For the most part, this is a correct and accurate assertion. Over 20 million patients worldwide and 800,000 in the United States undergo an inguinal hernia repair annually. Given that so many patients undergo this surgery, any long-term complication can significantly impact productivity and quality of life [2]. Traditionally, the success of an inguinal hernia repair has been judged by whether it recurs or not. Widespread adoption of mesh-based tension-free techniques has decreased recurrence rates to 1–3%. CPIP is becoming the most significant patient-centered outcome affecting quality of life, productivity, and gainful employment.

Chronic pain is defined as pain that persists for longer than 3 months [3]. For CPIP, postoperative mesh remodeling and its associated inflammatory response can last up to 6 months. Therefore, chronicity with CPIP is defined as pain lasting more than 3–6 months after hernia repair. The incidence of CPIP is variable, ranging from 0 to 63% in the literature. This is due to the heterogenous definitions, methodologies, and measured outcomes in the existing studies. The best estimate is that there is a 10–12% risk of moderate to severe pain, with a smaller percentage (0.5–6%) of patients experiencing symptoms that affect activities of daily living and gainful employment [4–7].

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Pathophysiology

The underlying pathophysiology of CPIP is complex and multifaceted. There are many pain types, including neuropathic, somatic, nociceptive, and visceral pain, that contribute to the spectrum of CPIP. Somatic pain is often caused by osteitis pubis, which in turn is due to damage to the periosteum of the tubercle from deep fixation sutures [8]. Neuropathic pain secondary to direct nerve injury affects the sensory distribution of the injured nerves. There are several mechanisms for nerve injury during and after inguinal hernia repair. Intraoperatively, the nerves can be inadvertently damaged, divided, or entrapped in fixation sutures or tacks. Postoperatively, scar tissue, folded mesh, or perineural inflammation can contribute to CPIP [7, 9]. After an anterior approach, the most commonly injured nerves are the ilioinguinal, iliohypogastric, and genital branch of the genitofemoral. Patients with a laparoscopic repair are susceptible to lateral femoral cutaneous and femoral branch of the genitofemoral nerve injury in addition to the previously mentioned nerves. Injury to the femoral nerve is rare but can happen if there is lateral suture fixation of the mesh during open repair or over-dissection with lateral fixation during laparoscopic repair. This often presents as motor deficits in addition to pain or numbness in the anterior thigh. Nociceptive pain occurs due to tissue injury leading to local inflammation. The inflammatory mediators then act on nociceptive receptors to create the sensation of pain [9, 10]. Involvement of the spermatic cord, intestine, or other periurethral structures will cause a deep, visceral pain [7, 9]. While discrete descriptions exist for these pain types, they manifest in patients along a broad spectrum with extensive overlap. This makes diagnosing the pain and subsequent management a formidable challenge (Table 39.1).

Risk Factors

High preoperative pain levels have been shown to be one of the most reliable predictors of CPIP development. Young age and female gender are other risk factors that have been identified [11]. The Carolinas Equation for Quality of Life (CeQOL) after hernia surgery is a validated risk calculator that has demonstrated correlation between preoperative symptoms and development of CPIP postoperatively [12]. Other factors, such as depression, have been shown to contribute to chronic postsurgical pain but not specifically CPIP [13]. Genomic research also suggests that there are potential polymorphisms that can make a patient more susceptible to experiencing chronic pain [10].

A specific surgical technique or repair does not intrinsically predispose a patient to CPIP. The best available data suggest that minimally invasive approaches mitigate immediate postsurgical pain but that the incidence of significant CPIP becomes equal with all approaches over time [5, 7, 9]. Rather, the emphasis should be placed on meticulous operative technique and careful identification and protection of the nerves of the inguinal region. There is data suggesting that CPIP can be reduced to less than 1% with routine identification and protection of the nerves [6].

Table 39.1 Types of pain, causes, and symptoms (adapted from references)

Type of pain	Potential causes	Symptoms
Somatic	• Damage to periosteum of pubic tubercle, usually from a deep medial anchoring suture	• Localized to pubic tubercle as area of maximal tenderness
Neuropathic	• Intraoperative or postoperative injury to inguinal nerves	• Pain in the sensory distribution of the inguinal nerves • "Sharp, stabbing, burning, throbbing, shooting, and prickling" • Radiating to the scrotum, labium, or upper thigh • Associated with hypoesthesia, hyperesthesia, paresthesia, allodynia, hyperalgesia • Trigger point with positive Tinel's sign • Worse with ambulation, twisting/stretching of the upper body, stooping/sitting, hyperextension of the hip, and sexual intercourse • Improves with lying down or flexion of the hip and thigh
Nociceptive	• Tissue injury and local inflammatory reaction, mediated by endogenous inflammatory mediators acting on nociceptors	• Deep, dull, constant ache • "Gnawing, tender, pounding, pulling" • Localized over the entirety of the groin area or prosthetic • No specific trigger point or radiating component
Visceral	• Injury or involvement of intestinal content, spermatic cord, or other periurethral structures	• Sexual dysfunction/ejaculatory pain • Located at superficial ring or testicular/labial region • Gastrointestinal complaints

There are numerous types of mesh available to the hernia surgeon. Lighter weight mesh may decrease the risk of CPIP compared to heavyweight mesh in open repair, likely due to better elasticity and biocompatibility in an area as dynamic as the groin [14]. There is evidence that the use of glue for mesh fixation as opposed to self-gripping mesh or suture may result in less CPIP [15, 16]. However, the data are mixed, and the best takeaway message is that the hernia surgeon should avoid excessive fixation, with atraumatic fixation statistically minimizing entrapment or injury to the nerves.

Hernia repairs are performed using local, regional, or general anesthesia. Local anesthetic infiltrated into the surgical field in open repairs has been shown to have reduced complications, earlier recovery and discharge, as well as early postoperative pain relief [17, 18]. Regional anesthesia can cause urinary retention and has not shown benefit when compared with other forms of anesthesia and is not recommended for open hernia repairs [18]. General anesthesia can be used, but there is not enough data to make strong recommendations [18].

Postoperative complications, such as hematoma, seroma, or wound infection, have been shown in some studies to be associated with chronic pain. The need for reoperation is also associated with CPIP [11, 19].

Clinical Anatomy

Groin neuroanatomy is highly variable and complex, both at the level of the retroperitoneal lumbar plexus to the sensory nerves exiting through the inguinal canal [20]. All hernia surgeons should possess in-depth knowledge and familiarity with the expected anatomy and common variations to avoid nerve injury. The nerves of the retroperitoneal lumbar plexus include the iliohypogastric, ilioinguinal, genitofemoral, lateral femoral cutaneous, and femoral. There are also paravasal autonomic nerves that are parasympathetic in nature and are associated with the vas deferens innervating the testicle (Fig. 39.1).

The ilioinguinal nerve enters the inguinal canal medial to the anterior superior iliac spine, traveling anterior to the spermatic cord underneath the external oblique aponeurosis. It is invested by fascia derived from the transversalis fascia, transversus abdominis, and internal oblique muscles. This investing fascia should be left intact. The original description of the Lichtenstein operation advocated for dissection and retraction of the nerve out of the operative field. Part of the Amid modification is to leave the ilioinguinal nerve in situ, as disruption of the investing fascia can cause perineural scarring and nerve entrapment by the mesh.

The iliohypogastric nerve enters the inguinal canal medial and superior to the ilioinguinal nerve. It travels between the internal oblique and external oblique muscles, exiting within the cleavage plane between the two muscles at the conjoint tendon. Up to 5% of patients do not have a visible iliohypogastric nerve in the inguinal canal. The nerve can often be subaponeurotic below the internal oblique aponeurosis [21]. This is important to remember when placing sutures to secure the medial aspect of the mesh as deep bites or bites perpendicular to the path of the iliohypogastric nerve can entrap it.

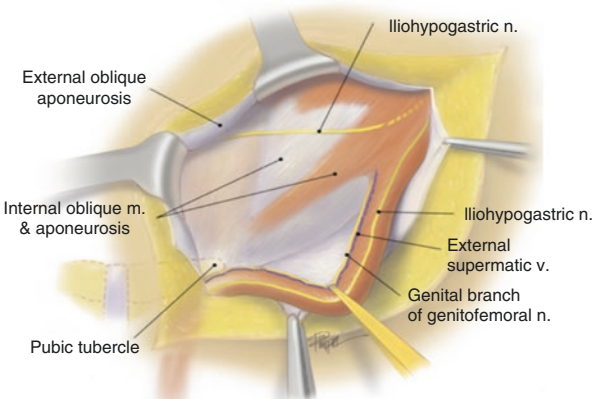

Fig. 39.1 Inguinal nerve anatomy, anterior view

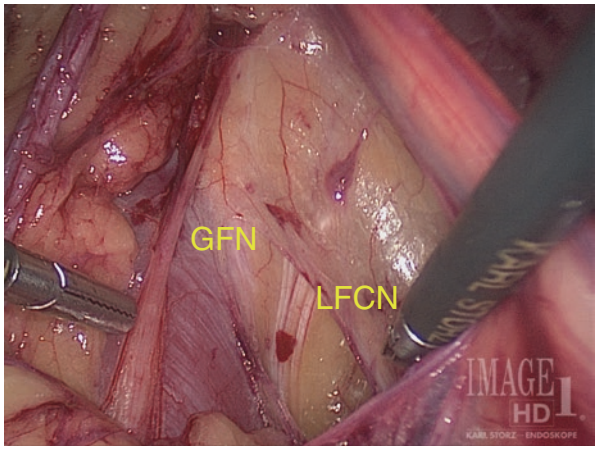

Fig. 39.2 Preperitoneal neuroanatomy (genitofemoral and lateral femoral cutaneous neves)

The genital branch of the genitofemoral nerve travels on the psoas muscle, joining the spermatic cord or round ligament at the internal ring and traversing the canal within these structures. When looking for the genital nerve, it is often easier to identify the external spermatic vein first, as the nerve runs in close proximity to the vein. Injury to the genital nerve may occur when isolating the spermatic cord off the inguinal floor. It is important to visualize the nerve keeping it intact within the spermatic cord. Disruption of the deep cremasteric fascia as the cord is dissected off the floor can cause perineural scarring and also facilitate contact between the nerve and mesh.

When working in the preperitoneal space with laparoscopic or open repairs, the surgeon will often encounter the genital and femoral branches of the genitofemoral nerve as well as the lateral femoral cutaneous nerve (Fig. 39.2). The genitofemoral trunk originates from the L1 nerve roots. It exits through the body of the psoas muscle and travels on its anterior surface. It then divides into a genital and femoral branch, with considerable variation in its subsequent course. The genital branch can usually be found medial to the iliac vessels on its way to the internal ring, while the femoral branch travels laterally under the iliopubic tract to innervate the anterior thigh. Ilioinguinal and iliohypogastric nerves are not visible during minimally invasive repairs. However, penetrating tack or suture fixation through transversalis fascia can inadvertently injure these nerves. The lateral femoral cutaneous nerve originates from L3, traveling over the iliacus muscle lateral to the psoas before traveling to the lateral thigh. The femoral nerve trunk is posterolateral to the psoas; therefore, aggressive dissection or fixation lateral and posterior to the iliopubic tract should always be avoided.

Patient Presentation

Patients with CPIP present with variable and overlapping symptoms. Patients with neuropathic pain often feel it in the sensory distribution of the inguinal nerves. The pain can be intermittent or constant, sometimes localized but also can radiate to the

femoral triangle or scrotum. They will often have trigger points that will create the pain sensation with palpation. Patients with neuropathic pain will describe sharp, stabbing, burning, throbbing, shooting, and pricking sensations. Sometimes, they will also have associated negative sensory changes, such as reduced sensation (hypoesthesia), increased sensation (hyperesthesia), burning sensation (paresthesia), pain to a non-painful stimulus (allodynia), or increased pain to painful stimulus (hyperalgesia) [8]. This may be aggravated by ambulation, stooping or sitting, hip hyperextension, or sexual intercourse [7].

Non-neuropathic or nociceptive pain is deep, dull, and constant. It can be localized over the area of the prosthetic or more broadly over the entire groin. It is typically exacerbated by strenuous exercise, or by position, especially if there is a meshoma or the patient can feel the mass of the mesh [9].

Visceral pain can be related to pain in the region of the external ring or testicle/labia with ejaculation. It can also be related to sexual dysfunction. Sometimes, it can manifest with gastrointestinal or urinary symptoms if there are adhesions, mesh migration, fistula, obstruction, or inflammation associated with the adjacent viscera [9].

Diagnosis

Surgeons who evaluate patients with chronic groin pain need to accurately characterize the types and likely causes of the symptoms. In patients with hernia repairs, it is easy to say that CPIP is the most likely culprit. However, one should always consider the breadth of surgical, neurologic, infectious, urologic, orthopedic, or gynecologic etiologies for chronic groin pain.

A detailed history and physical examination, while essential for any patient encounter, are crucial in helping the hernia surgeon determine the likely causes of the pain and its neuroanatomical correlation. Often overlooked is the original operative report. The operative report should be reviewed, with attention to the surgical approach, type of repair, type of mesh, nerve identification, and associated intraoperative and postoperative complications. Using validated pain, function, and quality of life surveys can help in understanding the type, severity, and impact that the pain has on the patient. This will help shape discussion and expectations regarding goals of therapy with the patient. On exam, Tinel's test can reproduce neuropathic pain by tapping over the area medial to the anterior superior iliac spine or over the area of maximal tenderness. Dermatosensory mapping is a simple but highly effective way of describing pain and identifying nerve involvement. The exam should also check for clinical recurrence, palpable meshoma, tenderness at the pubic tubercle, or musculoskeletal findings suggestive of core muscle injury. There can be overlap of different nerve involvement, non-neuropathic pain, and musculoskeletal injury in physical exam findings, making an immediate diagnosis difficult [22, 23].

Imaging studies, diagnostic blocks, and nerve studies are valuable diagnostic adjuncts. Ultrasonography is an effective, low-cost initial test to look for recurrence or meshoma [24]. If ultrasound is non-diagnostic, then computed tomography (CT) or magnetic resonance imaging (MRI) of the abdominal may be helpful in

determining recurrence, meshoma formation, core muscle injury, or hip pathology [25]. MRI is currently considered the most effective modality for differentiating different causes of groin pain. However, the interpretation of the MRI images is still very much radiologist-dependent [26]. Diagnostic ultrasound- or landmark-guided nerve blocks of the ilioinguinal, iliohypogastric, and genital nerves can help determine if there is a component of neuropathic pain. In addition, needle electromyogram (EMG) and magnetic resonance neurography (MRN) can provide information regarding neuritis or neuropathy [27–29].

Treatment

Patients with CPIP will generally experience improvement of symptoms over time with expectant management and conservative therapy. Expectant management for 3–6 months after hernia repair allows for healing and mesh remodeling. However, surgeons should not ignore postoperative pain with the expectation that it will go away, as chronic pain often develops from a persistence of acute pain leading to centralization of pain. CPIP is multimodal and complex and should be appropriately managed in a multidisciplinary setting (Table 39.2).

Non-interventional Pain Management

Nonsteroidal anti-inflammatory drugs (NSAIDs) are the main first-line therapy for CPIP with a moderate degree of success. NSAIDs work best in patients with

Table 39.2 Nonsurgical treatment options (adapted from references)

Pharmacological	
• GABA analogs (gabapentin, pregabalin) • SSNRIs • TCAs	First line
• Opioids • Tramadol	Second line
• Other medications: SSRIs, bupropion, cannabinoids, anticonvulsants, dextromethorphan, memantine, clonidine, or mexiletine	Third line
Topical	
• Lidocaine • Capsaicin	
Non-pharmacological	
• Physiotherapy • Acupuncture • Mind-body therapy	
Interventional	
• Inguinal nerve blocks • Neuroablation techniques • Neuromodulation techniques	

non-neuropathic inflammatory pain or nerve entrapment secondary to inflammation. Unfortunately, NSAIDs are not sustainable as a long-term solution due to their side effects, such as gastrointestinal bleeding and kidney injury. Other first-line options include the gamma-aminobutyric acid (GABA) family neuropathic medications such as gabapentin or pregabalin. Tricyclic antidepressants (TCA) or selective serotonin-norepinephrine reuptake inhibitors (SSNRI) are also used as first-line therapies. Opioids and tramadol can be used for acute exacerbations but are not a substitute for maintenance therapy. If there is failure of first-line therapy, then selective serotonin reuptake inhibitors (SSRI), bupropion, cannabinoids, anticonvulsants, dextromethorphan, clonidine, and memantine have all been described in the literature. However, the data regarding efficacy in treatment of chronic pain is sparse [30–35].

These medications should be prescribed in conjunction with enrollment in a chronic pain program. These programs are usually multidisciplinary in nature, with a pain physician, psychologist, physical therapist, nurse supervisor or coordinator, and pain pharmacist participating in the care of the patient. These programs focus on medication management and non-pharmacologic approaches to pain management, including cognitive behavioral therapy. In addition, acupuncture and topical medications can be attempted to help alleviate symptoms [30–35].

Interventional Pain Management

Nerve blocks can be diagnostic and therapeutic. Successful blocks of the ilioinguinal and iliohypogastric nerves can help select patients who would respond favorably to surgical neurectomy. Nerve blocks can be performed using anatomical landmarks or with image guidance. They should be performed several times to account for an inadequate effect of previous blocks. More durable options include neuroablative techniques using alcohol, cryoablation, or pulsed radiofrequency ablations [26]. Neuromodulation techniques with peripheral nerve field stimulation, spinal cord stimulation, and dorsal root ganglion stimulation have shown some promise and can be considered if the pain is refractory to medications, therapy, surgery, and blocks [35]. Success of neuromodulation techniques depends on careful patient selection and individualization of care.

Surgical Pain Management

In our experience, surgical treatment of CPIP is not recommended until at least 6 months to 1 year after initial hernia repair. Patients with CPIP refractory to pharmacologic and interventional treatments can be considered for surgery. However, failure alone is not an indication for surgery [6, 36].

Successful surgery for CPIP starts with understanding patient goals, intensity and impact of pain, and setting realistic expectations. Patients with potentially

remediable causes of pain, such as nerve entrapment, meshoma, foreign body sensation, recurrence, neuropathic pain, or orchialgia will likely end up with tangible results [36]. Neuropathic pain isolated to the inguinal distribution, not present prior to the operation, and responsive to nerve blocks will have likely improvement after surgery. Patients with recurrence may have improvement with a corrective repair. Those with meshomas or foreign body sensation can have improvement with mesh removal. Orchialgia can be addressed with neurectomy of the autonomic plexus investing the vas deferens.

Surgery for CPIP should simultaneously address all likely causes to mitigate the subsequent risk and difficulty of reoperation. At the same time, the surgeon should balance the benefits of surgery against the potential morbidity of surgery. Mesh removal alone, revision of prior repair, and selective neurectomy are all described and commonly performed for CPIP. However, these are less effective options as they do not account for cross-innervation of the inguinal nerves, anatomic variations, ultrastructural changes to the nerves, as well as other coexisting causes of pain [6]. Triple neurectomy of the ilioinguinal, iliohypogastric, and genitofemoral nerves is currently considered the most effective option for patients with neuropathic CPIP and neuropathic pain refractory to conservative therapy [6]. Concomitant removal meshoma performed open, laparoscopically, or as a hybrid approach is also performed if found at the time of groin exploration. This technique was pioneered at the Lichtenstein Institute in 1995 and, in the appropriate patient, will provide effective relief [6].

Risks and Complications of Surgery

Surgery for CPIP is not benign, and a thorough discussion of risks, complications, benefits, and alternatives is necessary before obtaining patient consent. It is important to do so to align patient expectations with the surgeon's expectation and projected outcomes. There are certain specific topics to discuss with patients, including permanent numbness, inability to access or identify the inguinal nerves, deafferentation hypersensitivity, abdominal wall laxity or denervation of the oblique muscles with retroperitoneal neurectomy, numbness in the labia in females, testicular atrophy, and loss of cremasteric reflex. Additional risks of reoperation include bleeding, testicular injury or loss, vasectomy, spermatic cord injury, vascular injury, visceral injury, and disruption of the prior hernia repair. Most importantly, the patient should understand that they may have ongoing pain and disability despite a technically successful operation due to nociceptive pain, neuroplasticity, centralization, and deafferentation hypersensitivity.

Technique

Open Triple Neurectomy and Groin Exploration

The ilioinguinal, iliohypogastric, and genital branch of the genitofemoral nerves are resected at a point proximal to the original surgical field when performing a triple neurectomy. With open triple neurectomy, the original open incision can be used to

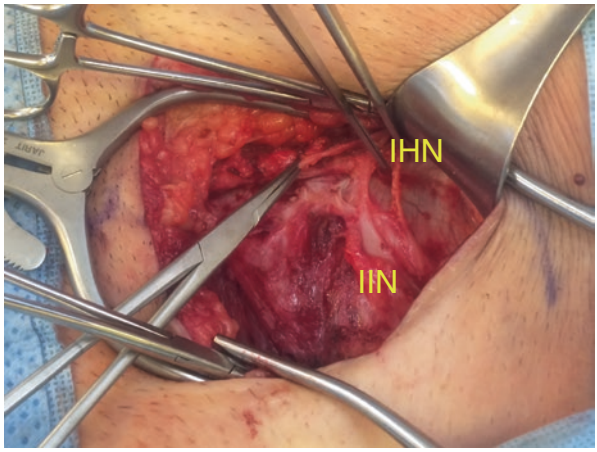

Fig. 39.3 Open inguinal neurectomy and mesh removal

facilitate exposure of the external oblique aponeurosis. Extending the original incision cephalad and lateral allows access to the external oblique aponeurosis and inguinal canal proximal to the mesh and scarred operative field.

The ilioinguinal nerve can be identified by dividing the crura of the internal ring and finding the nerve anterior to the spermatic cord. It can generally be traced in a line from the internal ring up to the anterior superior iliac spine, where it exits from the retroperitoneum to travel between the internal oblique and transversus abdominis muscles. The iliohypogastric nerve is found in the anatomic cleavage plane between the external oblique aponeurosis and internal oblique aponeurosis (Fig. 39.3). If this is not readily identified in the inguinal canal, the distal end can often be found exiting at the conjoint tendon, and the subaponeurotic component can be identified by splitting the fibers of the internal oblique. The nerve can then be followed as proximally as possible before being resected. The inguinal segment of the genital nerve can be identified by finding the blue line of the external spermatic vein. If that is difficult, it can also be found entering the canal at the lateral aspect of the internal ring. Sometimes the floor of the inguinal canal needs to be split to identify the psoas muscle and the genital branch traveling on its anterior surface. The nerves should be resected proximal to the prior operative field, with nerve endings ligated to avoid neuroma formation and then buried in the internal oblique muscle to prevent further scarring and entrapment. For the patient with associated orchialgia, the paravasal autonomic fibers can be resected by taking the lamina propria of the vas deferens during open groin exploration. This additional resection is effective for neuropathic orchialgia arising after hernia repair, but the results are less consistent than triple neurectomy in terms of pain reduction [19].

The open anterior approach can be complex, and the patient is at higher risk of injury to the spermatic cord as well as iliac and epigastric vessels. However, open exploration allows single-stage operation for triple neurectomy, mesh removal if needed, and repair of any disruption or coexisting hernia while leaving the preperitoneal plane relatively unscathed (Fig. 39.4).

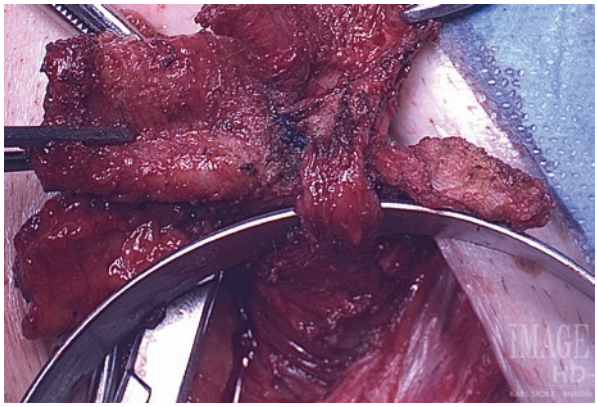

Fig. 39.4 Open meshectomy with cord preservation

Endoscopic/Hybrid Groin Exploration

Repairs of inguinal hernias in the preperitoneal space have become much more prevalent in the last two-decades. Managing CPIP that results from these repairs is difficult since both anterior and posterior planes can be involved. Furthermore, injuries to the nerves, vas deferens, and gonadal vessels can be difficult to address from an anterior approach. Transabdominal, extraperitoneal, or retroperitoneal approaches can all be utilized in these situations.

The surgeon should always start with diagnostic laparoscopy. This can reveal recurrence, mesh migration, intra-abdominal adhesions, or an interstitial hernia that could be a generator of the patient's symptoms. Fixation devices can also be identified and removed without violating the extraperitoneal space.

The preperitoneal space is then accessed via transabdominal preperitoneal (TAPP) or totally extraperitoneal (TEP) approach. The peritoneal flap should be preserved and mesh separated from it if possible (Fig. 39.5a, b). The myopectineal orifice (MPO) is explored and assessed for recurrence, retained cord lipoma, mesh migration, or meshoma. If there is a recurrence but the mesh is still flat, then the dissection space may be enlarged and additional mesh placed to provide adequate overlap of the defect. If the anterior space is untouched, another alternative is to perform an open modified Lichtenstein repair. When a meshoma is present, the first step is to determine whether it was an isolated TEP or TAPP repair, open preperitoneal repair, or plug technique. Meshoma after an initial flat mesh repair can often be removed totally laparoscopically (Fig. 39.5c). Meshomas can often scar, contract, or become adherent to the iliac and epigastric vessels, vas deferens, gonadal vessels, or bladder. These findings can make dissection and separation of the meshoma extremely difficult. The operating surgeon must consider the benefits of mesh removal against the risk of injuring major vessels or adjacent viscera. Meshoma pain is often related to its three-dimensional configuration, amount of mesh present, and how bulky it is in relation to the groin. Usually, reduction of the mass of the meshoma is enough to significantly alleviate symptoms. Therefore, it is often prudent to leave a cuff of mesh behind on vital structures rather than attempting to completely remove the meshoma (Fig. 39.5d).

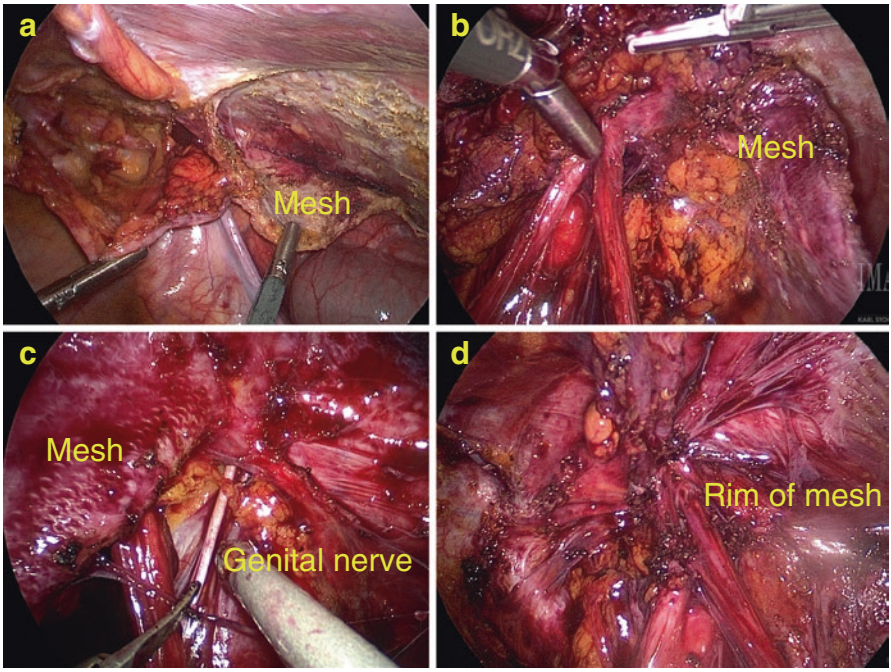

Fig. 39.5 (**a**) Superior approach to mesh and myopectineal orifice. (**b**) Inferior approach to mesh and myopectineal orifice. (**c**) Simultaneous genital neurectomy. (**d**) Preperitoneal mesh removed with small rim of mesh left on cord structures

The genitofemoral nerve and lateral femoral cutaneous nerves are also visible during endoscopic groin exploration. If the patient's exam is consistent with neuropathic pain in the distribution of these nerves, a concomitant neurectomy can be performed with minimal morbidity. The genitofemoral trunk can be identified over the anterior surface of the psoas muscle. The genital branch will pass toward the internal ring, while the femoral branch travels more laterally, inserting just posterior to the iliopubic tract. In our practice, clips or sutures to close the neurilemma are placed distally and proximally prior to resecting a segment of the nerve (Fig. 39.5c).

If there is coexisting orchialgia, a laparoscopic paravasal neurectomy can be performed. The autonomic fibers investing the vas deferens can be identified within the tissue between the skeletonized vas deferens and gonadal vessels proximal to the internal ring. These fibers can be stripped, ligated, and resected to address symptoms of neuropathic orchialgia (Fig. 39.6).

In cases of open repairs with plug or bilayer meshoma, we start with a laparoscopic groin exploration. If meshoma is identified, it is often advantageous to free as much of the meshoma as possible off vital structures laparoscopically and take the genital branch prior to doing an open groin exploration to explant the remaining mesh and resect the ilioinguinal and iliohypogastric nerves. If there is a recurrent hernia, it can then be repaired with Lichtenstein repair or TEP/TAPP approach.

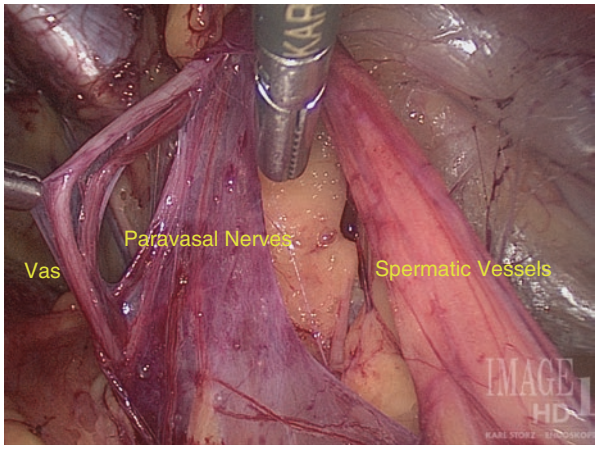

Fig. 39.6 Paravasal autonomic nerves enveloping the vas deferens

Endoscopic Retroperitoneal Triple Neurectomy

An endoscopic retroperitoneal triple neurectomy is highly effective at rendering a patient with severe neuropathic CPIP broadly numb in the relevant inguinal nerve distributions. The ilioinguinal, iliohypogastric, and genitofemoral nerves are resected proximal to potential injury sites in the retroperitoneum. The neuroanatomy of the nerves is less variable in this area; however, the disadvantage is that motor fibers to the oblique muscles are sacrificed with this operation and can cause flank bulging from denervation.

Access to the retroperitoneum is facilitated by placing the patient in lateral decubitus position with the table flexed to open the space between the costal margin and iliac crest. An incision is made 2–3 cm superior to the iliac crest in the mid-axillary line. The muscle fibers are split and the retroperitoneal space entered with identification of retroperitoneal fat. A balloon dissector is used to create the retroperitoneal space, medializing the peritoneum and associated viscera. The space is then insufflated and additional working ports inserted.

It is absolutely necessary to identify all relevant structures of the lumbar plexus prior to neurectomy. The subcostal nerve runs just inferior to the 12th rib, which can be identified with palpation. The iliohypogastric and ilioinguinal nerves exit at L1 overlying the quadratus muscle (Fig. 39.7a). They often can share a common trunk. The nerves should be traced out as distally as possible. The genitofemoral trunk exits through the body of the psoas as it makes its way to the groin (Fig. 39.7b). The psoas muscle is then identified, with ureter and iliac vessels seen medially (Fig. 39.7c, d). If preoperative dermatomal mapping does not suggest femoral branch involvement, it can be dissected out and preserved. The lateral femoral cutaneous nerve is identified exiting L3 lateral to the psoas muscle below the level of the iliac crest and crossing over the iliacus muscle. If there is an isolated neuropathy (meralgia paresthetica), then it can be resected as well. The femoral nerve is typically deep to the psoas muscle and lateral and should be left undisturbed (Fig. 39.7b, c).

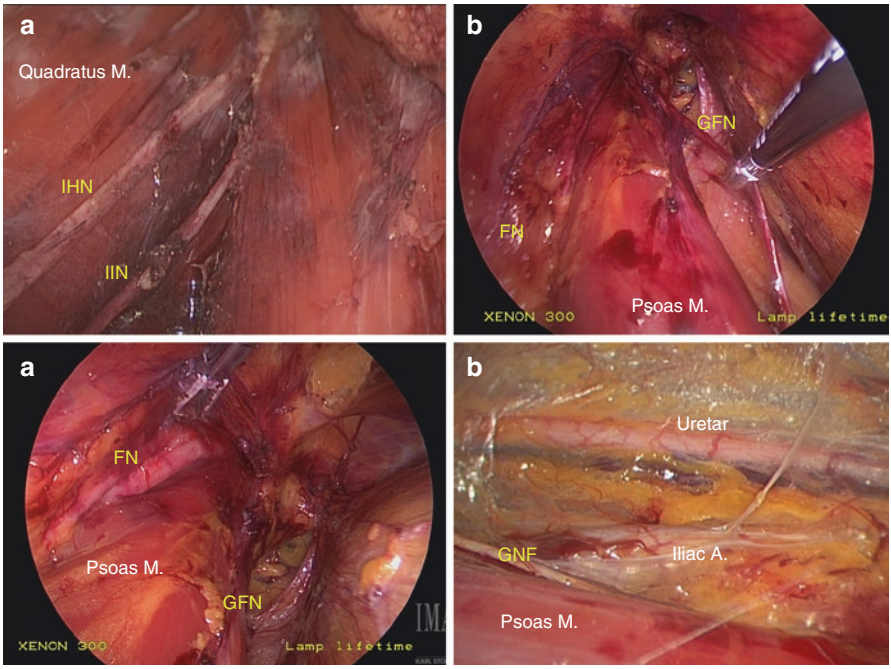

Fig. 39.7 (**a**) Cephalad view of retroperitoneal ilioinguinal (IIN) and iliohypogastric nerves (IHN). (**b**) Caudal view with genitofemoral nerve (GFN) isolated. (**c**) Lateral view with femoral nerve (FN) identified. (**d**) View of GFN with the iliac and ureter

Outcomes

Triple neurectomy was first described the Lichtenstein Institute in 1995. The current experience encompasses over 800 patients using an open or hybrid approach and 100 cases using an endoscopic retroperitoneal approach. Before 2004, only the extramuscular portion of the iliohypogastric nerve was resected as part of the triple neurectomy, with significant improvement in CPIP for 85% of patients. After 2004, the intramuscular portion was resected with an increase in CPIP resolution to 95% for patients with no entry into the preperitoneal space [21].

For patients with preperitoneal repairs, we initially performed extended triple neurectomy with resection of the genitofemoral trunk through the inguinal floor. There was a 90% success rate for patients in this highly selected cohort. Our experience with paravasal neurectomy for orchialgia consists of over 40 patients. We identified resolution of symptoms in over 80% of patients. Endoscopic retroperitoneal triple neurectomy resulted in significant and durable decrease in numerical pain scores over 3 years with elimination of narcotic dependence in 70% of patients and significant gains in activity level in 94% of patients but is reserved for selected or refractory cases to minimize the collateral denervation [37].

Conclusion

Chronic postoperative inguinal pain can significantly impact patients by affecting their productivity, employment, and quality of life. Systematically and thoroughly evaluating the patient is important to identify the types of pain the patient is experiencing and the possible etiologies. A multidisciplinary approach is necessary since CPIP is complex and multifaceted. Multimodal treatments using medications, interventional pain techniques, cognitive behavioral therapy, and physical therapy should be attempted prior to considering surgery. Patients who have refractory pain for longer than 6 months after the initial repair can be considered for surgery if their symptoms are severe or debilitating with remediable targets. Operating on CPIP aims to address all its likely causes at once to mitigate subsequent difficulty and risk of additional reoperations. For patients with neuropathic pain, triple neurectomy remains the most effective way to provide significant relief for patients. If meshoma is present, removal of the mesh in conjunction with triple neurectomy is effective. The care provided to patients with CPIP is highly individualized but is grounded in a thorough knowledge of neuroanatomy and a thoughtful plan of care based on symptoms, mechanism, and available techniques. However, the most effective way to address CPIP is through prevention with meticulous surgical technique and nerve identification at the time of the original operation.

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Intraoperative and Postoperative Complications of MIS Inguinal Hernia Repair

40

Paul Frydenlund and Archana Ramaswamy

Introduction

Inguinal hernia repair is a general surgery standard which has been performed for well over the past 100 years, undergoing an evolution with the development of minimally invasive surgery. First described in the 1980s, the laparoscopic approach to inguinal herniorrhaphy is now an accepted method for most patients with symptomatic inguinal hernias [1, 2]. Additionally, the increased experience with robotic surgery among general surgeons has led to a minimally invasive option being offered more frequently over the past decade. Disruptive innovations in medicine like laparoscopy and robotic surgery can be challenging for many reasons, including the necessary technologic support and safety concerns. One significant hurdle to the immediate and universal adoption of minimally invasive inguinal hernia repair has been concern about associated complications and rate of recurrence.

It is widely accepted that the rate and severity of complications should decrease as experience with a certain operation increases. This is commonly referred to as a "learning curve" and has significant implications during the adoption of new surgical technology [3–7]. The technical skills required for an adequate inguinal hernia repair through an open approach have little carryover into the laparoscopic approach for repair, particularly because the anatomy and location of mesh placement are generally different. Additionally, the lack of tactile feedback with current robotic technology provides another level of difficulty which must be managed to complete

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a safe and durable repair. Despite potential complications, in capable hands, the minimally invasive approach to inguinal hernia repair is a safe and in many ways superior method when compared with the open approach.

As described in detail in prior chapters, the two most well-described laparoscopic approaches to inguinal hernia repair are the totally extraperitoneal (TEP) and the transabdominal preperitoneal (TAPP) techniques. The complication profile is similar but not identical between the two approaches. Both will be discussed here with the differences and similarities highlighted where appropriate. The use of a robotic-assisted surgical approach is likewise distinct but comparable to the laparoscopic TAPP approach. It is of value during the discussion to also consider potential complications of the traditional open inguinal hernia approach; however, these will not explicitly be described.

This chapter will address the intraoperative and postoperative complications of minimally invasive inguinal hernia repair, paying specific attention to the causes, identification, and management of common and avoidable complications. In the final section, we will address the often-overlooked postoperative complication of hernia recurrence, focusing on patient and surgeon factors that contribute to this undesired outcome.

Intraoperative Complications

Intraoperative complications are typically caused by technical errors resulting from a misapplication of energy, either mechanical or thermal, or a misidentification of anatomic structures and their relationships within the operative field. Awareness of potential complications and their causes is critical for reducing patient morbidity and improving outcomes. The classic surgical teachings of adequate exposure, gentle handling of tissue, and absolute hemostasis cannot be overstated or forgotten. This section will specifically discuss injuries which can occur during entry into the abdomen and during dissection in preparation for mesh placement.

Entry Injury

Various methods for entry into the peritoneal cavity may be utilized during TAPP, and there has been considerable debate regarding the safety and efficiency of each. A Cochrane review published in 2015 evaluated multiple factors involving the safety of an open entry or closed entry utilizing a Veress needle [8]. There was no statistical difference in the rate of major vascular injury, solid organ injury, or of injury to a hollow viscous between open and closed entry. Additionally, the reported rate of major entry injury among the pooled studies was between 1 and 8 injuries per 1000 attempts. The choice of open versus closed entry should be based on patient factors and surgeon preference, and regardless of which method is employed, a survey of the abdominal contents should be done immediately after initial placement of the laparoscope.

Entry injury is believed to be less common with the TEP approach for inguinal hernia repair as access to the peritoneal cavity is not necessary or intended. In this technique, most utilize an open cutdown into the preperitoneal space with lateral retraction of the rectus muscle fibers. This method helps avoid accidental entry into the peritoneal cavity and allows the subsequent use of a dissecting balloon to develop the operative field. The dissecting balloon can be associated with several uncommon but troublesome complications. Peritoneal tears by the balloon can be decreased by the use of preemptive finger dissection in the preperitoneal plane and placement of the balloon contralateral to the site of previous incision (such as entry from the left side when a McBurney's incision is present). The plane of dissection of the balloon can sometimes be above the epigastric vessels, with the attendant possibility of shearing of these vessels. Avoidance of the use of the dissecting balloon in a space where finger dissection fails to identify an adequate plane is strongly recommended. The placement of the secondary ports in this technique does pose some risk for bladder or vascular injury. Mindful and controlled placement under laparoscopic vision can limit these injuries and aid in the early identification should an injury occur.

Injured Structures

Bowel injury is always a possibility when the peritoneal cavity is entered. Additional risk exists if small bowel is present in the hernia sac or has become densely adherent due to the chronicity of the hernia, previous pelvic surgery, or existence of previous mesh. Excessive traction on incarcerated small bowel and inadvertent direct thermal injury are the major culprits when bowel injury occurs, supporting the assertion that the TEP approach has a lower risk of bowel injury. However, thermal small bowel injury has been described after TEP without recognized violation of the peritoneum, causing peritonitis and necessitating a laparotomy with small bowel resection [9]. Thermal injury carries the additional difficulty that it is not always immediately apparent and can present as a delayed perforation. For this reason, thermal devices should be minimally used, if at all, in the proximity of bowel. If a bowel injury is identified intraoperatively, the surgeon may elect to repair it laparoscopically if he or she has adequate experience and exposure; alternatively one may convert to an open approach for repair of the enterotomy. Regardless, if gross contamination of the field occurs, mesh placement should likely be deferred.

Although uncommon, bladder injury may occur during laparoscopic inguinal hernia repair. Extraperitoneal bladder rupture has been described during balloon dissection after initial entry into the preperitoneal space [10]. Although prior abdominal surgery or suprapubic catheter placement has been suggested to increase the rate of injury, such dilation injuries have also been reported in patients with no past surgical history [11]. Data from a large series of laparoscopic inguinal hernia repairs demonstrates a rate of 1 bladder injury per 650 repairs [4]. Keeping the dissecting balloon anterior and superior to the pubic bone should reduce the risk of placing a dangerous level of force on the bladder wall.

Additionally, direct laparoscopic visualization during balloon inflation should be routinely performed. Placement of a urinary drainage catheter routinely for all inguinal hernia repairs carries its own complications but can be considered in cases where previous lower abdominal surgery or history of urinary retention is present. Some centers routinely perform preprocedural bladder scans to assess need for perioperative catheter placement, though at the least, the patient should be asked to void just prior to the procedure. The placement of secondary trocars inferior to the camera port may also cause a bladder injury if not done in a controlled and careful manner under visualization.

Recommendations for the management of bladder injuries largely come from the trauma literature in which extraperitoneal injuries are most often managed with catheter drainage alone [12]. In contrast, intraperitoneal bladder injuries require surgical repair in addition to indwelling catheter placement. For iatrogenic injuries, immediate laparoscopic primary repair with absorbable sutures is recommended in combination with indwelling catheter drainage [13]. Closed-suction drain placement in the preperitoneal space may be considered, as should a leak test involving the instillation of methylene blue into the bladder until moderate distention is achieved. Mesh placement following bladder injury is still possible if the urine is not colonized with bacteria and no clinical urinary infection is present. Following bladder repair, a cystogram may be performed in 1–2 weeks to evaluate for ongoing leak prior to removal of bladder catheter and surgical drain if placed intraoperatively.

Vascular injury during laparoscopy is always of concern given the potential for bleeding which may be difficult to control, thus requiring rapid conversion to open surgery. The operative field during an inguinal hernia repair contains several named arteries and veins which must be identified and avoided. This includes the iliofemoral, inferior epigastric, gonadal, and branches traveling over the pubic arch often referred to as the “corona mortis” vessels. Vascular injuries may occur during any stage of the surgery; however, particular caution should be taken during entry and dissection of the preperitoneal space. Special attention should be paid to the iliofemoral vessels when dissecting a large direct sac, a femoral sac, and in the presence of previous mesh in the form of a plug or flat sheet overlying this area. Fixation of mesh with tacks has been described as causing a clinically significant vascular injury which required reoperation [14]. Large vessel injury during point fixation application can generally be avoided by placement of the tacks above the iliopubic tract. Conversion to open surgery is indicated if large vessel injury is identified or if there is persistent blood loss that cannot be adequately controlled with laparoscopic instrumentation. Generally speaking, epigastric vessel injury can be controlled with usage of hemostatic clips, though larger vessels will require repair which may necessitate a high level of laparoscopic expertise.

The spermatic cords arise from the testicles and pass through the inguinal canals before traveling posteriorly and medially and entering the prostate near the base of the bladder. The contents of the cord, the vas deferens, arteries and veins, lymphatics, and nerves, are ensheathed in a multilayered myofascial outpouching arising

from the abdominal wall. The cord is an at-risk structure during inguinal hernia repair given its intimate relationship to indirect hernia defects and proximity to direct defects. Transection during dissection and compression with mesh placement or fixation are the two major concerns regarding the vas deferens. Reduced fertility and sexual dysfunction are potential long-term complications from operative injury and can be extremely distressing to patients. If the vas is inadvertently transected, a primary repair, with permanent suture over a stent, is recommended, ideally with urology assistance [15]. Injuries to the vasculature of the cord typically manifest as postoperative testicular complications and will be addressed in the following section.

Injuries to the peritoneum may occur during entry, dissection of the preperitoneal space or hernia sac, and when securing mesh during a TEP inguinal hernia repair. These injuries can cause problems in multiple ways. Firstly, opening the peritoneum allows insufflated air into the peritoneal cavity, reducing exposure and operating space. The intraperitoneal gas may also increase postoperative discomfort and distention. Secondly, if the peritoneal lining is disturbed and inadequately repaired, visceral contents may enter the preperitoneal space, adhering to uncovered mesh or even becoming incarcerated. Several options have been described to manage the above. Intraoperatively, increasing the pneumoperitoneum to 15 mmHg and placing the patient in Trendelenburg are often adequate to continue with dissection, with the addition of a Veress needle to vent the peritoneal cavity as necessary. The peritoneal tear can be sutured closed or closed with an Endoloop, although leaving a small opening for bowel entrapment may be worse than leaving a large one. Often, the redundant peritoneum following full reduction of the hernia allows the peritoneal defect to be repositioned above the mesh, thereby removing the concerns about having unprotected mesh in contact with bowel. If the hole is sufficiently large that closure is not an option and mesh would be in contact with bowel, then the usage of a mesh designed for intra-abdominal placement should be considered. Peritoneal tears can also occur during TAPP dissection. Again, closure is recommended and is often easier to accomplish from the intra-abdominal position. The defect can be often incorporated into the peritoneal closure following mesh placement, with use of the reduced hernia sac to cover any peritoneal tears. The use of barbed sutures, which have gained popularity with the rise of robotic TAPP repairs, introduces the possibility of exposed barbs causing injury and adhesions [16]. To avoid rare but important complications related to barbed sutures, all efforts should be made to assure that barbs are buried and a lengthy tail is not left behind.

Off-field injuries, those that occur outside of the visualized surgical field, can occur during minimally invasive inguinal hernia repair. This is more common with the TAPP approach and of specific concern with the use of robotic techniques. Initial instrument entry should be performed under direct visualization and instrument exchanges performed by someone proficient with the technique. As tactile feedback is relatively lost in this technique, instruments should always be within the field of view, and expansive movements should be avoided.

Postoperative Complications

Several potential adverse patient events may occur after completion of minimally invasive inguinal hernia repair. While many of these complications may be directly related to operative planning and intraoperative technique, the associated signs and symptoms manifest after closure and must be managed in the postoperative period. In the following section, we will discuss the common complications of urinary retention, as well as the less common but more severe complications of hematoma formation and testicular injury. We will conclude with a section addressing recurrence after minimally invasive inguinal hernia repair focusing on patient and surgeon factors. Chronic postoperative pain is covered in another chapter and will not be explicitly discussed in this section.

Urinary Retention

Postoperative urinary retention is a common problem following laparoscopic inguinal hernia repair with rates of 1–8% reported in randomized controlled trials [17]. Management by bladder catheterization often delays discharge and has the potential to cause significant patient discomfort, catheter-associated infections, and trauma to the urethra. Several potential risk factors have been evaluated for their role in postoperative urinary retention including patient demographics, type of anesthesia, and postoperative pain management. Male gender has been linked with increased postoperative urinary retention following some pelvic procedures, particularly anorectal surgery [18]. However, this higher prevalence in general for men has not been reliably demonstrated after minimally invasive inguinal hernia repair [19]. Increased age has been suggested as an independent risk factor for urinary retention given age-related bladder dysfunction and the increased prevalence of benign prostatic hyperplasia. Multiple studies have demonstrated increased postoperative urinary retention in patients older than 60 years old; however, this finding has not been uniformly replicated [19–21]. The decision to catheterize the bladder, either intraoperatively or immediately postoperatively while the patient is still anesthetized, should be individualized based on clinical judgement of the risk and benefit to the specific patient in question.

Type of anesthetic delivered intraoperatively has been evaluated for its role in postoperative urinary retention. A review of several studies specific to inguinal hernia repair have shown an increased rate of postoperative urinary retention following general or regional anesthesia versus local anesthesia [22]. This effect has been attributed to the inhibitory action of anesthetic agents on the autonomic nervous system and the anesthetic-induced reduction of activity in areas of the central nervous system responsible for voluntary voiding. Anesthetic selection as a means of reducing urinary retention is limited by the general lack of experience with regional or local anesthesia during minimally invasive inguinal hernia repair. Multiple groups have demonstrated the feasibility of performing TEP and TAPP repairs with spinal anesthesia; however, only a few small series of minimally

invasive hernia repair under local anesthesia and conscious sedation have been reported [23, 24]. General anesthesia remains the most commonly utilized anesthetic for minimally invasive inguinal hernia repair.

Postoperative analgesia is typically achieved through multiple modalities including nonsteroidal anti-inflammatory drugs, long-acting local anesthetic delivered intraoperatively, and both IV and oral narcotic pain medications. Narcotic use in the immediate postoperative period has been shown to contribute to urinary retention in prospective studies evaluating abdominal and pelvic surgeries [25, 26]. This association between postoperative narcotic use and urinary retention has also been demonstrated in inguinal hernia-specific populations [19]. Appropriate use of intraoperative local anesthetic and both pre- and postoperative nonnarcotic pain medications is recommended in appropriate patients with the goal of reducing narcotic use and potentially preventing urinary retention.

Hematoma

Postoperative bleeding complications are fortunately rare in patients undergoing minimally invasive inguinal hernia repairs. Multiple large series of laparoscopic inguinal hernia repairs report groin and abdominal wall hematoma formation of less than 2.1% with the need for reoperation due to bleeding at 0.35% of all hernia repairs [4, 27, 28]. Unfortunately, postoperative bleeding in the preperitoneal space can be life-threatening, infrequently resulting in hemorrhagic shock due to the large potential space preventing timely hemostatic tamponade. Of particular difficulty are patients who require anticoagulation for a history of hypercoagulability, cardiac arrhythmia, artificial heart valve, or cardiac assist device. For patients who can reasonably have anticoagulation held for the first several days postoperatively, we recommend bridging with low-molecular-weight heparin until the day of surgery, with resumption of long-term anticoagulation within a week postoperatively. For patients in whom temporary cessation of anticoagulation medication is unsafe, an open approach to repair should be strongly considered. The risks of bleeding are not decreased; however, a postoperative hematoma is likely to be smaller and to be noticed earlier.

Testicular Injury

Intraoperative injury to vascular structures of the spermatic cord typically manifest in the postoperative period. The pampiniform plexus is a network of small veins which drains the testicle and epididymis, coalescing to become the testicular vein. When this structure is ligated or occluded, patients may develop ischemic orchitis, manifested by swelling, pain, and warmth in the first 2–3 days postoperatively. Management of postoperative ischemic orchitis is generally expectant with symptom control. Rarely, necrosis may occur which can be diagnosed with ultrasonography and is an indication for urgent orchiectomy. Arterial injury which is significant

enough to prevent the inflow of oxygenated blood to the testicle manifests differently with gradual shrinking of the testicle and dysfunction. This occurs over weeks to months and is not usually painful. Ischemic orchitis and testicular atrophy are rare complications, with reported rates of <1% occurrence after initial hernia repairs, but both can be quite distressing to patients and affect long-term fertility. Avoidance of these complications is best accomplished by gentle handling of the spermatic cord during dissection of the hernia sac and by limited use of energy near the vascular structures of the cord [15].

Recurrence

Recurrence after inguinal hernia repair is frustrating for patients and surgeons alike. While not always appreciated as a postoperative complication, recurrence after repair undoubtedly represents a clinical failure. Typical reported rates of recurrence in large prospective or retrospective studies range from 0.5 to 5% [5, 6, 28–30]. Caution should be taken when considering these numbers, however, as a very large national series has reported that greater than 10% of all inguinal hernia repairs are performed after for recurrent hernias, suggesting that the historical data is overly optimistic [31]. Regardless of specific numbers, all efforts should be made to prevent recurrence after initial repair as the patient burden and surgical difficulty of repeat inguinal surgery increase with each repair.

It is prudent to consider both surgeon and patient factors when evaluating hernia recurrence. Patient factors that have been demonstrated to increase the rate of hernia recurrence include active smoking status, direct hernia (versus indirect), recurrent hernia, and elevated BMI [29, 32]. The proposed mechanism by which tobacco smoking increases recurrence rate is by altering connective tissue metabolism, reducing native tissue strength, and contributing to a critical failure of the repair. Patients who develop direct hernias may also have anatomic weakness which increases the rate of recurrence. Elevated BMI conceivably represents a surrogate measure for increased intra-abdominal pressure which adds additional stress to the freshly repaired myopectineal orifice and may result in an increased rate of recurrence. It has also been reported that patients who undergo outpatient inguinal hernia repairs have lower rate or recurrence [29]. This finding can be explained by noting that patients with significant medical comorbidities, obesity, or incarcerated hernias causing intestinal obstruction are unsuitable for same-day surgery and represent a higher-risk population.

The most significant surgeon factor as it relates to clinical success after minimally invasive inguinal hernia repair is experience. Multiple case series stratified recurrence and complication results into tiers based on level of experience. As expected, surgeons with more experience completing laparoscopic inguinal hernia repairs had a lower rate or recurrence. Reports suggest that after completing 30 procedures, a surgeon's operative time reaches a plateau consistent with more experienced surgeons [7]. Risk of recurrence appears much more likely in the first 25 cases a surgeon performs, improving to widely reported rates considered

community standard thereafter [5, 6]. It is clearly important to have adequate supervision by an experienced laparoscopic surgeon during the training period to reduce the risk of recurrence and patient harm.

Conclusion

The minimally invasive approach to inguinal hernia repair, either by total extra peritoneal or transabdominal preperitoneal approach, is a safe and reliable means to achieve a durable repair in most patients. As innovative technology increases the options for surgical management of disease, surgeons must be particularly cognizant of the adjustment and learning necessary to replicate results of established methods. Thorough understanding of the potential intraoperative and postoperative complications associated with these repairs will allow surgeons to counsel patients adequately and make appropriate clinical decisions.

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Repair of Paraesophageal Hernia

41

Abraham J. Matar and Edward Lin

Terminology and Pathophysiology

A hiatal hernia refers to any upward protrusion of an organ other than the esophagus through the esophageal diaphragmatic hiatus. The main causative factor thought to be involved in the development of a hiatal hernia is weakening of the phrenoesophageal ligaments involved in tethering the esophagus to the diaphragm and preventing the stomach from herniating upward into the thoracic cavity. The phrenoesophageal ligaments also serve to close the potential space between the esophagus and the diaphragm, preventing the stomach and other organs from herniating around the esophagus into the thoracic cavity. Increasing age is associated with decreased elasticity of these phrenoesophageal ligaments, predisposing to development of hiatal hernias. Thus, it is no coincidence that there is an increased incidence in the sixth and seventh decades of life. Chronic increased intra-abdominal pressure, such as in obesity and chronic obstructive pulmonary disease (COPD), also predisposes to hiatal hernias.

Hiatal hernias are classified into four anatomical types by the position of the gastroesophageal junction relative to the diaphragm (Fig. 41.1). Type I hiatal hernias are referred to as "sliding" hernias and represent approximately 90% of all hiatal hernias. These involve sliding of the gastroesophageal (GE) junction cephalad to the diaphragm, while the gastric fundus remains intra-abdominal. Type II–IV hiatal hernias are collectively termed paraesophageal hernias (PEH). Type II PEHs, known as

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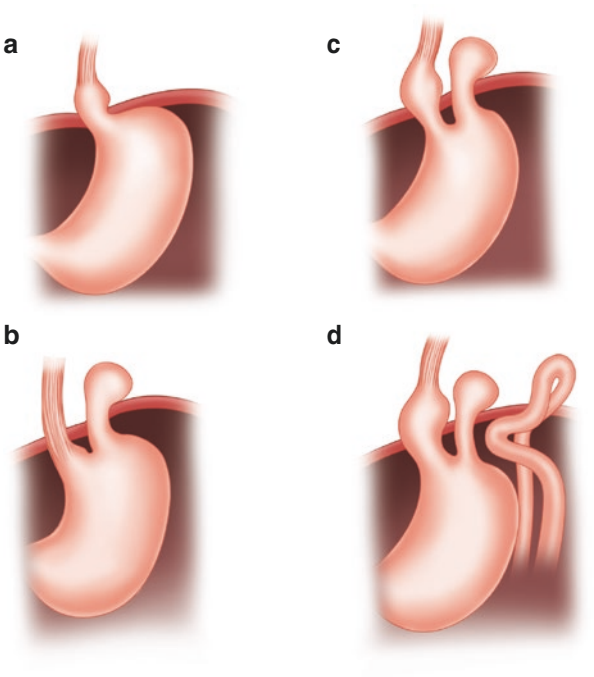

Fig. 41.1 Illustration of types I–IV hiatal hernias. (**a**) Type I "sliding" hiatal hernia. (**b**) Type II "pure" paraesophageal hernia. (**c**) Type III "mixed" paraesophageal hernia. (**d**) Type IV paraesophageal hernia

"pure" PEHs, are the least common hiatal hernia and involve herniation of the gastric fundus around the esophagus into the thoracic cavity, while the GE junction remains intra-abdominal. Type III PEHs, known as "mixed" PEHs, are the most common PEH, representing 90% of all PEHs. These involve both sliding of the GE junction cephalad through the diaphragm as well as herniation of the stomach around the esophagus into the thoracic cavity. Finally, type IV hiatal hernias involve herniation of any organ other than the stomach into the thoracic cavity and may include omentum, small bowel, and large bowel. The term "giant" hiatal hernia is often referred to in the literature. Although there is no consensus definition, the most common description appears to be one in which greater than 30% of the stomach has herniated into thoracic cavity. There are other descriptors of size being considered that include actual volume of herniation and three-dimensional measurements. However, these attempts to characterize the size of the PEH do not seem to influence treatment.

Presentation

Although many hiatal hernias are asymptomatic and do not warrant intervention, understanding the anatomical classification of hiatal hernias helps to understand the presenting symptoms. Symptomatic type 1 hiatal hernias typically present similarly to those with gastroesophageal reflux disease. With displacement of the GE junction into the chest, the lower esophageal sphincter is often displaced and becomes

incompetent. As a result, common presenting symptoms include chest pain, cough, dysphagia, regurgitation, heartburn, vocal hoarseness, and respiratory complaints. A type II hernia may involve extrinsic compression of the esophagus by the stomach, resulting in dysphagia. Type III and IV PEHs may present with a combination of symptoms, including both GERD and dysphagia. Depending on the size and chronicity of the PEH, symptoms related to mechanical obstruction, such as early satiety, postprandial discomfort, and vomiting, should be considered. Iron-deficiency anemia may be present in up to 25% of patients with PEH, some even requiring repeated blood transfusions [1]. Anemia is most likely a result of a combination of factors, including chronic venous congestion of the herniated stomach and repeated mechanical trauma as the herniated stomach slides back and forth against the diaphragm. Contributing to anemia are Cameron's erosions, which are linear ulcerations at the proximal stomach caused by repeated mechanical trauma related to the hernia. Following hernia repair, anemia may be resolved in up to 90% of patients [1].

Traditional dogma suggests that symptoms arising from uncorrected paraesophageal hernias are associated with a very high morbidity and mortality rate, especially those requiring emergent surgery for incarcerated or strangulated hernia contents. An uncommon but feared presentation of PEH is gastric volvulus, in which the stomach is rotated on its mesentery resulting in acute obstruction and ischemia. There are two main types of gastric volvulus, organoaxial and mesoaxial. Organoaxial volvulus occurs when the stomach rotates along its long axis, the cardio-pyloric line, while mesoaxial volvulus involves the stomach rotating along its short axis. Organoaxial volvulus is more common in adults, while mesoaxial volvulus is more common in children. The specific type of volvulus is probably more of an academic discussion because the clinical presentations are what govern the need for treatment. The classic presentation of a patient with a gastric volvulus is termed Borchardt's triad and involves severe epigastric pain, the inability to vomit, and an inability to pass a nasogastric tube. Although the sensitivity of Borchardt's triad for diagnosis of gastric volvulus is mediocre, any patient with a known PEH who presents with severe epigastric pain and an inability to vomit should raise a high suspicion.

Diagnosis

Diagnosis of a PEH can be made using several different modalities. Oftentimes, a PEH may be diagnosed incidentally, whether on routine imaging such as a chest X-ray or CT scan or on endoscopy or an UGI series as part of a workup for GERD or dysphagia.

Endoscopy

An upper endoscopy is a vital component of any workup for GERD, as many hiatal hernias are often noted incidentally on endoscopy. A hiatal hernia is best visualized endoscopically by retroflexing the endoscope once inside the stomach and viewing

from below. A herniation in line with the path of the endoscope is indicative of a sliding hiatal hernia. The finding of gastric rugal folds above the diaphragm is a telling indication of a PEH. In the case of a known PEH, an endoscopy can be valuable to assess for the presence of any masses, esophagitis, Barrett's esophagus, strictures, or any findings that may alter the operative plan. Further, the EGD provides useful anatomic information, including the size of the hernia, prior to operating. However, endoscopy is limited by its inability to differentiate large sliding hiatal hernias from PEH. Large hernia sacs that compress the esophagus may contribute to false estimates of esophageal length or obstruct passage of the endoscope. When a PEH is suspected, the use of endoscopy should be performed cautiously to minimize risks of perforation or discomfort created by overly vigorous air insufflation.

Radiological Studies

On chest X-ray (CXR), the finding of a retrocardiac air-fluid level is pathognomonic for a paraesophageal hernia, indicating the presence of an air-filled stomach that has herniated into the thoracic cavity. In the case of a type IV PEH, visceral gas may be seen in cases of intestinal herniation. The upper gastrointestinal (UGI) contrast study remains the most useful diagnostic study for hiatal hernia, as it provides information on the relationship between the GE junction and the diaphragm, as well as the size and location of the hernia. The barium esophogram that assesses the esophagus past the diaphragm can be useful as well but does not evaluate the entire stomach. Cross-sectional imaging such as CT scans are commonly utilized to investigate the source of vague abdominal complaints and thus often identify hiatal hernias. However, CT scans contribute minimally to the treatment algorithm for a patient with a known PEH, except to assess the anatomic relationship of adjacent organs that may be useful for operative preparation.

pH and Manometry

Manometry testing can be performed prior to operative repair of a PEH to exclude achalasia and other esophageal motility disorders. However, passage of the catheter through the anatomically altered lower esophageal sphincter is not always possible and portends higher risks of discomfort and trauma. In our experience, distal esophageal amplitudes are difficult to interpret due to external compression of the stomach on the esophagus. In cases where manometry cannot be performed to determine adequacy of distal esophageal peristalsis or healthy amplitudes, a Nissen fundoplication may risk postoperative dysphagia, and a partial fundoplication or no fundoplication at all should be considered. pH studies are often useful for the diagnosis of GERD but do not change the treatment algorithm in the setting of PEH repair.

Management

Indications for Surgery

Asymptomatic sliding hiatal hernias generally go undiagnosed and do not require surgical repair. Symptomatic sliding hiatal hernias are often first treated with a course of medical management including proton pump inhibitors (PPIs), and only after failing medical management are patients considered candidates for repair. The indications for repair of PEH are a bit more nuanced. Historically, all PEH were repaired on an elective basis regardless of whether the patient was symptomatic or not, due to the increased risk of complications associated with emergent surgery. However, recent data has shifted the paradigm to a more conservative approach such that it is reasonable to employ a watchful waiting approach to asymptomatic or minimally symptomatic patients [1–3]. Indications for repair of PEH include severe pain or reflux, dysphagia, and anemia. Practically, the fact that a patient presents for evaluation of PEH begins to lower the threshold for surgery as most asymptomatic PEH go undiagnosed.

Surgical Management

Transabdominal Versus Transthoracic

Historically, there have been two approaches for the repair of PEH—transabdominal and transthoracic—with advantages to both. Proponents of the thoracic approach claim superior visualization of the esophageal hiatus and thus allows for a more complete mobilization of the esophagus, which is highly correlative with a tension-free repair. This may be advantageous in the case of a shortened esophagus when maximal mediastinal dissection of the esophagus is recommended prior to attempting an esophageal lengthening procedure. However, the major disadvantage of the transthoracic approach is the obvious morbidity associated with a thoracotomy compared to an abdominal approach. To date, there is little data on minimally invasive thoracic approaches. The use of the thoracic approach clearly still has usefulness as data suggests the rate of this approach is not insignificant, even if it makes up the minority of cases.

Laparoscopic Versus Open

In the hands of experienced surgeons, recurrence rates following laparoscopic and open PEH repair are similar. However, laparoscopic repairs are associated with a reduced rate of perioperative morbidity and mortality, less pain, and shorter hospital stays [4]. As a result, a laparoscopic transabdominal approach is now the most common approach (Fig. 41.2). One potential disadvantage to the laparoscopic approach is the complexity of a laparoscopic Collis gastroplasty in the case that an esophageal lengthening procedure is indicated. Open PEH repairs are usually reserved for the

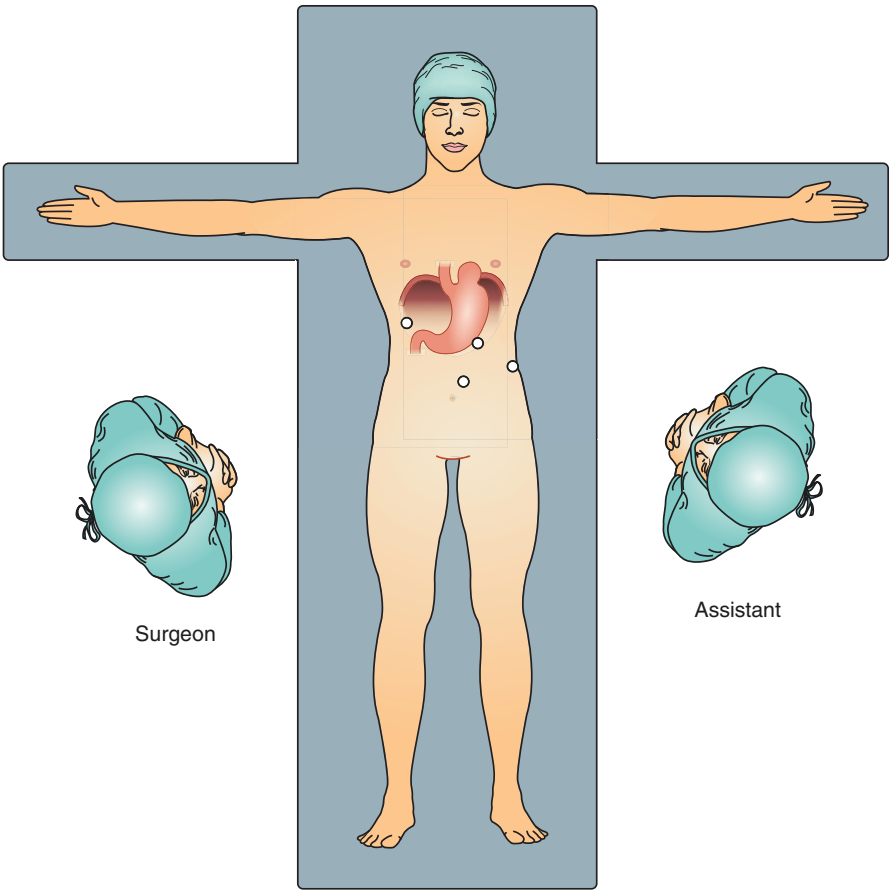

Fig. 41.2 Surgeon positioning and trocar placement for a transabdominal laparoscopic paraesophageal hernia repair. Source: Lin, Edward, and C Daniel Smith. "Paraesophageal Hiatal Hernias." *Laparoscopic Surgery*, 2nd ed., Marcel Dekker, Inc., 2004, pp. 243–258

urgent setting when there is suspicion for peritoneal contamination or gastric necrosis or when repair is concomitant with another major abdominal operation such as a pancreatic resection. Conversion from a laparoscopic to an open repair is rarer but may be necessary in the case of bleeding, injury, or dense adhesions. In cases where the abdominal approach is prohibitive, the thoracic approach is still an option.

Technical Considerations

The recurrence rate following laparoscopic PEH repair varies widely in the literature, likely due to varying approaches [5]. Historically, the technique of PEH repair has not been standardized, and many of the technical aspects of the operation have

stirred controversy for years. Although the technical aspects of the operation may vary among surgeons, the principles of surgical repair are the same. These are to return the herniated contents to their anatomically correct positions below the diaphragm, to repair the defect, and to prevent recurrence. Several of the controversial issues that surround the operative management of PEH will be discussed.

Role of Antireflux Procedures in PEH Repair

Gastroesophageal reflux is a common presenting symptom of those with paraesophageal hernias, as up to half of patients will give a remote history consistent with GERD. This is not unexpected as migration of the gastroesophageal junction into the thoracic cavity is associated with functional impairment of the lower esophageal sphincter. Furthermore, any inherent contribution of the diaphragmatic hiatus to LES function is disrupted with circumferential mobilization of the GE junction during surgery. As a result, historically, the majority of reports on PEH have included an antireflux procedure as part of the PEH repair. A recent randomized controlled pilot trial of 40 patients compared the dual procedure with the hernia repair alone and found significantly increased reflux in the hernia repair alone group at 12 months follow-up, with no differences in fundoplication-associated complications or dysphagia [6]. In essence, the deliberation for fundoplication should balance the need for reflux control and the risks of postoperative dysphagia.

The theoretical benefit of using the fundoplication to anchor the stomach below the diaphragm has not reduced recurrence rates. Furthermore, suture anchoring of the fundoplication to the diaphragmatic crura does not reduce recurrence but rather makes subsequent reoperations fraught with difficulty.

For the surgeon, the decision to perform a complete 360-degree wrap (Nissen) versus a partial 180-degree (Dor) or 270-degree wrap (Toupet) concomitant with a PEH repair is ideally based on preoperative manometry results. If an antireflux procedure is to be performed without knowledge of esophageal functional status, a partial fundoplication reduces the risks of postoperative dysphagia.

Hernia Sac Excision

Integral to any PEH repair is the reduction of hernia sac contents to their normal anatomical positions. However, the necessity of hernia sac excision and the impact of leaving the hernia sac on recurrence rates have sparked debate. Early data from the Mount Sinai Medical Center suggested that hernia sac excision was an essential component to PEH repair as there was a significant difference in recurrence rates between the cohort of patients who underwent complete sac excision and those that did not [7]. Complete sac mobilization and sac excision are thought to have several benefits. Removal of the serous membrane lining of the hernia sac prevents the formation of fluid collections in the mediastinum postoperatively. Further, the unexcised sac may serve as a point of negative force, pulling the esophagus and stomach back into the chest. Excising the sac eliminates this effect, allowing the esophagus to freely descend into its natural position followed by a tension-free crura closure. In fact, some experts argue that the need for an esophageal lengthening procedure is

often overstated and is a result of incomplete mobilization of the hernia sac from the mediastinum [8].

Conversely, advocates for leaving the hernia sac in place argue that laparoscopic resection of the sac can be a tedious task particularly in complex and recurrent hernias due to the potential injury to the esophagus itself, vagus nerves, and other structures within the mediastinum. Further, they argue that anchoring the fundoplication below the diaphragm and proper crura closure are actually more effective in preventing recurrence than hernia sac excision. The vast majority of centers advocate for the complete mobilization of the PEH sac when it can be accomplished safely. Once the sac is mobilized out of the chest, whether to excise the sac for pathologic examination is optional. It is necessary to excise the sac off the cardia completely if a fundoplication is to be performed.

Short Esophagus

An esophagus is considered shortened when the gastroesophageal junction is unable to lay tension-free at least 2 cm below the hiatus. Preoperative assessment may be able to identify patients suspected for a shortened esophagus, although confirmation is only made after extensive mediastinal dissection at the time of repair. The presence of tension on the crura closure is a known risk factor for hernia recurrence. Furthermore, any fundoplication performed around a shortened esophagus is at risk of disruption or slipping downward. When encountered during a PEH repair, extensive mediastinal dissection is preferred prior to considering an esophageal lengthening procedure. Mediastinal dissection of the esophagus via a transabdominal laparoscopic approach can theoretically be carried as far cephalad as the aortic arch, although most surgeons will not mobilize to this extent (Fig. 41.3). If transabdominal mediastinal dissection has been maximized and the esophagus still does not lay tension-free at least 2 cm below the hiatus, a right-sided transthoracic mobilization of the esophagus, by thoracoscopy or thoracotomy, can be carried to the level of the azygous vein to yield an additional 3–4 cm of esophageal lengthening. With increasing adequacy of transabdominal mobilization, the thoracic approach is required less frequently.

A Collis gastroplasty is the most commonly employed esophageal lengthening procedure and involves creating a gastric neo-esophagus, which allows for successful infradiaphragmatic fundoplication placement (Fig. 41.4). This procedure is safe to perform and has grown more popular among surgeons upon encountering a shortened esophagus. Postoperative dysphagia due to the absence of peristaltic activity of the gastric neo-esophagus may theoretically be an issue. A recent report evaluating quality of life after Collis gastroplasty in 795 patients found no increase in postoperative dysphagia compared to those receiving fundoplication alone and found that Collis gastroplasty patients were more likely to have symptom resolution after surgery [9]. Of note, Collis gastroplasty was associated with a significant increase in postoperative leak compared to the fundoplication only group [9]. The neo-esophagus constructed with the stomach is still functionally a stomach with acid-producing capacity.

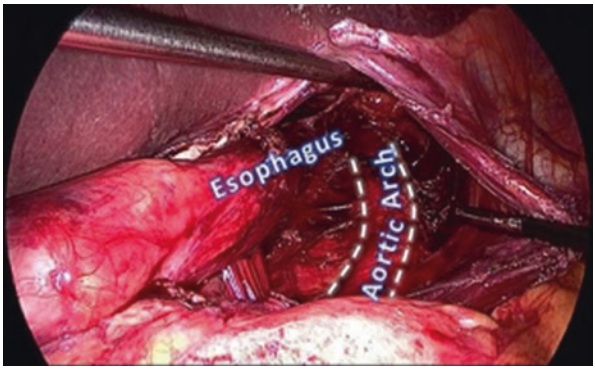

Fig. 41.3 Mediastinal dissection of the esophagus via a transabdominal laparoscopic approach carried up to the level of the aortic arch. Source: Lin, Edward, Swafford, Vickie, Chadalavada, Rajagopal, et al. Disparity Between Symptomatic and Physiologic Outcomes Following Esophageal Lengthening Procedures for Antireflux Surgery. *Journal of Gastrointestinal Surgery*. 2004 Jan;8(1):31–9

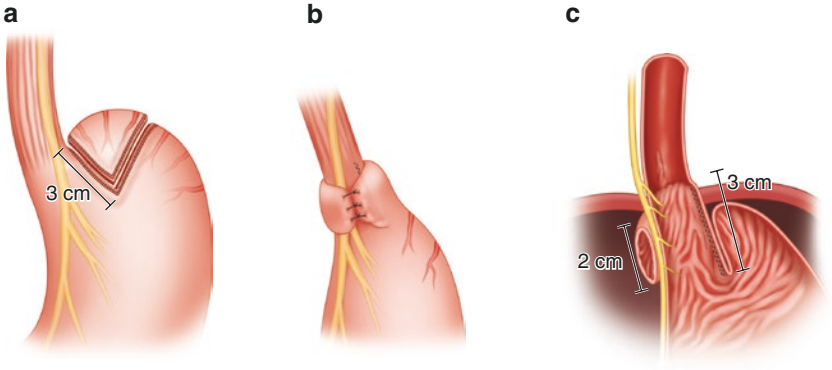

Fig. 41.4 Collis gastroplasty. (**a**) Stapled wedge resection at the level of the gastric fundus. (**b**) Fundoplication using the newly resected gastric segment. (**c**) Creation of a neo-esophagus with at least 3 cm intra-abdominal length

Gastropexy

The concern for the disturbingly high recurrence rates following PEH repair has led some to consider the addition of an anterior gastropexy with the hypothesis that fixation of the stomach anteriorly to the abdominal wall will prevent reherniation into the mediastinum. In a prospective series of 89 patients, Poncet et al. reported a much lower recurrence rate in patients undergoing anterior gastropexy versus those without as part of a large hiatal hernia repair [10]. Similarly, a recent multicenter prospective study reported a series of 101 PEH repairs using a modified Boerema anterior gastropexy alone without mesh cruroplasty or fundoplication. At a median follow up of 10.8 months, recurrence rates assessed by upper GI and

endoscopy were 16.8%. Importantly, despite the absence of a fundoplication, there was an acceptable incidence of postoperative reflux [11]. Although these reports provide some basis for the use of gastropexy, overall there is minimal data to suggest that routine addition of gastropexy reduces recurrence rates after PEH repair. Presently, the addition of an anterior gastropexy as part of PEH repair is dependent on surgeon preference and may be useful in certain situations such as preoperative gastroparesis.

Mesh Versus Primary Closure Alone

Primary cruroplasty using sutures is the technical basis for closing the hiatal defect. However, the concern for high recurrence rates following primary repair drove researchers to investigate the use of mesh prostheses for reinforcement of the crura closure (Fig. 41.5).

Proponents for routine mesh use refer to several prospective, randomized control trials that support decreased recurrence rates associated with mesh use. Initially, Frantzides et al. evaluated 72 patients undergoing hiatal hernia repair with a defect 8 cm or larger [12]. Thirty-six patients underwent posterior cruroplasty alone, and 36 patients underwent posterior cruroplasty and onlay of polytetrafluoroethylene (PTFE) mesh. Eight patients who underwent primary repair alone had evidence of recurrence either by EGD or barium swallow, while none of the patients who underwent mesh reinforcement had evidence of recurrence. In 2005, Granderath et al. evaluated 100 consecutive patients undergoing laparoscopic Nissen fundoplication for GERD and hiatal hernia repair [13]. Half of the patients (n = 50) underwent primary cruroplasty, while the other half underwent primary repair with onlay of a polypropylene mesh. At 1 year follow-up, 26% of the primary repair group had evidence of recurrence by barium esophagram, while only 8% of the mesh group had recurred. Finally, Oelschlager et al. evaluated the use of a porcine small intestinal submucosa (SIS) biologic prosthesis in laparoscopic PEH repair [14]. Similarly to the previous two trials, the use of mesh to buttress the primary repair resulted in a statistically significant decrease in recurrence rates when compared to primary repair alone at 6-month follow-up (9% versus 24%, $p = 0.04$). Interestingly, longer-term follow-up at 4 years revealed similar recurrence rates between the two groups (54% versus 59% $p = 0.7$) [15].

The routine use of mesh is not without complications. Stadlhuber et al. compiled a case series of 28 mesh complications after reinforcement of a hiatal closure [16]. The type of mesh was variable to include polypropylene, PTFE, and biologic mesh. The most common presenting symptom among the 28 patients was dysphagia, followed by chest pain and heartburn. Of the 28 cases described, 23 required reoperation. The most common complication observed at the time of reoperation was intraluminal mesh erosion. Esophageal stenosis and dense fibrosis were also observed. Reoperation on patients with previous mesh closures is associated with longer operative times, increased blood loss, and increased rates of esophageal resection. In a large series of patients undergoing laparoscopic antireflux surgery and hiatal hernia repair with polypropylene mesh over a 15-year period, the reported incidence of esophageal mesh erosion was 0.49% [17].

		No mesh used		Mesh used					
Study	Inclusion criteria	No of patients	Recurrence (%)	Mesh patients	Recurrence (%)	Mesh Type	Fundoplication	Mean follow up (montgs)	Recurrence Detection
Frantzides et al. 2002	Hiatal defect ≥ 8 cm	36	22% (8)	36	0%	PTFE	Nissen	40	Radiologic (Esophagram)
Granderath et al. 2005	Gastroesophageal Reflux Disease Undergoing Repair	50	26% (13)	50	8% (4)	Polypropylene	Nissen	12	Radiologic (Esophagram)
Oelschlager et al. 2011	Hiatal defect >5 cm	34	59% (20)	26	54% (14)	Porcine Small Intestinal Submucosa	Nissen	12	Radiologic (Esophagram)
Watson et al. 2011	At least 50% of the stomach involved	43	23.10%	41	30.80%	Surgisis (Small intestinal Submucosa)	Nissen	12	Radiologic (Esophagram)
Watson et al. 2015	At least 50% of the stomach involved	43	23.10%	42	12.80%	TiMesh (polyproylene)	Nissen	12	Radiologic (Esophagram)

Fig. 41.5 Randomized control trials comparing mesh versus no mesh repair of paraesophageal hernias. Adapted from "Guidelines for the Management of Hiatal Hernia" by G.P. Kohn, R.R. Price, S.R. Demeester, et al. Guidelines for the Management of Hiatal Hernia – A SAGES Publication. 2013

Despite the appeal of mesh use in paraesophageal hernia repair, a consensus is lacking. A survey of 261 SAGES members revealed a wide range of preferences for using mesh that include the size of the hiatal defect, the perceived tension on the crura, and concern for recurrence [18]. Among the different types of meshes used, the three most common were polypropylene, PTFE, and biologic, which were all used with equal frequency.

While the use of mesh reinforcement for PEH repairs is variable among surgeons, it is reasonable to consider what is known. First, any reinforcement should be considered only after all the essential steps for sac excision, adequate esophageal mobilization, and crural closure are achieved. Second, while the complication rate for mesh placement is claimed to be low, the morbidities are significant to include mesh erosions into the esophagus. Third, and a corollary to the previous point, is the choice of mesh should have minimal erosion risks. Fourth, to minimize dysphagia, consideration should be given to mesh characteristics that best match the native tissue (i.e., material compliance, strength, inflammatory reaction) and mesh position (i.e., circumferential verses posterior or anterior placement). Lastly, none of the reports of mesh placement used a bridging technique spanning one crura to the other without first closing the crura. Thus, mesh placement is not intended to replace proper crura closure.

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Repair of Congenital Diaphragm Hernias: Morgagni and Bochdalek

42

P. Bennett Brock and S. Scott Davis Jr.

Introduction

Congenital diaphragmatic hernias (CDH) are a common surgical issue for the pediatric surgeon but are also rarely encountered in the adult population. In this chapter we will examine the incidence of these hernias presenting in adulthood (either symptomatically or incidentally) and examine in more detail two of the most prominent congenital diaphragmatic hernias—Bochdalek and Morgagni—including their embryology, presentation, and finally the surgical approaches to repair of these hernias.

The incidence of CDH in the pediatric population is cited as 1 out of every 2000–3000 live births and accounts for 8% of all major congenital anomalies. There are four main types of congenital diaphragmatic hernias that are described in the literature: (1) the anterolateral, (2) the posterolateral (also known as the Bochdalek hernia), (3) the pars sternalis, and (4) the anteromedial (also known as Morgagni hernia) [1].

Given the rarity of these hernias, the number of reported cases guiding recommendations for treatment is low. A large number of reported repair techniques are described using a variety of thoracic and abdominal approaches. In general, reported recurrence rates from many different repairs are low. Therefore, advanced minimally invasive techniques are likely to provide significant benefits in short-term morbidity and mortality as is true for many other thoracoabdominal procedures. We believe they should be applied where applicable. In addition, these procedures may be particularly suited for robotic surgery and the proposed advantages of that platform.

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Embryology

To better understand congenital diaphragmatic hernias and the problems they pose for patients and surgeons, it is important to understand the embryology of the normal diaphragm and the alterations in normal development that can occur which result in these defects.

The development of the diaphragm occurs during the fourth week of gestation and is composed of four components: the septum transversum, the pleuroperitoneal membranes, the dorsal esophageal mesentery, and the body wall (Fig. 42.1). The septum transversum is the most important component, forming the central tendon. This fuses with the mediastinal mesenchyme dorsally and later with the pleuroperitoneal membrane. The pleuroperitoneal membrane fuses with the dorsal mesentery of the esophagus and the dorsal aspect of the septum transversum, forming the primitive diaphragm. It is the fusion of these two muscle groups that forms the anatomical region most vulnerable to congenital diaphragmatic hernias, occurring around week 6 of gestation (Fig. 42.2) [1, 2].

Bochdalek Hernia Overview

Of the congenital diaphragmatic hernias, the Bochdalek hernia is the most common; however in adults, the incidence is still only 0.17%. Originally described by the Czech anatomist and pathologist Vincenz Alexander Bochdalek in 1848, the Bochdalek hernia remains one of the most common congenital anomalies of the thorax [3].

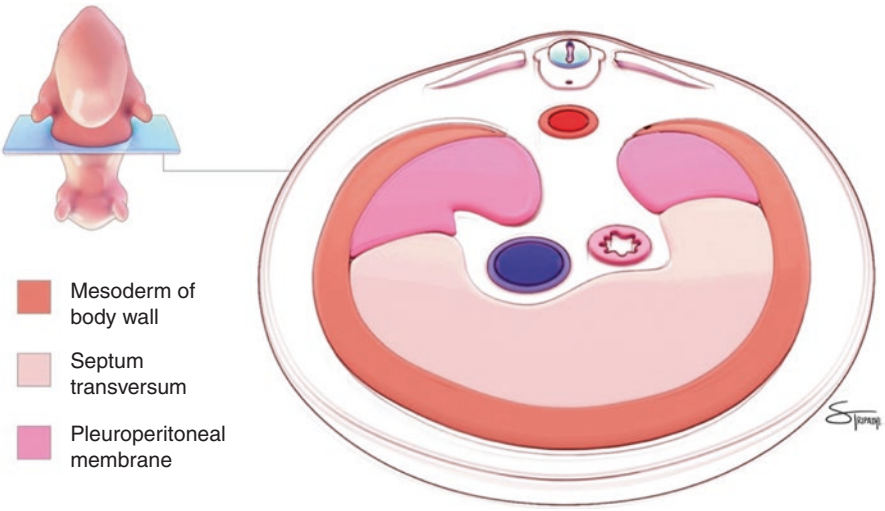

Fig. 42.1 Embryological development of the diaphragm

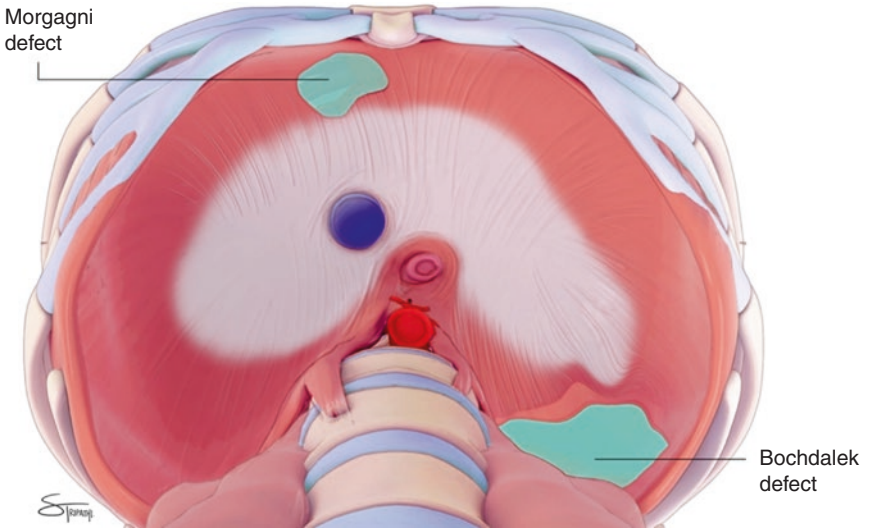

Fig. 42.2 Congenital diaphragmatic hernia

The Bochdalek hernia occurs due to failure of the posterolateral foramina to fuse properly. The location of this defect is defined by the location of the diaphragmatic coronary ligaments bilaterally. While a well-known neonatal defect, the finding of a Bochdalek hernia in adults is much less common. This hernia has a prevalence for occurring mostly on the left side, as noted in 85% of cases. Left-sided hernias can contain the small and large bowel, as well as other intra-abdominal organs including the spleen and stomach. Right-sided hernias occur in 13% of cases and have been noted to contain the liver as well as the large bowel. These right-sided hernias are more uncommon due to the right pleuroperitoneal canal closing earlier during gestation, as well as the liver creating a buttress for the right diaphragm. Bilateral hernias are much rarer, accounting for 3–6% of documented Bochdalek hernias [4].

Morgagni Hernia Overview

First described by Giovanni Battista Morgagni, an Italian anatomist in 1769, the Morgagni hernia accounts for 2–3% of all diaphragmatic hernias, therefore causing it to be the least common of the diaphragmatic hernias [5].

The Morgagni hernia, also known as the retrosternal or parasternal hernia, occurs due to failure of fusion of the pars sterna of the septum transversum, leading to development of a defect in the anteromedial aspect of the diaphragm adjacent to the xiphoid process. A majority of these hernias occur on the right side, and only 20% occur on the left. The space through which the Morgagni hernia can be found has also been called the space of Larrey, which is also the retrosternal space, described through which a pericardial tamponade can be treated. While this space is small, it can often expand with periods of prolonged increased abdominal pressure, as is seen in pregnancy [6].

In a paper published by Horton et al. in 2008, a review of literature was performed on case reports of Morgagni hernias in the adult population after the year 1951. They examined 135 articles totaling 298 patients; the results of this review showed that 72% of adult patients with Morgagni hernias presented with symptoms related to their hernia, and with those patients that presented with symptoms, pulmonary complaints were the most common complaint (32%). In the study, it was also noted that on average, men tended to present earlier than women [5].

Presentation

In the neonate, these diaphragmatic hernias are usually symptomatic, with the primary clinical presentation of respiratory distress at birth. Other symptoms in the neonate or pediatric population are related to the contents of the hernia sac, as well as the size of the sac. These symptoms include repeated chest infections, coughing, dyspnea, and/or retrosternal pain, as well as pulmonary hypoplasia and pulmonary hypertension seen in neonates. However, 5–10% of those with CDH have no symptoms at birth, and about 1% of those with CDH have no symptoms and are discovered incidentally on imaging later in life [7].

In the adult population, the Morgagni and Bochdalek hernias are most commonly noted incidentally on imaging in otherwise asymptomatic patients. They can be detected on CXR, CT scan, or barium swallows, although CT scan is the most accurate method for diagnosing and evaluating the contents of a Bochdalek or Morgagni hernia [8]. It has also been postulated that the hernia will present following periods of prolonged increased intra-abdominal pressure, the most common reason being pregnancy. For the rare instance of adults presenting with symptomatic CDH, the most common abdominal symptoms described are recurrent abdominal pain, postprandial fullness, as well as vomiting [8].

Indications for Surgical Repair

There is currently no set criteria or guideline in the literature regarding optimal timing for repair in adult patients with asymptomatic congenital diaphragmatic hernias. While these hernias are commonly noticed incidentally in the otherwise asymptomatic individual, the risk of strangulation or incarceration of hernia contents requiring emergent intervention is a very real concern, leading to the recommendation from our institution that these hernias be surgically repaired once diagnosed once patient is as medically optimized as possible. The one exception to this would be a posterior right diaphragmatic defect which is often small, fat containing, and is anatomically covered by the liver. In many cases these can be observed without progression. In medically unfit patients, observation of certain smaller hernias without concerning involvement of the gastrointestinal tract can also be considered. Smoking status and body habitus would be other important considerations in recommending repair.

Surgical Techniques

Multiple techniques have been described for the repair of such hernias, including a transabdominal approach, a transthoracic approach, a combined transabdominal/transthoracic approach, as well as minimally invasive approaches. Due to the lack of randomized controlled studies or even large cohort series comparing various techniques, there is no standard of care surgical technique for the repair of these hernias, and the approach is left up to the surgeon's preference and level of comfort with each approach.

The approach to repair does depend on presentation, including emergent versus elective, the size of the defect based on pre-op imaging, as well as the side of the diaphragmatic defect. In the emergent or acute setting in which there is concern for possible strangulation or ischemia of the sac content, many advocate for the open abdominal approach using a midline or subcostal incision. That stated, a surgeon comfortable with foregut surgery in the acute setting could in all likelihood approach these situations via minimally invasive techniques as well. Right-sided defects have been described as being repaired with a thoracic or combined thoracoabdominal approach due to the presence of the liver, but for left-sided defects, no one approach seems to have significant advantages over the other. In the case of dense adhesions or large volume of the hernia sac, most case reports have used the thoracoabdominal approach as well.

Many published reports predate advances in minimally invasive surgical techniques, and these would be likely to contribute similar benefits seen in other procedures (shorter length of stay, shorter recovery, less wound morbidity). The first laparoscopic approach was reported by Kuster et al. [9], and subsequent laparoscopic approaches have been described primarily in the elective setting. Patients are generally placed in the left lateral decubitus position or in the supine position in Trendelenburg position. The use of a 30- or 45-degree scope has been advocated. Some have discouraged the use of sac dissection in Bochdalek hernias, as there is a risk of pleural injury, and instead recommend leaving the sac in place [10]. While the use of the robot for repair of Morgagni and Bochdalek hernias has been described in a few small case reports, both in adults and in the pediatric population, there is insufficient data available at this time regarding this approach. The same theoretical advantages purported in other procedures are likely applicable in these procedures. Enhanced abilities to suture minimally invasively would in theory provide a meaningful advantage as sutures placed posteriorly on the diaphragm can be technically challenging.

Debate exists regarding the use of mesh versus a primary repair without mesh. While some have advocated for the use of mesh if the hernia defect is 20 cm^2, others have used mesh in defects as small as 8 cm [10]. There is no high-level data to guide surgeons on the need for prosthetic reinforcement. These decisions are likely guided by surgeon past experience in foregut surgery, specifically repair of large hiatal hernias where some tenets have been established that can guide the repair of congenital defects. One major difference in these procedures is that the defect will be closed, and without any direct contact to the viscera, so more liberal use of

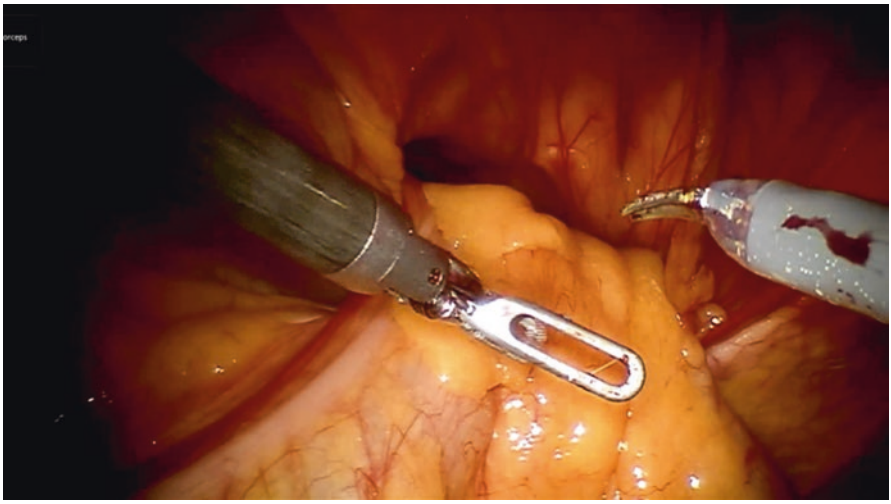

Fig. 42.3 Morgagni hernia defect visualized containing the colon and omentum

prosthetic reinforcement makes sense. The surgeon should be mindful of the properties of the material chosen given the dynamic function of the diaphragmatic muscle. The suture of choice for primary repair also has no standardization, with techniques of running as well as interrupted suture, permanent suture, and absorbable suture being described. However, based on review of case reports, the use of nonabsorbable braided suture in an interrupted or continuous fashion has been the most frequently used.

At our center, we would approach adult diaphragmatic hernias using a minimally invasive transabdominal approach, unless the defects were right-sided posterior defects. Right-sided posterior defects are most likely defects that can be observed serially unless they are symptomatic. Given the excellent results of the minimally invasive approach, we recommend repairing the medial Morgagni defects and the posterolateral left-sided Bochdalek defects. They can often be repaired using only three or four ports.

Morgagni defects are visualized using a supraumbilical camera site and right- and left-sided 5 mm cannulas (Fig. 42.3).

We have routinely attempted to reduce and resect the hernia sac which has been possible in most cases. Defect closure is routinely attempted and often achievable without undue tension. There are two possible ways to achieve defect closure. In some cases, there is sufficient diaphragmatic laxity that the defect can be closed with either running or interrupted nonabsorbable braided suture (Figs. 42.4 and 42.5).

These sutures can be placed with or without pledgets which can be used to buttress the suture line. In this location, we will often use Teflon pledgets as there is little risk of the permanent pledgets eroding into any part of the gastrointestinal tract. In some cases with more horizontally oriented defects, sutures can be placed

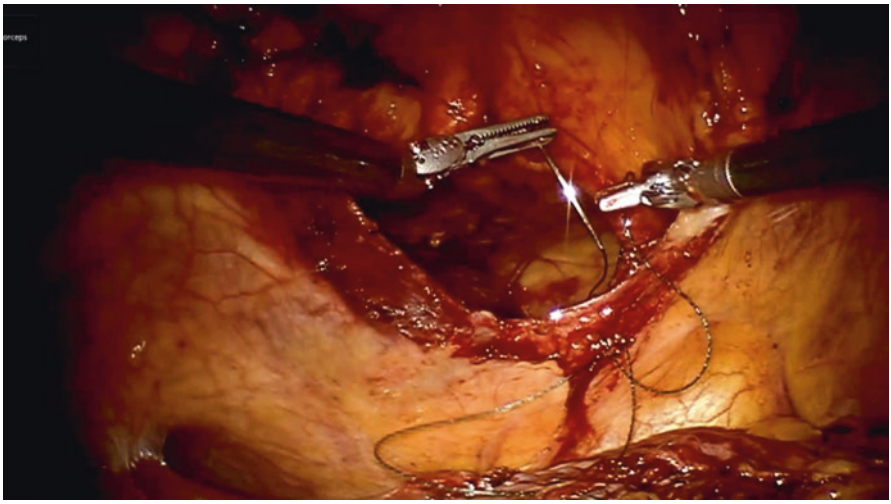

Fig. 42.4 Initiation of primary closure of hernia defect using running continuous suture technique

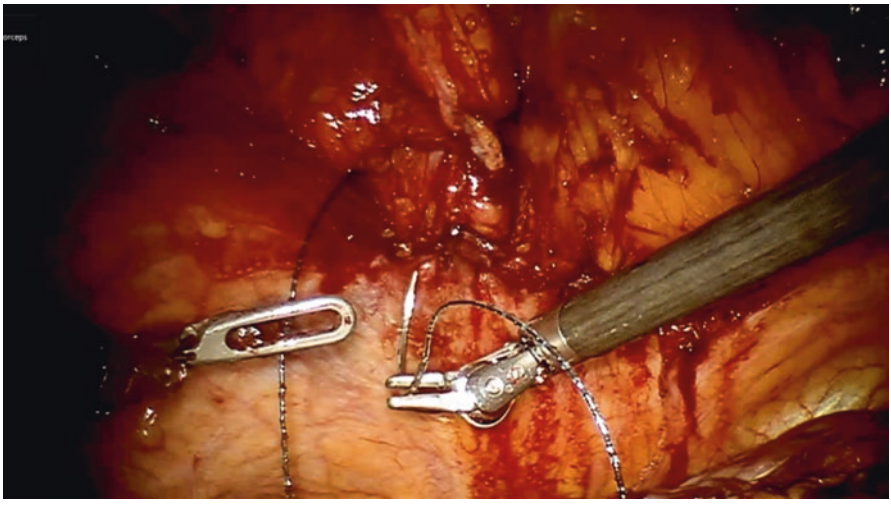

Fig. 42.5 Completion of primary closure of hernia defect

sequentially subcostally through the posterior rim of the hernia defect using a suture passing device. With decreased pneumoperitoneum, the defect can be closed by tying down the sutures bringing the posterior rim of the hernia defect to the subcostal cartilage. In most cases, we prefer an onlay reinforcement of this closure (Fig. 42.6).

Permanent composite materials are recommended, and this can be done with any of the commercially available products. We do not use tacks in these cases and

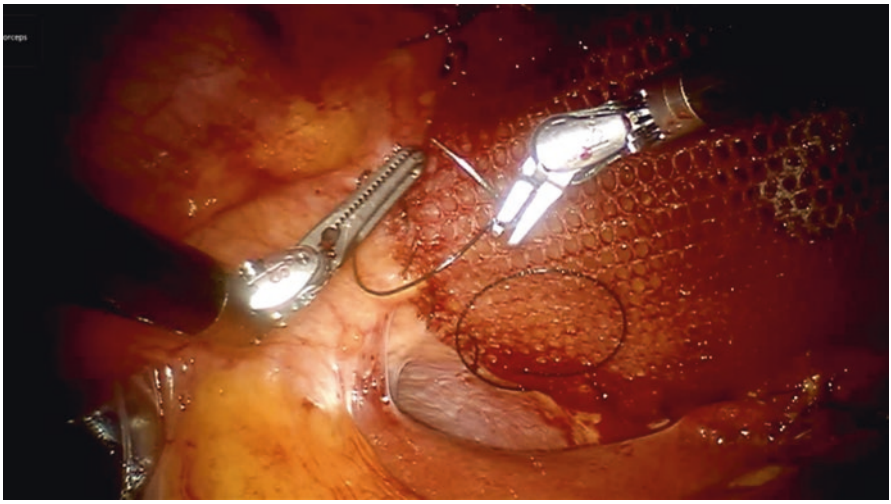

Fig. 42.6 Placement of mesh onlay with running continuous suture for fixation

prefer to fixate with interrupted sutures taking care not to injure the hepatic veins deep to the liver's triangular ligament.

Bochdalek hernias are repaired using similar principles. For these hernias, a liver retractor is often needed for exposure. These hernias can be very posterior in the diaphragm behind the spleen, and so positioning the patient preoperatively to be able to achieve steep reverse Trendelenburg and tilt positions facilitates exposure. In cases where the colon or spleen herniates through the defect, care must be taken in reduction of the contents, as neither structure is as hardy as the stomach for manual traction. We have routinely attempted to reduce the sac; however, this has led to pneumothorax in some cases. This does not typically require chest tube thoracostomy as there is no lung injury and the insufflation will be resorbed after the procedure resolving the pneumothorax. While we have seen pleural injury in doing this leading to pneumothorax, we have not seen any lung injury, and this trade-off has been preferable to us over the potential of leaving an endothelial-lined space in the chest. The defect is closed in a similar manner, often using Teflon pledgets. Onlay mesh reinforcement is done routinely even for small defects. The mesh typically lays posterior to the spleen, and so adhesive disease to abdominal organs is not generally an issue. We have typically used lightweight composite monofilament polyester materials for this repair, which are the same products we have used in intraperitoneal onlay mesh repairs of ventral hernias.

Robotic surgery can lend some particular advantages in repairing diaphragmatic defects. We desire to avoid tacks, and thus circumferential suturing is required to secure the prosthetic. This is greatly enabled with the robot and technically easier to accomplish. For this procedure we will place two cardinal barbed sutures on the left and right sides of the mesh and fix these to the diaphragm to

suspend the mesh. We have found that sewing the anterior side of the mesh in a running fashion facilitates exposure of the posterior aspect of the mesh. The posterior running suture is then completed. Careful bites are taken with the sutures to avoid pleural or pericardial injury, and the use of the barbed suture eliminates the need to tie multiple knots. These benefits are technical and not currently supported by data.

In the pediatric population, laparoscopic repair of these hernias has been well-documented and standardized. The repair is described as using nonabsorbable, interrupted sutures. A recent multicentric review was performed in the pediatric population by Esposito et al. which examined 43 patients who underwent laparoscopic repair of Morgagni hernias in eight pediatric surgery hospitals during a 5-year period. In this review, there was no conversion to the open approach, and the average operative time was 61.2 min, ranging from 45 to 110 min. In 38/43 patients (88.3%), a transparietal stitch was placed in order to reduce tension during the repair. In 14/43 cases (32.5%), the sac was resected. A mesh was used in only 1/43 patients. The average hospital stay was 2.8 days [11]. These results may be difficult to extrapolate to adult patients, particularly the need for mesh. Mesh placement would not be something to recommend in small patients who will continue to grow and in whom abdominal forces are not as great.

Outcomes

A recent meta-analysis was performed that examined cases of CDH repair from 1966 to 2013 in the pediatric population, looking specifically at outcomes related to open versus minimally invasive approach (MIS). This analysis included nine studies reporting on 507 patients. The MIS group had a significantly lower rate of postoperative death with a risk ratio of 0.26 [95% confidence interval (CI) 0.10–0.68; $p = 0.006$] but a greater incidence of hernia recurrence with a risk ratio of 3.42 (95% CI 1.98–5.88; $p < 0.00001$). Rates of prosthetic patch use were similar between the two groups. Fewer cases of surgical complications were found in the MIS group with a risk ratio of 0.66 (95% CI 0.47–0.94; $p = 0.02$) [12, 13].

Machado's review for Bochdalek hernias described 368 reported cases over 65 years in the adult population. In the 184 patients who underwent surgical intervention, 74 underwent open laparotomy approach (40.27%), 50 underwent thoracotomy (27.7%), a combined thoracoabdominal approach was seen in 27 patients (14.6%), and a laparoscopic approach was used in 23 patients (12.5%). These repairs spanned all generations of possible operative techniques. The overall recurrence rate was 1.6%. Among the patients that underwent the laparoscopic approach, 82% were elective repairs. Of the 184 patients, 66% underwent primary repair of the defect, with 61% requiring interposition or mesh with or without primary repair [14]. Given the low recurrence rates in this accumulated reported experience, it is not possible to make evidence-based recommendations regarding optimal technique at this time.

Summary

While Bochdalek and Morgagni hernias are rare in the adult population, the treatment of choice is surgical repair due to risk of strangulation, and a working knowledge of the different approaches to repair is imperative for the surgeon. The different techniques described include open via abdominal, thoracic, or combined incisions, as well as the minimally invasive approaches. In the elective setting, the laparoscopic approach is a safe and effective technique for the repair of these hernias, and in the acute or emergent setting, it is up to the surgeon's comfort level with the different approaches as to which method is employed.

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Revisional Paraesophageal Hernia: Tips and Tricks

43

Rana M. Higgins and Jon C. Gould

Introduction

Recurrent paraesophageal hernias are a challenging technical problem. Recurrence rates reported in the literature after primary laparoscopic and open paraesophageal hernia repair range from 2 to 59% [1]. The wide range in reported recurrence rates highlights the issues surrounding the challenges faced in repairing these hernias. There are many different opportunities for technical variation in paraesophageal hernia repair. Mesh or no mesh, fundoplication or no fundoplication, esophageal lengthening procedure, gastropexy, or gastrostomy tube are just a few of the options and techniques commonly utilized. Patients differ widely in their medical and physiologic status as well as their ability to tolerate an operation upon presentation [2]. Paraesophageal hernias also differ greatly in terms of the difficulty of performing a successful repair based on the amount of stomach herniated, the presence of other organs in the hernia sac, the size of the hiatal defect, and the integrity of the diaphragm when attempting to place sutures, especially under tension.

There are a variety of known risk factors for paraesophageal hernias recurrence. The esophageal hiatus is a "hostile environment" when it comes to the durability of any kind of surgical repair or reconstruction. The diaphragm is a thin muscle that is constantly in motion. The hiatal defect cannot be closed or covered, and the pressure differential between the abdomen and the chest is perpetually pushing the stomach cephalad. In patients with a large hiatal defect and thin or attenuated crural muscle, primary closure of the defect may create significant radial tension on the diaphragm contributing to failure of the repair [3]. "Diaphragm stressors" such as gagging, retching, and vomiting in the perioperative period

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represent a major risk factor for recurrence [4]. Morbid obesity is also a significant risk factor for recurrence [5]. Technical factors such as the use of mesh have been demonstrated to decrease early [6] but not late recurrence [7]. Even surgeon volume has been demonstrated to correlate with the rate of recurrence following paraesophageal hernia repair [8]. When paraesophageal hernias recur, it is important to understand the potential mechanism or recurrence and what can be done differently if a reoperation is required.

Clinical Evaluation

Not all paraesophageal hernia recurrences are symptomatic. Some patients have a "radiographic" recurrence with either a CT scan or an esophagram that demonstrates a variable amount of stomach above the diaphragm without symptoms of gastroesophageal reflux or obstructive symptoms. For the most part, patients with radiographic paraesophageal hernia recurrence without symptoms can be managed without repeat surgery. When surgery for a recurrent paraesophageal hernia is under consideration, an appropriate diagnostic workup is essential. Upper endoscopy, upper GI esophagram, CT scan, gastric emptying study, ambulatory pH studies, and esophageal manometry are among the tests that may be needed. A review of the previous operative report is helpful as well. Details from the operative report that can be useful include comments regarding the size of the hernia and extent of mediastinal mobilization needed, difficulty encountered closing the hiatus, technique used to close the hiatus, presence of mesh (including what type, configuration, location, and fixation method), and if a fundoplication was performed.

Upper GI esophagram: We attain an upper GI esophagram in all patients in whom we are considering a reoperative paraesophageal hernia repair. An upper GI can help demonstrate the anatomy and evaluate for the presence of a hiatal hernia. A timed barium esophagram with a marshmallow challenge (or any other kind of barium-soaked food bolus such as hamburger or a bagel) is helpful in patients with dysphagia after a paraesophageal hernia repair to determine if there is a degree of esophageal stasis and impaired emptying that may account for these symptoms.

Upper endoscopy: Upper endoscopy prior to reoperative paraesophageal hernia repair is essential. An upper endoscopy can identify pathology such as erosive esophagitis, ulcers, Barrett's metaplasia, or other lesions. Eosinophilic esophagitis and candida esophagitis may be identified and should be treated prior to revisional surgery. The presence of permanent sutures related to the prior surgery or mesh at the hiatus in the lumen of the esophagus or stomach should be documented. The location of the hiatus and the fundoplication (if previously performed) should be noted. In patients with esophageal outflow obstruction and stasis, partially digested food and secretions may be pooled in the esophagus. In patients with vagal nerve injury and postsurgical gastroparesis, a bezoar or partially digested food may be noted in the stomach.

Gastric emptying study: Following truncal vagotomy for peptic ulcer disease, the incidence of postsurgical gastroparesis may be as high as 5% [9]. The exact

incidence of postsurgical gastroparesis in patients undergoing primary paraesophageal hernia repair is much lower than that and hard to define based on the literature. The fact that delayed gastric emptying can be a complication following hiatal and paraesophageal hernia repair is well described based on numerous published case series of patients suffering from postsurgical gastroparesis [10]. In patients with symptoms consistent with gastroparesis (nausea, vomiting, severe bloating, early and prolonged satiety) or in patients with retained food in the stomach on upper endoscopy, a nuclear medicine gastric emptying study should be attained. In a patient with significant symptoms of gastroparesis and delayed gastric emptying on a nuclear medicine study, consideration should be given to a concurrent pyloroplasty of possibly even a Roux-en-Y gastric bypass as a salvage operation.

Esophageal manometry: Esophageal manometry is indicated in patients with dysphagia and especially in cases where a manometry was not attained prior to the index operation. In general, one should err on the side of performing as thorough a preoperative assessment as possible given the high stakes of reoperative paraesophageal hernia repair. In cases where the esophageal motility is ineffective, consideration can be given to a partial fundoplication, such as a Toupet. The authors favor a Toupet partial fundoplication in reoperative paraesophageal hernia repair in patients with moderate or more severe dysphagia, in patients with documented poor esophageal motility, and in patients who are older given the high rate of esophageal dysmotility in these patients [11]. It is worth noting that esophageal manometry can be difficult and sometimes inaccurate in patients with large and complex paraesophageal hernias.

Esophageal pH monitoring: Esophageal pH monitoring can help confirm that symptoms consistent with gastroesophageal reflux (GERD) following a previous paraesophageal hernia repair are indeed GERD-related.

Chest/abdomen CT scan: Images and reconstructions from a CT scan with oral and IV contrast can complement what is learned about the hernia recurrence from an upper GI series. Additional information that can be gained from a CT scan includes the size of the defect in the diaphragm and whether other organs such as the spleen or colon are present in the hernia sac.

Patient Selection

Repair of recurrent paraesophageal hernia is technically complex and associated with increased morbidity when compared to primary repair [12]. The nature and severity of symptoms related to a paraesophageal hernia recurrence needs to be taken into account when determining if reoperative surgery is indicated. GERD symptoms that can be managed with acid suppression medications may not warrant a reoperative paraesophageal hernia repair in a frail or deconditioned patient. Frailty is defined as a decrease in physiologic reserves giving rise to vulnerability separate from the normal aging process [13]. Frailty has been demonstrated to be associated with increased morbidity following paraesophageal hernia repair [2].

Operative Technique

Reoperative paraesophageal hernia repair is a complex procedure and requires a great deal of skill, experience, and judgement to attain an optimal outcome. We have noted in our large clinical experience of reoperative paraesophageal hernia repair that the number of prior reoperative attempts in a given patient is directly related to the perioperative morbidity and inversely related to the symptomatic and functional outcomes. In these author's opinions, reoperative paraesophageal hernia repair is best performed at high-volume centers and by surgeons with significant experience in reoperative foregut surgery for these reasons.

Selecting the appropriate procedure based on the patient's medical and surgical history, the mechanism(s) of failure of prior procedure(s), and the results of a thorough preoperative evaluation is critical for success. In general, morbidly obese patients with a recurrent paraesophageal hernia should be considered for reoperative repair of the hernia and conversion to Roux-en-Y gastric bypass [14]. As noted, obesity is a significant risk factor for recurrent paraesophageal hernia. A reoperative paraesophageal hernia repair in the setting of morbid obesity is likely to fail.

Our preferred approach to reoperative paraesophageal hernia repair in almost all cases is laparoscopic. There are advantages in terms of decreased wound complications (hernias and infections) and postoperative pain and recovery for a laparoscopic compared to an open approach. With a laparoscope, visualization and mobilization of the stomach and esophagus high into the mediastinum are attainable to a degree not possible with an abdominal laparotomy. Some surgeons prefer the use of a surgical robot for these reoperative cases, but our bias is that the tactile feedback and the ability to rapidly and frequently change instruments with standard laparoscopy are important features of our preferred approach.

In a reoperative paraesophageal hernia repair, the basic steps can be broken down into adhesiolysis and identification of the anatomy, mediastinal mobilization of the stomach and esophagus, takedown of fundoplication if present, ensuring adequate intra-abdominal esophageal length, closure of the hiatus, fundoplication if indicated, and additional steps to further anchor the stomach if deemed necessary. In frail patients with more urgent indications such as severe dysphagia, failure to thrive, or incarceration/obstruction secondary to recurrent paraesophageal hernia, a palliative procedure designed to relieve the obstruction or even to simply gain enteral access for feeding distal to the hiatus may be in the patient's best interest. An 8-h operation to achieve a perfect reoperative repair is inappropriate if the patient is too debilitated to survive such an effort. In these very frail patients with an urgent need for reoperative repair, we try to limit our operative time and address the primary issue, which is usually obstruction. Untwisting the stomach and relieving the obstruction without going to the work to achieve significant intra-abdominal esophageal length and a perfect fundoplication is usually enough to address the primary life-threatening issue that led to surgery in these patients. Gastropexy with sutures to the hiatus, to the more lateral diaphragm, and to the anterior abdominal wall as well as placement of a gastrostomy tube (or more than one G-tube) can be performed [15]. For patients able to tolerate a definitive repair of a recurrent paraesophageal hernia, the operation is deconstructed as follows:

Adhesiolysis and Identification of the Anatomy

A review of the previous operative report may be informative as to whether the hernia sac was dissected off the crura at the time of the original procedure. When a surgeon simply manually reduces the hernia contents and performs a repair without taking the sac off the diaphragm and getting up into the mediastinum, the paraesophageal hernia is bound to recur. In these patients, dissecting the sac off the crura and entering the mediastinum allow the reoperative surgeon to enter a relatively adhesion-free plane, and reducing the recurrent hernia may be easier than most reoperative cases. For most patients with a recurrent paraesophageal hernia, the sac has been dissected off the diaphragm and often resected in whole or in part. The dissection in the mediastinum is quite a bit more difficult in these patients than in a primary paraesophageal hernia repair.

Abdominal access for laparoscopy is attained with a Veress needle in the left subcostal area in the midclavicular line. Upon successful insufflation, a 5-mm optical viewing bladeless trocar is used to access the abdomen through the Veress site. A total of four 5-mm ports are used. If mesh at the hiatus is removed or placed, the left subcostal port is upsized to 10-mm. A subxiphoid Nathanson liver retractor is placed in all patients. Additional 5-mm ports should be placed as needed.

Adhesiolysis involves a combination of sharp dissection with a scissors, dissection with an ultrasonic shears, and blunt dissection with a laparoscopic suction irrigator tip where appropriate. When technically feasible, the caudate lobe of the liver is identified first, which allows for identification of the right crus of the diaphragm. Dissection typically starts at the base of the right crus and proceeds anteriorly in the plane between the right crus and the fundus/esophagus if possible. Ultimately, the fundoplication or esophagus is circumferentially mobilized off the hiatal muscle—preserving as much muscle and fascia as possible on the diaphragm. In some cases with severe and dense adhesions, the anatomic landmark that proves easiest to find is the base of the left crus, and this is after dividing branches or the gastroepiploic vessels to the body of the stomach and entering the lesser sac posterior to the stomach and somewhat removed from the operative site and hiatal adhesions.

In cases with pre-existing mesh at the hiatus, the mesh is removed in its entirety when possible. Care is taken to preserve as much diaphragm muscle as possible when removing mesh. Care is also taken to ensure that mesh adherent to the fundus or esophagus can be safely removed without damage or perforation to the foregut. Mesh excision from the esophagus or fundus is almost always done sharply with scissors. Sometimes, more than one fresh scissors tip is needed in these cases. A sharp scissors tip is essential.

If an enterotomy is made, the strategy for repair varies based on where the injury occurred. Enterotomies to the stomach removed from the gastroesophageal junction are often best addressed with an endoscopic linear cutting stapler. Enterotomies to the esophagus and the stomach near the gastroesophageal junction are best addressed with a primary sutured repair buttressed with a serosal patch from a properly constructed fundoplication.

Mobilization of the Esophagus and Reduction of Herniated Stomach

Circumferential and high mediastinal mobilization of the esophagus is performed until 3–4 cm of intra-abdominal esophageal length can be attained without tension. A Penrose drain around the esophagus is used for gentle retraction. The vagus nerves are identified and preserved when possible. Esophageal lengthening procedures are rarely necessary. When needed, we perform a laparoscopic wedge fundectomy for a Collis gastroplasty as described by others [16].

Takedown of Fundoplication

Once the fundus or esophagus is freed from the hiatus, the fundoplication is taken down. Usually, the fundoplication sutures can be visualized, and a combination of dissection with an ultrasonic energy source or with scissors is utilized to dismantle the fundoplication. Ultrasonic shears are only used when the sutures and tissue planes can be clearly visualized. An advantage to using the shears in this context is better hemostasis but also a "cavitation" effect that can facilitate the dissection and help to identify tissue planes. A disadvantage to the ultrasonic shears is the fact that tissue injury and perhaps delayed perforation is a potential consequence. Fundus to fundus, fundus to esophagus, and ultimately fundus to retroperitoneum/diaphragm adhesions are carefully taken down until the greater curve of the stomach and angle of His is restored to its native anatomic position. In cases with dense adhesions, endoscopy is useful to confirm that the fundoplication has been taken down in its entirety on retroflex views.

Closure of Esophageal Hiatus

Primary crural repairs are performed in all patients. Some surgeons prefer to use pledgeted sutures. The used of running unidirectional barbed suture has even been described in hiatal closure. Placement of permanent, interrupted sutures is the most common technique. The ideal crural closure will have the crura just approximating an empty esophagus without constriction or severe angulation. If there is space remaining anterior to the esophagus, interrupted sutures can be placed here to avoid additional anterior angulation of the esophagus by posterior sutures as long as the esophagus is not constricted.

In patients with a dilated hiatus or loss of muscle at the hiatus from the dissection, bridging the hiatus with mesh is discouraged due to a very high recurrence rate [17]. In these patients, a right-sided crural relaxing incision can be performed to allow for primary closure. To perform a relaxing incision, a hook cautery or ultrasonic shears are used to incise the right crus of the diaphragm starting about 2–3 mm medial to the vena cava when possible. The most important aspect of this relaxing incision is the anterior component where the most amount of tension can be relieved. It is important that this incision is below the anterior crural vein to avoid injuring the

intrathoracic vena cava. The incision should not be taken too far inferiorly near the decussation of the right and left crus to avoid aortic injury. A full-thickness muscle incision is made, and if possible the right pleural cavity is not entered. In most cases, good medialization of the right crura is possible without opening the pleura. In cases where the pleura is entered, the pleura on the right side is opened through the hiatus and a 19Fr silastic drain is placed through the hiatus anteriorly, into the mediastinum, and into the right chest. At the end of the case, this drain is externalized through a 5-mm port. The anesthesiologist then gives several big Valsalva breaths with the ventilator as the drain is slowly removed under suction. Chest tubes or abdominal drains are not routinely left in these cases. If a right-sided crural relaxing incision is not possible or insufficient, a left-sided incision can be performed. The left-sided incision should be parallel to the seventh rib and coursing laterally toward the spleen. If this incision is radial instead of parallel, there is a risk of phrenic nerve injury. In one study of 64 patients, tension at the hiatus was reduced 36% with a left-sided and 46% with a right-sided relaxing incision (56% when bilateral incisions performed) [3]. When a relaxing incision is performed, the crura are closed, and mesh should be placed as an onlay [18]. The use of a crural relaxing incision has not been shown to increase the rate of hernia recurrence in the short term when compared to primary closure [19, 20]. There has not yet been long-term data examining the effects of crural relaxing incisions in these patients.

Mesh placement at the hiatus is a controversial topic. There may be an advantage in short-term recurrence rates of paraesophageal hernias when mesh is used to reinforce the hiatus at the time of primary repair [6, 21]. Decreased long-term recurrence rates when mesh is used at the hiatus in primary paraesophageal hernia repair have not been definitively demonstrated [7, 22]. Synthetic mesh at the hiatus has been associated with dysphagia, stricture, and esophageal erosion [23]. In patients who ultimately require a repeat operation for a recurrence, the presence of previously placed mesh at the hiatus may increase the risk of morbidity and the need for esophageal or gastric resections [24, 25].

Almost all of the published data related to recurrence and morbidity when mesh is used at the hiatus is in patients undergoing primary repair. When a patient undergoes surgery to repair a recurrent paraesophageal hernia, the incidence of repeat recurrence is likely higher with each subsequent reoperative attempt [26]. In patients undergoing reoperative paraesophageal hernia repair in whom the hiatal closure is determined to be under tension or for whom a crural relaxing incision is needed, we use a U-shaped piece of synthetic bioabsorbable mesh (Gore Bio-A, Flagstaff, AZ) to reinforce the hiatus. We anchor the mesh with interrupted, permanent sutures.

Fundoplication

In patients capable of tolerating a definitive repair, we routinely perform a fundoplication at the time of reoperative paraesophageal hernia repair, even in the absence of preoperative GERD. We feel that the bulky fundoplication prevents recurrence, although there is no data to support this theory. Small studies with limited follow-up have demonstrated that the GERD-related outcomes, even in patients without

pre-existing GERD, are worse when a fundoplication is not performed with a paraesophageal hernia repair [27, 28].

In the setting of pre-existing dysphagia or impaired esophageal motility (based on manometry), a posterior partial fundoplication (Toupet) is constructed. In patients to undergo reconstruction of a Nissen fundoplication, a 56–60 French esophageal bougie is utilized. Care must be taken when passing the bougie, as the esophagus in some patients with a recurrent paraesophageal hernia may be dilated and tortuous. In addition, if the bougie is passed after crura reapproximation, the esophagus may be angulated anteriorly therefore increasing the possibility of an esophageal perforation from the bougie at the hiatus. Clear communication between whoever is passing the bougie and the surgical team is essential. Gastropexy sutures between the fundoplication, the posterior hiatal repair, and the anterior left and right crural pillars are routinely placed. Endoscopy is performed liberally during the procedure to help identify the anatomy and to ensure there are no unrecognized perforations. Endoscopy is performed at the end of the procedure to ensure the same and that the fundoplication is in the right location relative to the gastroesophageal junction and that the hiatus and fundoplication are easily navigated endoscopically.

Gastropexy and Gastrostomy Tube

Anterior gastropexy is sometimes performed to reduce the possibility of recurrence, especially when a definitive repair is not possible or not a good choice. There is limited data to support the efficacy of this practice in preventing recurrence [29]. From a practical perspective, anterior gastropexy is easy to accomplish. A suture passer can be used to anchor the stomach to the anterior abdominal wall with full-thickness fascia bites. Anterior gastropexy can also be accomplished with a gastrostomy tube and sometimes more than one tube in the same patient [15]. The advantage to a gastrostomy tube is that it allows for gastric decompression and venting and for enteral access for supplemental feeding or medications.

Postoperative Course and Outcomes

We don't routinely place nasogastric tubes. Drains are placed in the upper abdomen or mediastinum selectively. In cases where an intraoperative esophageal or gastric perforation was repaired, in cases with ongoing bleeding throughout the procedure, or in cases where the liver was densely adherent to the stomach and the capsule was damaged extensively during adhesiolysis, we usually place a drain. Upper GI esophagrams are not routinely performed, although we like to get these studies to document the baseline post-procedure anatomy following reoperative surgery. We perform intra-operative leak tests with endoscopy and do not rely on an upper GI to document the absence of a leak. In the bariatric surgery literature, upper GI studies have been demonstrated to suffer from poor sensitivity and specificity when it comes to the detection of postoperative gastrointestinal leak [30].

We routinely start limited clear liquids on the day of surgery once nausea resolves and if there were no intraoperative perforations or other relevant concerns. If clear

liquids are tolerated, we advance to a pureed esophageal diet on the first postoperative day. The patient remains on this pureed diet for at least 2 weeks and then begins to slowly advance to solids in the absence of dysphagia. Advancing to an unrestricted diet may take another 4–6 weeks depending on the patient. Patients are encouraged to take small bites, chew thoroughly, and go slow.

Some patients, especially patients in their 80s and frail patients, seem to be more likely to develop gastric distention and ileus postoperatively. If abdominal distention is noted and a plain abdominal film suggests a large gastric bubble, a fluoroscopically placed nasogastric tube may be needed for a couple days. This is a rare event in our experience. Aggressive antiemetic medical therapy is instituted to prevent retching and vomiting, which in rare circumstances can lead to acute paraesophageal hernia recurrence.

Most patients do quite well following reoperative paraesophageal hernia repair when the proper operation is performed correctly. One recently published retrospective review of 288 patients to undergo revision hiatal hernia repair with a median follow-up of 91 months demonstrated an increased morbidity rate for reoperative hiatal hernia compared to primary repair, mostly due to gastric (9.5%) and esophageal (2.1%) perforation [31]. Recurrence rates following revision in the screened portion of the population was 21%. Symptoms improved and satisfaction was high. A comprehensive review of reoperative fundoplications revealed that in 17 included studies involving more than 1000 patients, intraoperative complications occurred in 18.6% of cases and were most commonly gastrointestinal perforations. Success rates, defined variably, were 81% [12]. The authors of another systematic review included 81 studies and more than 4500 patients and reached similar conclusions but also felt that morbidity and mortality after redo surgery are higher than after primary surgery and symptomatic and objective outcome is less satisfactory [32].

Conclusions

Recurrent paraesophageal hernia repair is a complex intervention with significant potential for morbidity. Proper evaluation, patient selection, and operative approaches are essential to achieving good outcomes. A variety of different tricks and techniques may be needed to successfully repair these recurrent hernias. Because of these issues, surgeons with experience and expertise in reoperative foregut surgery should perform reoperative paraesophageal hernia repair. Overall, good clinical and symptomatic outcomes can be attained.

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Establishing a Hernia Program

44

Karla Bernardi and Mike K. Liang

Introduction

Abdominal wall and groin hernias are among the most common pathologies seen by clinicians. The prevalence of these hernias is on the rise due to their strong relationship to patient comorbidities such as smoking and obesity. Patients with comorbidities are not only more likely to develop a hernia, but they are also more likely to suffer a major complication whether their hernia is treated (e.g., hernia recurrence) or not (e.g., incarceration). In addition, after each failed repair, a successful subsequent repair is less and less likely.

Because of this, there has been interest in regionalization of care for patients with comorbidities or complex hernias. Specialized hernia programs aim to improve outcomes, control cost, and promote research. This chapter will review the evidence behind and provide a guide to development of a Hernia Center of Excellence. In addition, evidence for and guide to long-term follow-up of patients with hernias will be discussed.

Establishing a Hernia Center of Excellence

> [E]veryone can say he or she has the best technique or their practice is a Hernia Center of Excellence. There is no board that regulates Hernia Centers of Excellence. It is more or less just hanging out a shingle. Most of the time, it is just a matter of calling yourself a Center of Excellence [1].
>
> Robert Fitzgibbons, Professor of Surgery, Creighton University School of Medicine in Omaha, Past President Americas Hernia Society

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What Makes a Program a Hernia Center of Excellence?

In order to establish a Hernia Center of Excellence, a clear definition at the institutional and national level is needed. There should be a credible certification and review process. We define a Hernia Center of Excellence as a high-volume, referral center for patients with comorbid conditions or complex hernias where the primary goal is to improve outcomes and quality of care. For the purposes of this chapter, Hernia Center of Excellence encompasses hernia referral center, hernia specialty clinic, or hernia specialist.

The German Hernia Society defines a high-volume hernia center as those where over 250 hernia surgeries are performed per year of which at least 50 cases are ventral incisional hernias [2]. High-volume surgeons are those who perform more than 50 ventral incisional hernia repairs per year. They recommend setting up a certification process that is made up of different levels for which the centers can apply once the requirements are met. This can be accomplished in a progressive, stepwise fashion. As the volume increases, programs can then apply to the next stage and at the last level become a referral center or hernia program. In the United States, no standard or oversight exists for physicians to establish a Hernia Center of Excellence [1]. The Ventral Hernia Outcomes Collaborative defined the criteria for a hernia expert as a surgeon who performs at least 50 ventral hernia repairs per year and presented or published hernia research at an international or national forum [3].

Although these centers are available to any patient with a hernia, there are certain groups of patients who will benefit from such specialized care: patients with multiple or advanced medical comorbidities and/or patients with a complex hernia (Table 44.1) [3, 4]. The most common comorbid conditions that affect outcomes with hernia repair include obesity, obesity-related diseases such as diabetes, and current smoking. However relevant patient comorbidities may include advanced medical diseases such as chronic obstructive pulmonary disease or cirrhosis. Complex hernias include recurrent hernias, large hernias, or uncommon hernias (e.g., lateral ventral hernias) [4–8]. Patients with these comorbid conditions or hernia types are at the highest risk for a major complication including hernia recurrence, mesh infection, or reoperation [4].

Finally, the primary goal of a Hernia Center of Excellence is to improve outcomes and quality of care [3, 9–11]. There are substantial barriers to assessing improvement in outcomes or quality of care among patients with hernias including (1) selecting the optimal outcome measures, (2) measuring the outcome accurately and reliably, (3) and risk-adjusting outcome measures across a highly heterogeneous disease and patient population. For example, it is common to select hernia recurrence as a primary outcome (Table 44.2). However, substantial variability and subjectivity exist in the clinical and radiographic diagnosis of ventral hernia. Differences can affect outcomes by as much as 2–3 times [12]. In addition, a patient can suffer a substantial complication such as enterocutaneous fistula with no hernia recurrence. Alternatively, a more "objective" outcome often chosen is reoperation rate. However, in reality, reoperation is highly subjective as a surgeon may choose not to reoperate despite major complications. The Danish registry found a four to five fold difference between clinical recurrence and operative recurrence [13].

Table 44.1 Recommendation of patients to refer to or accept at a Hernia Center of Excellence [4–8]

	Referral to Hernia Center of Excellence[a]	Referral to general surgeon
Patient risk factors	ASA 3–5 BMI ≥ 30 kg/m^2 Cirrhosis COPD Immunosuppression Poorly controlled diabetes (HgbA1C ≥ 7%) Prostatitis/benign prostate hypertrophy Tobacco user	ASA 1–2 BMI < 30 kg/m^2
Hernia factors	Large hernia [5–8] Ventral incisional hernia [7] Lateral, subxiphoid, suprapubic ventral hernia [7] Recurrent Parastomal [8] Multiple prior abdominal surgeries	Small hernia [5–8] Primary ventral hernia [7] Midline ventral hernia [7]

ASA American Society of Anesthesiologists, *BMI* body mass index, *COPD* chronic obstructive pulmonary disease, *HbA1C* hemoglobin A1C or glycosylated hemoglobin
[a]Consider referred to Hernia Center of Excellence

Table 44.2 Outcome measures recommended by different hernia societies [3, 9–11]

Americas Hernia Society Quality Collaborative
1. Identify factors contributing to recurrence 2. Assess quality of life after hernia repair 3. Reduce surgical site complications 4. Evaluate potential advantages of laparoscopic or open repairs 5. Explore mechanisms of hernia recurrence 6. Identify factors that contribute to mesh infection 7. Minimize perioperative pain 8. Evaluate the impact of hernia characteristics on outcomes 9. Evaluate optimal methods of mesh fixation 10. Validate a hernia classification system
German Hernia Society (30-day outcome)
1. Total complication rate for inguinal hernia surgery <5% 2. Reoperation rate for inguinal hernia surgery <2% 3. Reoperation rate for incisional hernia surgery <10% 4. Infection/revision rate after open incisional hernia surgery <10% 5. Infection/revision rate after laparoscopic incisional hernia surgery <3%
Ventral Hernia Outcomes Collaborative (Annual assessment)
1. Major complication including clinical hernia recurrence, reoperation, or major wound infection (deep organ space infection including mesh infection) 2. Patient-centered outcomes utilizing modified Activities Assessment Scale

Based on these considerations, the Ventral Hernia Outcomes Collaborative recommends the utilization of two main outcomes: major complications including clinical hernia recurrence, reoperation, or major wound infection (deep organ space infection including mesh infection) *and* patient-centered outcomes utilizing the modified Activities Assessment Scale [3, 11]. The composite outcome of major complication

captures most significant adverse outcomes such as enterocutaneous fistula or mesh infection that may not necessarily be identified with hernia recurrence or reoperation alone. All outcomes should be appropriately stratified by the European Hernia Society classification system as well as patient comorbidities such as obesity, nicotine use, and diabetes mellitus [5–8].

Other Features

Evidence- and Guideline-Based Medicine

Part of being a Hernia Center of Excellence is to know and follow evidence- and guideline-based medicine (Table 44.3). It has been well established that physicians who follow guidelines experience improved outcomes as compared to those who do not [21–24]. At our institution, we utilize guidelines developed by the European Hernia Society, the Society of American Gastrointestinal and Endoscopic Surgeons, the Ventral Hernia Outcomes Collaborative, and the World Hernia Society.

In settings where recommendations are weak or based upon low-quality evidence, centers may choose to pursue other options as part of research or quality improvement project (see below, section on "Quality Improvement and Clinical Research"). In addition, recommendations may remain years behind the evidence,

Table 44.3 Society and national organization consensus and guidelines

Society/organization	Consensus or guidelines
EHS	European hernia society groin hernia classification: Simple and easy to remember[a] [5, 6] Classification of primary and incisional abdominal wall hernias[a] [7] European Hernia Society classification of parastomal hernias [8] European Hernia Society guidelines on the treatment of inguinal hernia in adult patients[a] [14]
EAES	EAES consensus development conference on endoscopic repair of groin hernias [15]
SICE	Laparoscopic ventral incisional hernia repair: evidence-based guidelines of the first Italian consensus conference [16] Laparoscopic ventral/incision hernia repair: updated guidelines from the EAES- and EHS-endorsed consensus development conference [17]
SAGES	Guidelines for laparoscopic ventral hernia repair[a] [18]
VHOC	Ventral hernia management: expert consensus guided by systematic review[a] [3] Ventral hernia: patient selection, treatment, and management[a] [4] Ventral hernia repair: a meta-analysis of randomized controlled trials[a] [19]
WHS	World guidelines for groin hernia management[a] [20]

EHS European Hernia Society, *EAES* European Association for Endoscopic Surgery, *SICE* Italian Society of Endoscopic Surgery, *SAGES* Society of American Gastrointestinal and Endoscopic Surgeons, *VHOC* Ventral Hernia Outcomes Collaborative, *WHS* World Hernia Society
[a]Guidelines utilized by our institution (all or part of)

and centers may choose to follow different recommendations based upon institutional review and understanding of the quality of evidence. However, surgeons and centers should be aware that a substantial proportion of hernia research is flawed, is biased, or has a financial conflict of interest [25–27].

Multidisciplinary Approach

As a part of preoperative counseling, patients seen in a Hernia Center of Excellence may need to undergo multidisciplinary preoperative preparation and management of their comorbidities [3, 4]. Other specialists involved may include addiction counselors, hepatologist, or metabolic team including physical therapist, nutritionist, diabetic manager, endocrinologist, and bariatric surgeon. Smoking is considered an absolute contraindication to elective ventral hernia repair or recurrent inguinal hernia repair, and all patients should be counseled to quit smoking or using tobacco products at least 1 month prior to repair [3, 4]. Cirrhosis is intimately associated with hernia development and progression due to increased intra-abdominal pressure [4, 5]. Patients with advanced cirrhosis can be challenging to manage, and their care and risk stratification should include an experienced hepatologist. However, the most utilized team to include is the metabolic team. Often, patients with hernias have poor physical conditioning and believe that they cannot exercise because of their hernia. An exercise and walking program can rapidly improve patient exercise tolerance and pulmonary reserve. In addition, physical conditioning can have a positive effect on obesity and obesity-related diseases. Nutritionists and endocrinologists can work together to improve a patient's diet and glucose control. In situations where diet and exercise alone cannot achieve the established goals, there is the option of undergoing a sleeve gastrectomy or bypass procedure prior to hernia repair [4, 5].

Other services that are routinely involved in the care of patients include infectious disease for patients with mesh infections, pulmonology to optimize patients before and after large hernia repairs, pain management for pre- and postoperative pain management, and social work and case management.

Aligning all of these specialists to routinely meet and work together improves team dynamics and allows members to develop experience in addressing the specific needs of patients with hernias. In addition, this team-based design is convenient for patients, particularly for those traveling long distances and coming from a different city, state, or country.

Surgical Technique

Although our definition of a Hernia Center of Excellence includes criteria for volume, participating surgeons should also be facile at multiple procedures including open and laparoscopic hernia repair (for both groin and ventral hernias), component separation, nerve blocks, and revision surgery. Some common procedures that a Hernia Center of Excellence should provide are shown in Table 44.4.

Table 44.4 Common clinical presentations and treatments surgeons at Hernia Center of Excellence should provide

Clinical presentation	Treatment options	Evidence [28] and comments
Recurrent inguinal hernia following open repair	Laparoscopic inguinal hernia repair	Grade 1B [14, 15, 20]: Recommended by the World Hernia Society. Recurrent and bilateral inguinal hernias should be repaired laparoscopically.
Chronic pain following inguinal hernia repair	Ultrasound-guided ilioinguinal nerve block	Grade 1B [20, 29, 30]: Recommended by the World Hernia Society. Low-risk and low-effort procedure that has shown some benefit among patients with chronic pain.
Infected mesh following open inguinal hernia repair	Mesh explantation and salvage options	Grade 1C [14, 15, 20]: Recommendation to explant the infected mesh and perform the appropriate salvage operation.
Ventral incisional hernia	Laparoscopic ventral hernia repair	Grade 1A [5, 19, 31]: For small- and medium-sized ventral incisional hernias, at least 80–90% of hernias should be repaired using a laparoscopic technique.
Laparoscopic ventral hernia repair	Laparoscopic primary fascial closure	Grade 2C [32]: Weak evidence showing some reduction in wound complications and recurrence.
Open ventral incisional hernia	Sublay repair: retromuscular and/or preperitoneal repair	Grade 1B [4, 19]: For midline ventral incisional hernia, it is recommended to perform a sublay repair.
Large ventral incisional hernia or loss of domain	Component separation	Grade 2C [4, 33]: Weak evidence supporting component separation over bridged repair.
Off-midline ventral incisional hernia	Primary option: laparoscopic ventral hernia repair Secondary option: sublay repair and posterior component separation	Grade 1A [16–19]: Laparoscopic approach is recommended over open repair due to faster recovery. Grade 1B: Recommended by Americas Hernia Society Quality Collaborative.
Parastomal hernia for permanent ostomy	Laparoscopic Sugarbaker repair	Grade 2C [16–19]: Weak evidence showing this technique is safe and efficacious.
Infected mesh following ventral hernia repair	Mesh explantation and salvage options	Grade 1C: Some patients may need mesh explantation and at the same time appropriate salvage operation.
Enterocutaneous fistula with ventral hernia	Salvage options	Grade 1C: Treat the enterocutaneous fistula first, and perform the appropriate salvage operation.

Perioperative Care

There has been a recent explosion of interest in enhanced recovery after surgery (ERAS) with hernia repair. Even for outpatient procedures such as inguinal hernia repair or straightforward ventral hernia repair, ERAS protocols can address issues of early postoperative pain, chronic pain, pulmonary challenges, constipation, or ileus [34, 35] (Table 44.5). While little high-quality evidence exists for the role of

Table 44.5 Current guidelines and recommendations for ERAS [34, 35]

	General recommendations
Anesthesia	Nerve blocks or regional anesthesia
IV fluids	Limit intraoperative intravenous fluids • Induction period: 7 mL/kg of LR over 30 min • During surgery: 5 mL/kg/hr of LR Limit intravenous fluids after surgery
Pain management	Standardized pain regimen Multimodal pain management
Postoperative medications	Prophylaxis for nausea and vomiting Standardized bowel regimen
Mobility	Early postoperative mobilization Out of bed same day of surgery
Common practices	Early and daily use of incentive spirometer Pulmonary toilet

ERAS in hernia surgery [36], numerous randomized trials exist on the role of perioperative pain management including blocks, multimodal therapy, and general versus regional anesthesia [37, 38].

Quality Improvement and Clinical Research

As leaders in the field, Centers of Excellence should participate in quality improvement projects and/or clinical research. This may come in the form of a registry, quality improvement projects, or clinical trials. Registries available for participation include national hernia databases (e.g., Danish National Registry) or national quality improvement projects (e.g., National Surgical Quality Improvement Project or Americas Hernia Society Quality Collaborative). However, participation in registries has not been shown to improve outcomes [39].

The highest level of scientific evidence remains well-designed randomized controlled trials [4, 26, 28]. Centers of Excellence should actively seek participation in unbiased randomized controlled trials, particularly those with appropriate power (e.g., sample size) and blinding of outcomes assessment. Currently the greatest challenges to performing and completing trials include reluctance of surgeons to randomize their patients due to a pre-existing bias, inadequate study power (i.e., small sample size), and lack of blinding of outcomes assessment. However, Centers of Excellence should be held to a higher standard, and participation in a randomized controlled trial should be a requirement of this designation [39–41]. Unlike registries, participation in randomized controlled trials has been proven to improve outcomes [41].

Finally, the surgeons who are involved in the Hernia Centers of Excellence should be active participants of national or international surgical societies (e.g., American College of Surgeons, Society of American Gastrointestinal and Endoscopic Surgeons). This will encourage discussion and exchange of ideas with other specialists. The Ventral Hernia Outcomes Collaborative mandated that a requirement of the designation of "hernia expert" include presenting or publishing hernia research at an international or national forum within the past year [4].

Benefits of Hernia Centers of Excellence

The greatest potential benefit of Hernia Centers of Excellence is improvement in patient outcomes given appropriate risk stratification [42]. The reproducibility of technique and procedure has been shown to improve outcomes. High-volume or specialized surgeons are more likely to attempt and complete hernia repairs utilizing a minimally invasive approach that has been proven to improve outcomes [31, 43–45]. Surgeons not facile with these techniques are six times more likely to have to convert to an open approach. In addition, non-experts are more likely to have complications such as enterotomies or missed enterotomies [23, 24, 31, 45].

Another potential benefit of Hernia Centers of Excellence includes improved patient satisfaction. When patients are seen at specialized centers, they may benefit from a more organized perioperative process, convenient access to a multidisciplinary team, and shorter hospital length of stay. Patients perceive this expertise and convenience positively [43].

From the hospital and healthcare system's perspective, a major potential benefit of Hernia Centers of Excellence includes financial benefits [31, 43, 44, 46]. These centers are associated with a significant increase in the number of hernia cases performed per year, which translates to increased billing by the hospital. In addition, Hernia Centers of Excellence have the opportunity to make cost-conscious choices that provide substantial value (value = quality outcomes/cost). Generalists are more likely to use expensive resources, such as biological mesh, which may not be necessary [31, 46]. Finally, preventing common complications such as surgical site infections, chronic wound complications, and hernia recurrence may also significantly decrease cost. For example, on average, every surgical site infection costs the healthcare system an additional $11,000–$21,000 [31, 47, 48]. A mesh infection has been estimated to cost $150,000, while an enterocutaneous fistula has been estimated to cost $250,000 [47, 48].

Challenges

Concerns with the number of cases being referred to specialty centers have been raised. In Scotland, a review of a large database of inguinal hernia repairs found that specialists, and not general surgeons, now perform most of these cases [49]. A shift in patient load can frustrate the general surgeon who now finds a substantial portion of their practice eroded and being sent to Hernia Centers of Excellence. In addition, general surgeons may feel less facile with complex hernia repair and face challenges in performing acute hernia repairs that are almost always complex. These potential challenges should be addressed up front. Hernia Centers of Excellence should not encourage the referral of patients with uncomplicated hernias and those with no comorbidities. Societies and teaching institutions should provide didactic and hands-on courses with focus on management of patients requiring acute hernia repair from the general surgeon's perspective [42].

Additionally, with the establishment of a Hernia Center of Excellence, patients are more likely to travel long distances to access care [46]. Patients who traveled over 100 miles represented an increase in cost for their procedure when compared to those who traveled less than 25 miles. Surgeons report challenges with early discharge of patients traveling long distances. For this group of patients, follow-up care and access to care represent a new challenge.

Among other specialties, the designation of "Center of Excellence" is associated with quality measures and outcomes assessment (e.g., bariatric surgery, stroke centers) [42]. The challenge of outcomes requirements in the treatment of patients with hernias is the heterogeneity of the patients and the disease. Complicated patients and hernias are referred, while straightforward patients and hernias can be repaired locally. Outcome and quality measures must be appropriately risk adjusted, and clear and widely accepted guidelines on appropriate patient selection must be adopted by any oversight agency.

Conflict of Interest with Industry

A major concern with hernia specialists is the rampant conflict of interest with industry [27]. Currently, industry, such as mesh companies, develops financial relationships with surgeons they consider to be "key opinion leaders" (KOLs) to utilize, endorse, and "sell" their products at dinners, industry-sponsored meetings, and national meetings. Among published hernia research, 70% had an author with a financial conflict of interest, yet only 10% of authors fully disclosed all of their financial conflicts of interest. The vast majority of these were relevant conflicts of interest (80%). Compared to authors with no financial conflict of interest, authors with a financial conflict of interest are 200% more likely to present results favorable to industry.

While it remains unproven if financial relationships with industry affect surgeon practice and choice, it seems plausible and likely that these relationships impact decision-making and patient care [39]. In other settings, financial conflict of interest has been shown to affect choices made by individuals. It is recommended that surgeons developing Hernia Centers of Excellence abide by the recommendations developed by the Institute of Medicine [50]. Some of the most relevant recommendations are as follows:

- *Recommendation 4.1*: Individuals generally may not conduct research with human participants if they have significant financial interest in an existing or potential product or company that could be affected by the outcome of the research.
- *Recommendation 6.1*: Physicians should limit their financial conflict of interest and avoid undue influence by industry.
- *Recommendation 7.1*: Groups that develop clinical practice guidelines should exclude as panel members individuals with conflicts of interest.

Hernia Centers of Excellence and their practicing clinicians should explicitly list all financial relationships in the past 3 years. Patients and referrers should be encouraged to utilize the Centers for Medicare and Medicaid Services Open Payments database (https://www.cms.gov/openpayments/) to help decide which Hernia Center of Excellence is right for them [51].

Our Experience

At our institution, we developed a Hernia Center of Excellence with the purpose of improving patient outcomes, controlling cost, and decreasing surgical site infections [31]. Three high-volume hernia surgeons cared for patients in a dedicated hernia clinic and implemented an institution-wide set of practice guidelines (Table 44.6). A pre-post quality improvement project was performed, and 789 patients were enrolled: 399 pre-intervention and 390 post-intervention. The primary short-term outcome was surgical site infections. Patient selection for treatment in the Hernia Center of Excellence included those with multiple comorbidities, or one or more poorly controlled comorbid conditions, multiple prior complications, or failed repairs. Prior to the quality improvement intervention, the rate of surgical site infections was 13.5%. Following the quality improvement intervention, the rate of surgical site infections decreased to 1.7% in general surgery clinics and 1.4% in the Hernia Center of Excellence.

Even though patients treated at the Hernia Center of Excellence were more likely to have comorbidities, including higher BMI, higher ASA score, previous surgical site infections, prior ventral hernia repairs or abdominal surgeries, and more complex hernias, there was still a significant decrease in the number of surgical site infections. In addition, there was increased adherence to guidelines and recommendations among patients treated at the Hernia Center of Excellence. This project demonstrated that a symbiotic relationship between general surgeons and hernia specialists working together to improve outcomes among all patients treated is feasible and effective [31].

Table 44.6 Guidelines and recommendations [4, 5, 31]

Guidelines and recommendations for ventral hernia repairs
• Preoperative management is required for patients with the following: – Current smokers – BMI greater than or equal to 35 – Hemoglobin A1C greater than or equal to 8.0% – Patients with BMI 30–40 or Hemoglobin A1C 6.5–8.0 require individualized intervention to reduce surgical risk
• Mesh reinforcement for elective ventral hernia repair with no contamination
• Laparoscopy is recommended for clean and elective ventral hernia repairs

Follow-Up of Hernia Patients

Importance of Follow-Up

An important aspect of a Hernia Center of Excellence is follow-up care of those treated in order to accurately determine short-term and long-term outcomes. Centers are encouraged to establish baseline data during an encounter prior to any treatment, highlighting comorbid conditions, self-reported abdominal wall function, and pain. During follow-up, surgeons should capture the patient's perspective and experience. In addition, it is important to follow not only patients who are treated with surgical repair but also those treated nonoperatively [4, 5, 9–11].

Due to the significant long-term complication rates and long life expectancy of most patients with hernias, a paradigm shift is needed in follow-up of patients with hernias [11, 52]. These patients should be treated similar to oncology patients who receive routine, annual follow-up. In order to achieve this, all key stakeholders need to be engaged including patients, clinicians, and payers. Patients should be aware of the long-term complication rate of even "simple" hernia repairs. No longer should patients have the perspective that they are "just having a hernia repair." Instead, hernia care should be perceived as a long-term strategy that requires active participation from the patient. Surgeons should be invested in regular follow-up of their patients. Long-term follow-up of patients should be considered a quality measure for surgeons at Hernia Centers of Excellence. Internal medicine should develop a medical counterpart to the hernia surgeon, i.e., medical herniologist. Finally, payers must be invested in the long-term follow-up of these patients supporting annual clinic visits including physical exam by an experienced clinician, quality of life measures, medical optimization of comorbidities associated with hernias, and on-demand imaging [9–11, 52].

Patients initially managed nonoperatively typically have limited clinical symptoms or have comorbid conditions that make them poor candidates for elective surgery [4, 5, 53–56]. Assessing changes in medical history and signs/symptoms over time is an important part of the care provided by a Hernia Center of Excellence. This patient population allows clinicians to determine the safety of nonoperative care among different subgroups while emphasizing the risk factors that may cause patients to convert to operative management.

For patients who undergo surgical repair, variables such as readmission, clinical recurrence, surgical site infections, reoperations, and mortality should be tracked in a prospective, real-time manner [9–11]. Patient-centered outcomes such as pain, abdominal wall function, and abdominal wall satisfaction should be a routine part of follow-up. These components are valuable for both patients who had complications from surgery and those who did not.

Current State of Follow-Up

The reported complication rates for many studies are lower than the true number of complications experienced by patients due to poor follow-up. Most patients do not

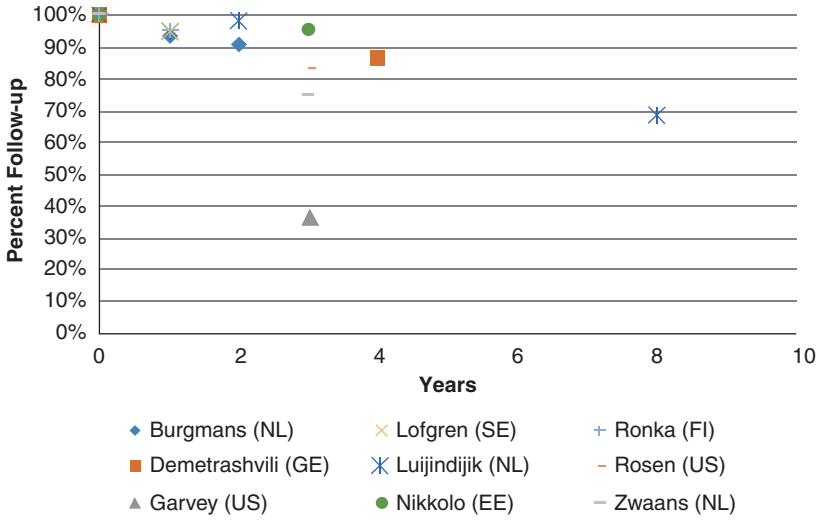

Fig. 44.1 Follow-up duration and rate among prospective studies (authors and country codes [57–66])

return to their original surgeon once they encounter a complication [13, 45]. If the complication takes place after the initial 30-day postoperative period or the postoperative visit, patients are more likely to seek help from their primary care or general practitioner regarding the issue. Among high-quality studies, long-term follow-up has been limited in both duration and percentage followed (Fig. 44.1). Some studies have simply used "chart check" or review of administrative databases to report misleadingly high follow-up rates [67].

There is a discrepancy among studies reporting outcomes depending on who is performing the assessment: the patient, primary care physician, researcher who "chart checks," unblinded surgeon, blinded surgeon, or radiologist [12, 67–70]. Patient self-reporting, primary care physician, and "chart checks" of outcomes such as SSI or hernia recurrence have been shown to be less reliable when compared to surgeon actively evaluating patients. Unblinded surgeons assessing outcomes on patients they treated are more likely to report biased results compared to blinded surgeons who did not perform the procedure. Finally, hernia recurrence is three times as likely to be noted on radiographic imaging as compared to clinical examination [12, 67–70].

How to Improve Follow-Up Rates

Maintaining high follow-up rates is not always possible due to multiple barriers [71, 72]. These challenges will differ based on location, patient population, and resources available. Some obstacles can be addressed with proper planning from the surgical team or hernia program. It is important for the team to foresee common factors that reduce the follow-up rate. For example, transportation issues, distance needed to travel, family support, and expectations are all factors that can be addressed even

before the procedure. With the help from different healthcare teams such as social workers, case managers, and nursing staff these can be resolved prior to the follow-up appointments [71, 72].

Setting expectations with patients regarding follow-up appointments and answering follow-up phone calls is crucial. These discussions should take place during the first encounter with the patient. In addition, clinic appointments should be scheduled in advance when possible. Following a standardized process when scheduling an appointment is useful even though there is also great variability in follow-up of surgical patients.

A flexible follow-up mechanism can help alleviate some of the burdens that patients and surgical teams face during the follow-up period. For example, we recommend that along with the outpatient follow-up visit, patients should also have the opportunity to answer some questions about their progress by email or phone call.

Our Practice

In our institution, we have established a multifactorial process of promoting follow-up, both in the short and long term [71]. When the patient is first evaluated during their preoperative visit, a baseline survey is given to the patients assessing their abdominal wall function. Following an evidence-based algorithm, patients are treated with surgical and nonoperative strategies. Both the patients who undergo surgical repair of their hernia and those that do not are followed.

For those who undergo surgical repair, a follow-up appointment window is provided prior to discharge from the hospital. Most are seen in the hernia clinic within a window of 2–4 weeks following their procedure. At this early visit, patients receive a questionnaire to assess changes and early complications. Patients are contacted annually after their procedure. Initially, patients are contacted by phone, and if there are reported concerns or complications, a clinic appointment is made. During these encounters, the patients are asked to also complete follow-up surveys to assess for recurrence, complications, and abdominal wall function. Patients that are difficult to reach by phone can be contacted by electronic mail, standard mail, or during visits with other physicians or specialists in the outpatient setting. Study patients are provided reimbursement for their parking and time on the order of $20–$50. With this combination of strategies, we have achieved an 80% long-term follow-up in a challenging population (underserved, underprivileged patients) at a safety-net healthcare system [71].

All patients enrolled in clinical trials undergo an examination by a blinded surgeon who did not perform the surgery as well as an unblinded surgeon who also did not perform the surgery. Any patient where there is a concern for an adverse outcome such as hernia recurrence, a CT scan is obtained. A board of three surgeons blinded to the treatment adjudicates all adverse outcomes.

Conclusion

Hernias are a common problem, and care of patients with hernias has become a big business in medicine with benefits to the hospital, healthcare providers, and other industries. Because of this, development of “Hernia Centers of Excellence”

is gaining popularity. However, most healthcare systems have no guidelines, regulations, or review of the designation of a Hernia Center of Excellence. This chapter provides a template for oversight agencies, healthcare institutions, and surgeons on standards, recommendations, and expectations for developing a Hernia Center of Excellence. There is an urgent need among surgical societies and healthcare systems to oversee this process.

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Prevention of Abdominal Wall Hernias

45

Rajavi S. Parikh and William W. Hope

Introduction

Incisional hernias are a common complication with rates ranging from 1 to 20% [1–4]. Many incisional hernias are symptomatic, requiring approximately 348,000 operations per year in the United States and 400,000 operations per year in Europe [5]. Because the long-term recurrence and complication rates of incisional hernia repairs are high, this can cause a cycle of chronic and sometimes lifelong problems for some patients [6]. Incisional hernias are a common and sometimes predictable outcome of abdominal surgery, and they cause great morbidity to the patient. Apart from the clinical morbidity associated with incisional hernias, they are a major financial burden to patients and to the healthcare system. Approximately 3.2 billion dollars were spent on incisional hernias in the United States in 2006 [5]. The development of an incisional hernia can result in an additional $3875–$98,424 in healthcare costs [7, 8].

Based on the clinical and economic burden of incisional hernias and poor long-term outcomes of their repair, hernia prevention should be a major focus for surgeons operating on the abdominal wall.

Risk Factors

Knowledge of the risk factors for formation of incisional hernias is the first step in helping to reduce the incidence. The cause of incisional hernias is multifactorial and related to many patient and surgical factors. Risk factors include patients with a BMI >25 kg/m^2, surgical site infections, chronic obstructive pulmonary disease, smoking history, a suture to wound length ratio of <4:1, malnutrition, diabetes mellitus,

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immunosuppression, and chemotherapy [7]. It has been also demonstrated that incision type (laparotomy>hand-assisted surgery>laparoscopy) is an important variable in determining the risk of incisional hernia [7]. In addition, the type of operation, likely through correlation with other patient factors, also predicts the risk of hernia. Operations such as open and minimally invasive bariatric procedures, ostomy and fistula closures, colorectal surgeries, open abdominal aortic aneurysm repairs, and emergency operations have the highest risk for incisional hernias development [8].

Choice and Technique of Incision

In addition to an extensive understanding of the advantages and disadvantages of each incision type, surgeons can decrease the risk of incisional hernia formation by undertaking surgeries in the least invasive manner possible when clinically appropriate. Although the incision choice and technique may play a role in future hernia formation, it is not always considered because the surgeon is focused on the current operation and may be less worried about a potential complication months or years in the future. Despite this, surgeons should consider the potential effects that location and incision technique have on future hernia formation.

There is no agreement on whether skin and fascial incisions are best made with scalpel or electrocautery. Although some animal studies report the benefit of the scalpel over electrocautery for skin and fascia [9–12], these do not appear to be clinically relevant to human studies showing no appreciable differences and no impact on the rate of incisional hernia formation [13–20].

The most common incisions used by surgeons to access the abdominal cavity are midline, transverse, oblique, and paramedian. The location of the incision as it relates to hernia formation is debated, with conflicting results from randomized trials [21–24]. In 2015, the European Hernia Society published guidelines on closure of abdominal wall incisions. In this guideline based on their review of the literature, the Society recommended using non-midline incisions when possible due to the decreased incisional hernia rate associated with these [25]. Despite this strong recommendation, midline incisions are commonly used probably due to the ease of access to the abdominal cavity, ability to access all four quadrants of the abdomen, and possibly unawareness of the impact that this incision has on incisional hernia formation.

Abdominal Wall Closure Techniques

Although location of incision is an important variable in incisional hernia formation, the method and technique of closure are two of the most important factors affecting incisional hernia formation. Many variables must be considered when evaluating closure techniques including type of suture used. Although there remains disagreement about closure techniques, many important principles have been borne out in well done, randomized, prospective trials and meta-analyses [26–29].

The type of suture material and technique of closure, interrupted or continuous, have been well researched. Closure techniques and recommendations were reviewed/ summarized by the European Hernia Society. The Society recommends continuous suturing of midline incisions with a slowly absorbing monofilament suture using a small bite technique and suggests the use of a suture to wound length ratio of at least 4:1 for elective surgeries [25]. They also recommend using a single-layer aponeurotic closure and discourage closing the peritoneum as a separate layer during laparotomy closure [25]. Few studies have been published regarding the best techniques of closure for urgent/emergent abdominal surgical operations and for off midline incisions, so there are no recommendations in the recent guidelines [25].

Two European Hernia Society recommendations require additional discussion as they are important technical points for the surgeon. The suture to wound length ratio is basically the amount of suture used to close an incision and is simply calculated by measuring the amount of suture used and the length of the incision. It is generally agreed that a suture to wound length ratio of at least 4:1 is the minimum amount of suture needed to provide a strong closure and reduce hernia formation [30, 31]. A threefold higher risk of herniation is reported when the ratio is less than 4 [32, 33]. Adhering to this suture to wound length ratio and auditing this practice is an important first step in decreasing the rate of incisional hernias.

A second important factor that should be discussed relates to the size and distance between bites in the fascia. Traditional teaching is that fascial bites should be at least 1 cm from the fascial edges with 1 cm advances; however, this practice has been recently questioned by clinical and experimental studies. Studies from Israelsson and colleagues reported that smaller bites in the aponeurosis (<1 cm) result in less hernia formation and recommend this technique for closure [33–38]. This finding was replicated in a Dutch multicenter trial reporting the small bite technique was more effective than the large bite technique for prevention of incisional hernias without an increase in adverse events [39].

Despite much recent research on the topic of abdominal closure, many aspects are still unclear. The type of suture needle, size of suture, and whether to use a double-stranded or single-stranded suture have not been determined. Another unsolved issue relates to the ideal tension that should be placed on the closing suture/fascia. Despite the old surgical adage related to closing the fascia: "approximated and not strangulated," there is little scientific data to support recommending a specific amount of tension with which to close the fascia.

Prophylactic Mesh and Adjuncts for Prevention

A major frustration with incisional hernias is their continued occurrence despite using good surgical technique and evidence-based practices of laparotomy closure. This is probably related to patient/operative factors outside the surgeon's control. Because of this, laparotomy incisions with prophylactic mesh (prophylactic mesh augmentation or PMA) to prevent hernia formation are being used in some medical centers. Theoretically, PMA increases the biomechanical strength of the healing

laparotomy incision, which has been demonstrated in animal and human studies. Despite studies including randomized controlled trials and meta-analyses on the use of the prophylactic mesh, the European Hernia Society guidelines on the closure of abdominal wall incisions (2015) offered a weak recommendation for its use pending more long-term data [25]. Despite a low incidence of complications with PMA, many fear a permanent mesh prosthetic and the potential for long-term complications such as infection and pain. If PMA is to be used, it should be used in patients that are high risk for developing incisional hernias. The following sections discuss PMA in several high-risk patient populations that have been well described and are good initial targets for this treatment.

Open Abdominal Aortic Aneurysm Repair Patients undergoing open abdominal aortic aneurysm (AAA) repair have a 32–60% risk of developing an incisional hernia [25, 40]. The same connective tissue defects that predispose individuals to aortic aneurysms predispose them to incisional hernias [25]. Two recent randomized trials on prophylactic mesh use in patients undergoing AAA repair show a significant reduction in incisional hernias using prophylactic mesh compared with primary suture closure [41, 42]. Both trials used permanent polypropylene mesh [41, 42]. Longer-term data are needed; however, preliminarily, using PMA has reduced incisional hernias following open AAA repair. The ideal mesh type and location for placement for prophylaxis have not been proven.

The Obese Patient The incidence of incisional hernias in obese and morbidly obese patients ranges from 25 to 50% [43, 44]. Several studies examined the use of PMA in morbidly obese patients undergoing open bariatric surgery and showed a lower incidence of incisional hernia using PMA [37, 44]. Although, most bariatric surgery is now accomplished laparoscopically, it is likely that PMA will play a role in this patient group as the obese population in the United States increases and these patients require open incisions.

Patients Undergoing Colorectal Procedures There is reluctance to use PMA in patients undergoing open colorectal surgery due to the clean contaminated nature of the surgery and high risk for wound infection. However, a study by Garcia-Urena and colleagues demonstrated that PMA is effective and results in little morbidity [45]. In 107 patients undergoing elective and emergent operations (54 patients in the control group and 53 patients in the mesh group), there was a significant reduction in incisional hernias in the PMA group (11.3%) compared with the control group (31.5%). The study reported no significant difference in morbidity (surgical site infection, seroma, mesh rejection, or evisceration) between the control and PMA groups [45]. This study reinforces the utility of PMA in hernia prevention in high-risk patients and demonstrates its feasibility in contaminated cases.

Patients Requiring Permanent Ostomies Although the parastomal hernia incidence varies widely, a literature review by Aquina and colleagues reported the incidence to be up to 78%, with the majority occurring within 2 years after ostomy

creation [46]. In a French study, parastomal hernias were symptomatic in up to 76% of patients; 56% of these patients were affected to the extent of requiring surgical treatment [47]. Because of the high incidence and recurrence rates, prevention techniques should be a major focus for surgeons performing stomas.

Many well-performed studies show the safety and efficacy of PMA in patients with permanent ostomies. A meta-analysis looked at three different randomized clinical trials comparing prosthetic mesh reinforcement versus conventional stoma formation. Three different types of mesh were used: Permacol (porcine-derived acellular matrix), Vipro (synthetic mesh with low Prolene (nonabsorbable) content and high Vicryl (absorbable) component), and Ultrapro (equal parts Prolene (nonabsorbable) and Monocryl (absorbable)). The mesh was positioned either preperitoneal (between peritoneum and posterior rectus sheath) or sublay (anterior to posterior rectus sheath and behind rectus muscle). The meta-analysis showed mesh use in either preperitoneal or sublay position reduced incidence of parastomal herniation and decreased incidence of parastomal herniation requiring surgical intervention. No increased morbidity was noted [48].

Two additional randomized, controlled trials reported a significant reduction in the parastomal hernias in patients receiving mesh compared with no mesh. One study created an end colostomy with placement of an intraperitoneal, onlay prophylactic DynaMesh, a dual component structure with 88% high-purity polyvinylidene fluoride and 12% polypropylene. The other used 10 × 10 ProLite Ultra, a large-pore, low-weight polypropylene mesh and Parietene Light and placed the mesh between the rectus muscle and the posterior rectus sheath [49, 50].

PMA is associated with a significant reduction in the postoperative risk of incisional hernia compared with traditional suture repair for high-risk patients undergoing elective, midline laparotomy closure. The technique appears to be safe and efficacious in high-risk patient groups, with comparable postoperative complication profiles. Despite strong evidence, a lack of US-based randomized controlled trials and evidence-based guidelines for using PMA is a barrier to widespread adoption. Further reinforcing these challenges is a lack of appropriate Category I coding and reimbursement mechanisms for PMA. A Category III CPT code (0437 T) for prophylactic mesh augmentation was created in July 2016 by the American Medical Association.

Despite the above evidence regarding these patient groups, many unknowns remain including additional groups that might benefit from PMA and the indications for mesh use, best mesh choice, and most beneficial techniques of surgery in each group. Studies with longer follow-up are needed to define the role of PMA in these challenging patients.

Education and Future Directions

Incisional hernia prevention continues to be a prevalent issue. A possible explanation is the lack of surgical education regarding the fundamental and technical aspects of creating and closing abdominal incisions. Altering closure techniques by

employing small bite techniques and ensuring a >4:1 suture to wound length ratio are important steps surgeons can take to decrease the incidence and cost of incisional hernias [4, 51]. Because abdominal wall closure is rarely considered a major part of abdominal operations, surgeons may not stay current with literature regarding the importance of improved closure techniques. A recent study evaluating resident education and abdominal wall closure reported that although residents had the technical ability to close incisions well, only 10% knew the correct suture to wound length ratio, and only 40% were aware of medical literature discussing closure techniques [52]. If incisional hernia rates are to be decreased, education related to the most fundamental areas of hernia prevention needs major focus.

More accurate identification of patients at risk for hernias and more attention to advanced surgical techniques such as single incision and natural orifice surgery will impact hernia prevention. The push to develop ways to make abdominal surgery less invasive may decrease or even eliminate abdominal wall incisions, eventually eliminating abdominal wall incisional hernias.

Additional future focus will be on the biology of hernia formation and preemptive prevention for high-risk patients. More accurate risk stratification for hernia development might eventually make incisional hernias obsolete. Until then, our focus should be on hernia prevention, education to evaluate new incision techniques, materials and methods of closure, and prophylactic measures with the goal of eliminating the difficult problem of incisional hernias.

Conclusion

Despite research and improvements in surgical technique, hernias following abdominal incisions continue to occur. Much work is needed to improve and teach the best surgical techniques for closing abdominal incisions, to understand risk factors for developing incisional hernias, and to understand and expand the role of prophylactic mesh in preventing incisional hernias. Incisional hernia prevention is an essential field of research in promising areas such as genetic profiling of at risk patients, improved closure techniques, surgical education, and prophylactic mesh use.

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Hernias in the Pediatric Population

46

Sophia Abdulhai and Todd A. Ponsky

Introduction

Pediatric hernias, particularly indirect inguinal and umbilical hernias, compromise a large percentage of the pediatric surgeon's practice. This article will review the surgical management of the most common pediatric hernias.

Indirect Inguinal Hernia

Epidemiology

Indirect inguinal hernias are one of the most common congenital defects treated by pediatric surgeons worldwide. The overall incidence of inguinal hernias in pediatric patients ranges from 0.8 to 4.4% and is more commonly found in males compared to females. The highest incidence is found in premature and low birth weight infants, estimated between 9 and 30% [1, 2].

Embryology

Indirect inguinal hernias are congenital defects that result from failure of the processus vaginalis to close. During fetal development, the testes are guided down to the scrotum by the gubernaculum and a small outpouching of the peritoneum, which eventually forms the processus vaginalis. This process is similar in females, but the peritoneal outpouching is called the canal of Nuck and terminates in the labia majora. In normal fetal development, the canal of Nuck and processus vaginalis

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obliterate between 36 and 40 weeks of gestation. An arrest in this portion of development results in a patent processus vaginalis (PPV).

The incidence of PPV has been reported to be as high as 48–63% and decreases with age [3–5]. Rowe et al. reported that about 40% of PPV close within the first few months of life and an additional 20% close by 2 years of age [5]. While a PPV is a major risk factor in the development of an inguinal hernia, only 3.8–14.8% actually develop into inguinal hernias [6].

Clinical Presentation/Diagnosis

Pediatric patients present to a surgical clinic with a history of an intermittent groin bulge with straining. If the clinician is able to feel the upper edge of the bulge in the scrotum on physical examination, then it is likely a hydrocele or a retractile testis.

It is not uncommon for the surgeon to not see a bulge during their physical exam, so some surgeons will operate based on history alone or ask the parents to take a picture of the bulge and return to the clinic. A "silk glove" sign has been described as a tool to aid in inguinal hernia diagnosis, and it involves rolling the cord structures over the pubic tubercle to assess for thickening. The accuracy rate of this diagnostic tool is widely varied in the literature, ranging from 66 to 93% [7, 8].

While ultrasound is used as a tool to differentiate a hernia between a hydrocele, a retractile testis, and a lymphadenopathy, it has also been described in the diagnosis of a PPV in multiple studies [9–11].

While most patients present electively in the outpatient setting as described above, some patients may also present to the emergency room with an acute incarceration. This will be discussed in more detail below in the "Incarcerated Hernia" section.

Timing of Surgery

The incidence of incarceration ranges between 3 and 16%, with up to a 31% risk in premature infants [2, 12]. Stylanios et al. reported that 35% of their patients with an incarcerated hernia had a known inguinal hernia [13]. Also, the risk of complications after an incarcerated hernia is 11–31% [13, 14] (i.e., gonadal infarction, necrotic bowel, wound infections, and recurrence), compared to about 1% in elective hernia repairs [15]. For these reasons, inguinal hernias are repaired soon after diagnosis.

Timing of repair in premature and low birth weight infants is controversial given the risk of anesthesia-related cardiopulmonary complications, such as apnea [16]. Additionally, premature and low birth weight infants have a higher risk of recurrence, ranging from 2.6 to 12.1% [17]. However, the risk of incarceration in premature infants increases with time, and Lautz et al. found that the risk in fact doubled in patients that were repaired after 40 weeks postconception compared to those that were repaired 36–40 weeks [18]. At this time, there is no clear consensus in the

management of these patients, but a survey of pediatric surgeons found that 63% would repair the hernia prior to discharge from the NICU (in preterm infants >29 weeks postconception and minimum 1 kg weight) [19].

Treatment

Open Repair (High Ligation)

Technique

The key step in the repair of indirect inguinal hernias is high ligation of the sac. The procedure is typically performed under general anesthesia. The patient is placed in the supine position, and pubic tubercle and anterior superior iliac spine are used to identify the approximate location of the inguinal canal. The skin incision is created along the inguinal crease, superior and lateral to the pubic tubercle. The incision is carried down to the external oblique muscle, which is then divided up to the external ring, exposing the cord structures and the hernia sac. The cord structures and hernia sac are then cleared off the superior and inferior flaps of the external oblique muscle using blunt dissection. Afterward, the sac is then carefully dissected away from the cord structures until reaching the internal ring. The sac is then dissected to the level of the internal ring, divided and ligated. If the internal ring appears widened, then some place a single stitch to close it slightly to minimize the risk of recurrence.

Outcomes/Complications

Open repairs have an overall complication rate of about 1% [15, 20]. The risk of wound infection is 0.6–1.2%, and risk of recurrence is 0.4–1.2% [20, 21]. There is also a 0.3–2% risk of testicular injury, 0–0.5% risk of injury to the vas deferens, and 0.6–2.9% risk of iatrogenic cryptorchidism [22].

Laparoscopic Repair

Prep and Patient Positioning

The procedure is performed under general anesthesia. The patient should void prior to the procedure to avoid the need for a urinary catheter during the operation. The scrotum should be prepped in addition to the abdomen to allow the surgeon to push on the scrotum to remove pneumoperitoneum prior to ligating the hernia sac. The patient is placed in the supine position, and Trendelenburg may be used to improve visualization by moving the bowel caudally.

The author's preference is to stand on the patient's left side regardless of the side of the hernia, but the operating surgeon may also consider standing on the ipsilateral side of the hernia.

Anatomy

The deep internal ring has the spermatic cord running through it in males, and the round ligament runs through it in females. When visualizing it from inside the

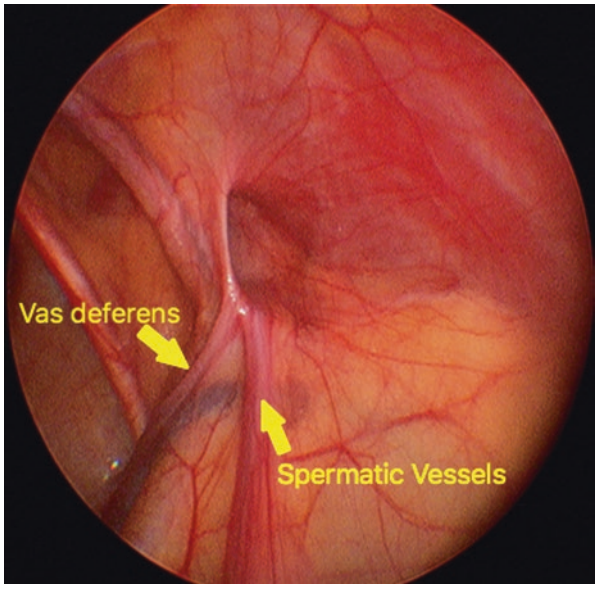

Fig. 46.1 The locations of the vas deferens and spermatic vessels on a right-sided inguinal hernia

abdomen, the inferior epigastric vessels are superior to the internal ring, the spermatic vessels are inferior/lateral, and the vas deferens is inferior/medial to the inguinal ring (Fig. 46.1). The genital branch of the genitofemoral nerve enters the internal ring alongside the spermatic vessels.

Approaches

There are multiple intraperitoneal and extraperitoneal laparoscopic techniques currently being used to repair inguinal hernias. The author's preferred technique is a two-port extraperitoneal approach, which is a variation of the percutaneous internal ring suturing technique (PIRS) [23], and will be described here in detail.

The key steps to this technique are hydrodissection of the peritoneum away from the cord structures, thermal injury to the peritoneum at the superior aspect of the internal ring, and suture ligation of the hernia. Thermal dissection is used to create scar tissue, which was found in a rabbit model to increase the strength of the closure [24].

Equipment

This procedure is performed using a laparoscope (3 mm/70-degree in neonates, 5 mm/30-degree in larger children), a Maryland dissector or hook cautery, a 25-gauge finder needle, an 18-gauge spinal needle, a 3-0 monofilament suture, and a 2-0 permanent braided suture.

Surgical Steps

- The 18-gauge needle is bent using two needle drivers to create a gentle curve. The 3-0 monofilament suture is folded in half, and the looped end is threaded

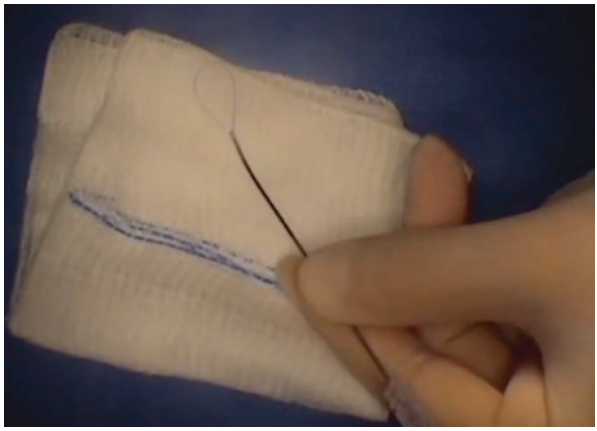

Fig. 46.2 The 3-0 monofilament suture is threaded through the 18-gauge needle, with the looped end just inside the tip of the needle

through the 18-gauge needle, with the looped end just inside the tip of the needle (Fig. 46.2).

- A trocar is placed infraumbilically, and the laparoscope is inserted after the desired pneumoperitoneum is reached (a 3-mm trocar is typically used unless it is a larger patient, i.e., >40 kg).
- A separate stab incision is placed in the lower abdomen for placement of the Maryland dissector or hook cautery. This stab incision may be placed on the ipsilateral side of the hernia, but the author's preference is to always place it in the left lower abdomen. This allows for the author's right hand to always be maneuvering the needle, while the left hand assists with the Maryland dissector.
- The Maryland dissector/hook cautery is used to cauterize the internal ring. This is performed from the 8 to 5 o'clock position only, so to avoid injuring the cord structures (Fig. 46.3).
- A 25-gauge finder needle is then used for hydrodissection. It is inserted until just anterior to the peritoneum, and either local anesthetic or normal saline is injected circumferentially around the internal ring to dissect the peritoneum away from the cord structure (Fig. 46.4).
- The 25-gauge finder needle is then used to identify the 12 o'clock position of the internal ring, and a 1-mm stab incision is made in the skin at this location.
- The spinal needle is then placed through the 1-mm stab incision and passed laterally around the internal ring in the hydrodissection place, over the spermatic vessels and also the vas deferens, if possible (Fig. 46.5). Maryland dissector may be used to aid pulling counter tension on the peritoneum to allow for easier and safer passage of the spinal needle.
- After passing the spermatic vessels (and possibly the vas deferens), the spinal needle is pushed through the peritoneum into the abdominal cavity, at approximately the 6 o'clock position. The loop of monofilament suture is pushed partially out of the needle, and the needle is removed, leaving the suture in place (Fig. 46.6).

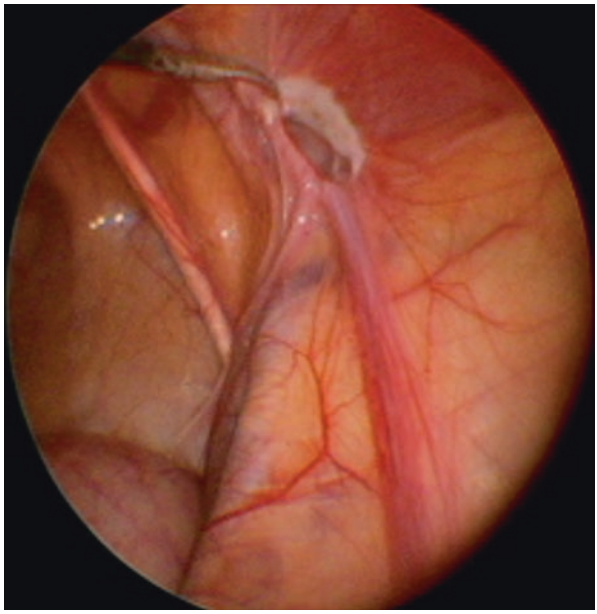

Fig. 46.3 The internal ring is cauterized using the Maryland dissector from approximately the 8 to 5 o'clock position

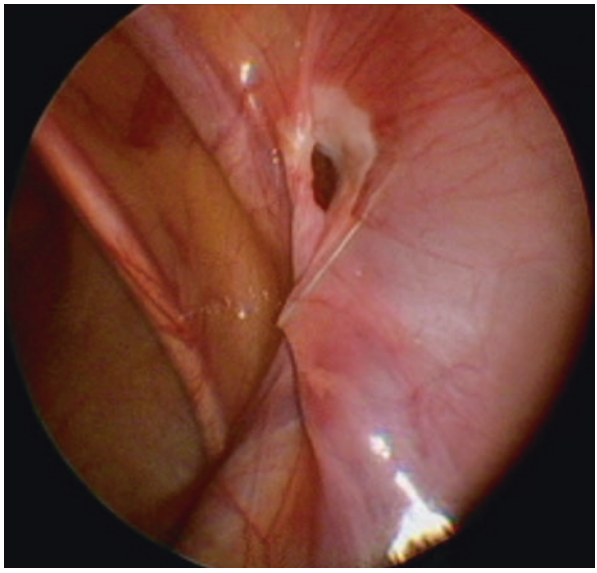

Fig. 46.4 The 25 G needle is used to perform hydrodissection to separate the peritoneum away from the cord structures

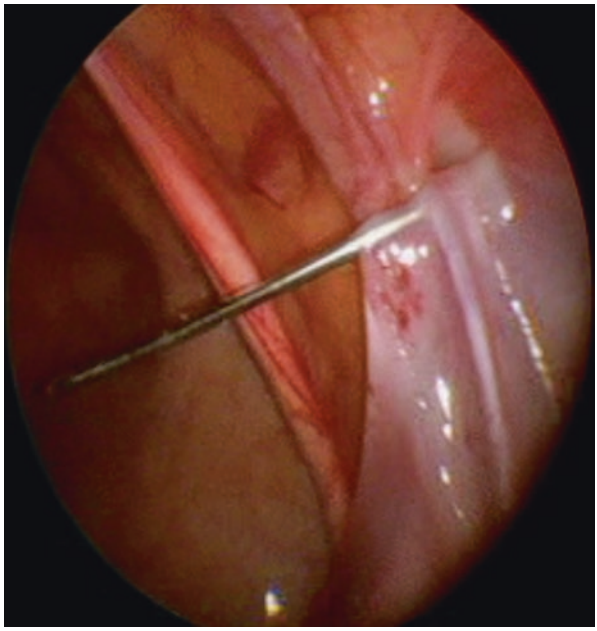

Fig. 46.5 The spinal needle is passed laterally around the internal ring in the hydrodissection plane and passed over the cord structures

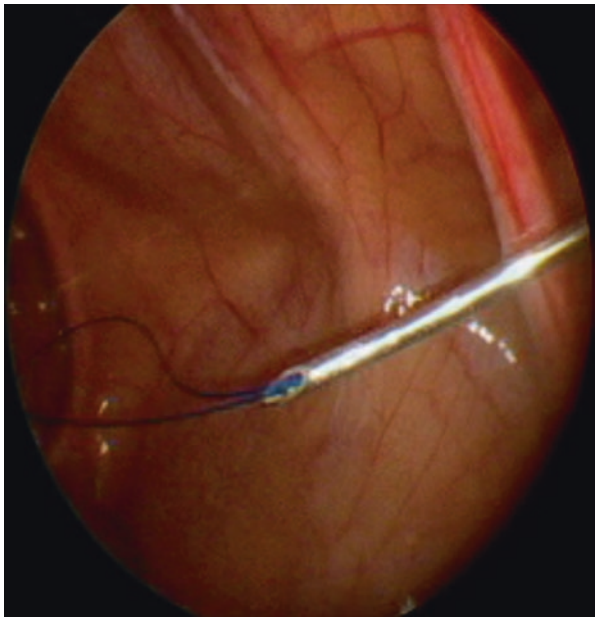

Fig. 46.6 The spinal needle is passed through the peritoneum around the 6 o'clock position, and the suture is pushed out of the needle end

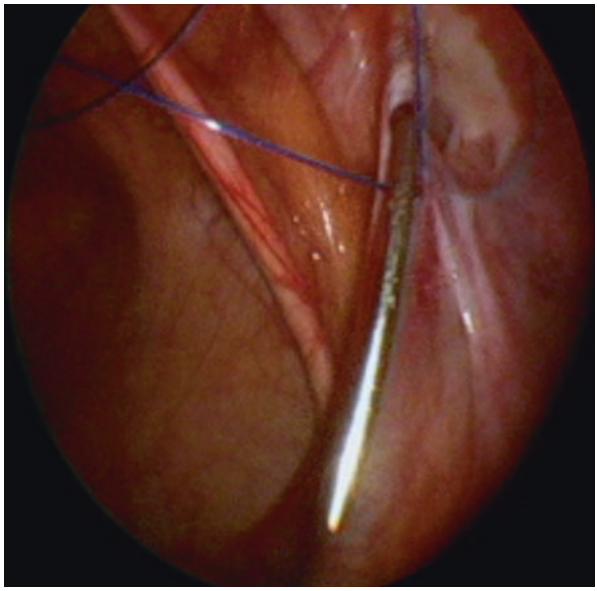

Fig. 46.7 The spinal needle is then passed medially around the ring and placed through the first loop of suture

- The spinal needle, with a new looped monofilament suture, is again placed through the same 1-mm stab incision and now advanced medially around the internal ring through the dissection plane. If the vas deferens was unable to be passed laterally, it should be attempted to pass it medially, with the goal to pierce the spinal needle through the peritoneum in the same location. If it is too difficult to pass over the vas deferens, then push the needle through the peritoneum medial to the vas deferens, and just leave the peritoneum over the vas deferens in place.
- Once the spinal needle is through the peritoneum, it is pushed through the first loop (Fig. 46.7). This first loop is then pulled snug against the needle, and then the second loop that is in the spinal needle is pushed out (Fig. 46.8). The needle is then removed while keeping the first loop snug. This first loop will act as a snare to pull the second loop laterally around the internal ring and out of the abdomen.
- The monofilament suture is then exchanged for the braided nonabsorbable suture by looping the braided suture around the monofilament suture and then using the monofilament suture to pull the braided suture around the internal ring (Fig. 46.9). The reason for this exchange is that the author has demonstrated in a rabbit model that nonabsorbable, braided suture is more effective than monofilament and this type of suture leaves a softer knot in the subcutaneous tissue postoperatively [24]. This suture, however, is too soft to slide easily through the spinal needle when it is looped, which is why we start with a stiff, monofilament suture.
- The looped end of the braided suture is then cut, and four ends of the suture are tied down to create two knots, double ligating the hernia. Make sure to apply pressure to the scrotum prior to tying down the sutures to evacuate any pneumoperitoneum. In infants, one of the sutures is removed, and only single ligation is performed to prevent a potential suture granuloma.

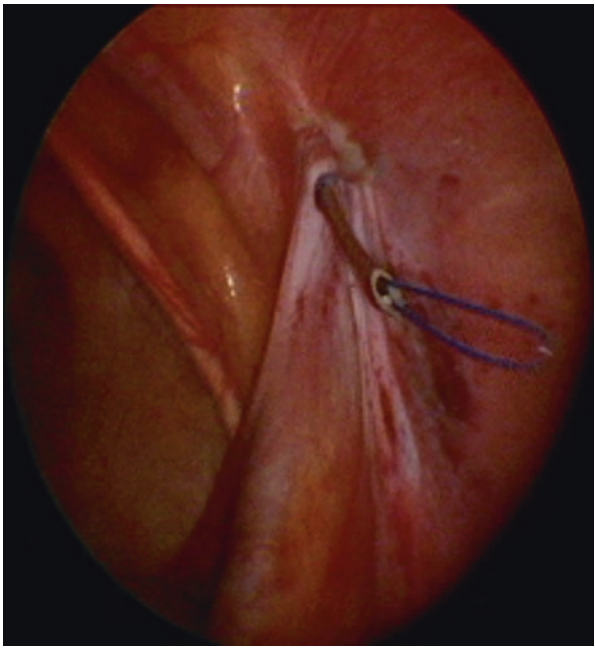

Fig. 46.8 The second looped suture is then passed through the spinal needle

Other Techniques

Intraperitoneal high ligation and closure of the ring may be performed using a variety of suturing methods such as the Z stitch, purse-string suture, or interrupted sutures [25]. Endoloop closure of the hernia has also been described, but this should only be used in females, given the risk of spermatic cord injury [26]. Riquelme et al. also described performing hernia sac dissection without closure of the ring in patients with an inguinal ring of <1 cm and report no recurrences in 91 patients [27]. It is thought that the scarring from the hernia sac dissection creates a sufficient enough closure that a suture is not necessary.

Additional percutaneous/extracorporeal approaches are the SEAL (subcutaneous endoscopically assisted ligation) and the PIRS technique. The SEAL technique involves placing the suture percutaneously and advancing it circumferentially around the internal ring avoiding the cord structures [28]. The PIRS technique uses the spinal needle to advance a suture circumferentially around the internal ring [23]. Additional instruments have been created, such as a blunt hook, to dissect around the internal ring [29].

Outcomes/Complications

In addition to the complications listed for open repair (wound infection, recurrence, testicular atrophy, injury to vas deferens), there is also risk of injury to surrounding structures, such as the inferior epigastric vessels, bladder, and bowel [30].

In a recent meta-analysis, the overall incidence of recurrence was 0.7%, incidence of injury to surrounding structures was 0.32%, and incidence of conversion was 0.05% [30]. It was also found that hydrodissection and the use of an assisting forceps significantly reduced the incidence of injury and recurrence.

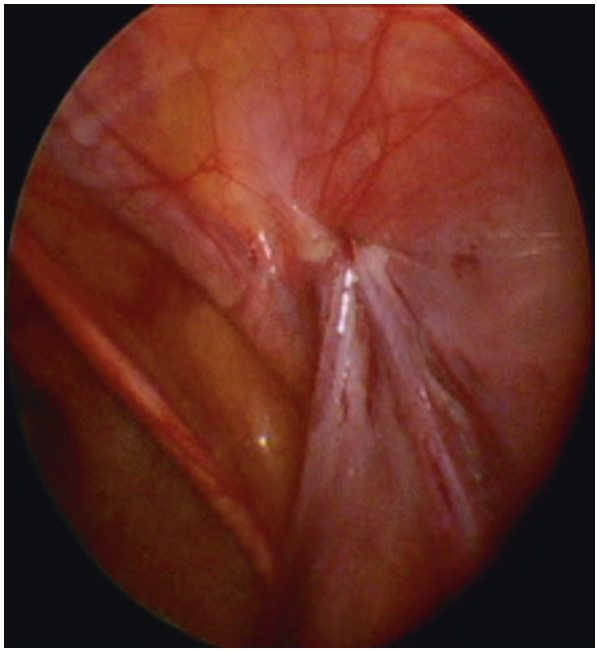

Fig. 46.9 Final appearance of the inguinal ring after suture ligation

Contralateral Groin Exploration

There is continued debate on the use of routine contralateral groin explorations during an open unilateral repair. Routine exploration evaluates for and treats a contralateral PPV or subclinical contralateral hernia, which would avoid a potential future operation, anesthesia exposure, and possible incarceration.

However, as discussed previously, PPV have the potential to close and of those that do not close, not all develop into clinical hernias. While the incidence of a PPV is reported up to 63% in the first 2 months of life, it steadily declines after that, and about 60% of them close by the age of 2 years [5]. Of those that don't close, about 3.8–14.3% develop into clinical hernias [1, 6, 31–33]. Additionally, Ron et al. also reported that 14 contralateral explorations are required to prevent one potential hernia [34], and Maillet et al. found that the risk of morbidity of a routine exploration is greater than potential morbidities of not exploring the contralateral side [35]. For these reasons, routine open exploration is no longer recommended.

Routine laparoscopic exploration of the contralateral side, including both a transumbilical and transinguinal approach, is more controversial. Some have advocated the use of a laparoscopic evaluation of the contralateral side through a transinguinal approach, which would avoid negative open explorations [36]. Additionally, laparoscopic exploration and repair of the contralateral side during a laparoscopic unilateral repair avoid the use of a separate incision, minimally increase operative time,

and may be cost-effective [37, 38]. Despite this, many still advocate against routine repair of contralateral PPV. While laparoscopy has a high sensitivity and specificity in diagnosing a contralateral PPV, it has a poor predictive value in detecting which PPV develop into clinical hernias [37, 39]. This would subject certain patients to an unnecessary procedure, and observation is found to have a lower incidence of complications, including injury and anesthesia risk, than a contralateral repair [35, 40]. However, a survey by Holcomb et al. found that 90% of parents request contralateral evaluation and repair at the time of a unilateral exploration [41]. At this time, there is no clear consensus on how to manage a contralateral PPV found on laparoscopic evaluation. The author always consents the patients undergoing the lap repair for a possibility of bilateral repair.

Incarcerated Hernias

Nonoperative reduction should first be attempted as it is successful in 70–95% of patients and may be performed using sedation or analgesia [42, 43]. If the hernia is unable to be reduced or if there is concern for an incomplete reduction, then emergent operative intervention is indicated. Otherwise, given the risk of recurrent incarceration, the hernia should be repaired during the same hospitalization. Many clinicians wait for 24–48 h after reduction to allow the edema to resolve and make the repair technically easier; however, this is not required with laparoscopic repair.

Laparoscopic repair is considered a safe alternative to an open repair and also offers potential advantages. These advantages include easier reduction of the hernia content because of the widening of the internal ring from pneumoperitoneum and allows for direct visualization of the hernia contents to assess for complete reduction and viability. The operation is also considered technically easier and may be performed immediately after reduction, since it avoids dissection of the edematous tissue [44–46].

Necrotic Gonads

Testicular infarction may occur from incarceration secondary to compression of the gonadal vessels by the hernia contents. The appearance of a necrotic testes does not necessary signify irreversible damage, and testes have been found to be functional in 25–50% of the cases, so orchiectomy is not recommended [47].

Uterine adnexa is found in about 15% of inguinal hernias and has a strangulation risk of 0.2–33% [21, 48]. Unlike the mechanism for testicular infarction, strangulation occurs from ovarian torsion. The angle between the suspensory ligament of the ovary and ovarian ligament becomes narrowed when the ovary enters the inguinal canal, predisposing it to torsion [48]. Like in males, the appearance of a necrotic ovary does not necessary mean irreversible damage, and multiple studies have found on follow-up that most ovaries were found to be viable [49, 50]. For this reason, oophorectomy is not indicated in these patients.

Umbilical Hernias

Anatomy and Pathophysiology

Umbilical hernias occur from incomplete closure of the fascial defect at the umbilicus after birth. The incidence is estimated at 26%, with higher incidences in black and premature infants [51, 52]. Walker found in an evaluation of black children that 84.7% of all umbilical hernias close spontaneously before the age of 6 and 96% of defects less than 0.5 cm close before the age of 6 years [53]. He additionally found that defects larger than 1.5 cm rarely close spontaneously.

Surgical Timing

The overall risk of incarceration is low, estimated at 1 per 1500 umbilical hernias or between 0.19 and 4.5% [54, 55]. Given the overall low risk of incarceration and the high likelihood of closure with time, most surgeons wait to operate until the age of 4–5 [55]. Indications to operate sooner are history of incarceration and presence of symptoms.

Surgical Technique

The procedure is performed in the supine position, and an infraumbilical or paraumbilical curvilinear incision is created. Dissection is carried down to the hernia sac, which is then freed up circumferentially from the fascia and subcutaneous tissue. The contents are then reduced back into the abdomen. There is no clear benefit to resecting the hernia sac [56]. The fascial defect is then closed using simple interrupted sutures and the skin is closed. An umbilicoplasty should be considered in patients with a large proboscis for cosmesis. Pressure dressings at the site of the umbilicus have not been found to decrease the risk of hematoma or seroma formation [57].

Epigastric Hernia

Epigastric hernias are midline fascial defects superior to the umbilicus. They represent 4% of all hernias and are a congenital defect from improper union of the rectus muscles to create the linea alba during development; however, some studies suggest that they may actually be acquired defects [58]. Epigastric hernias do not close spontaneously and are often scheduled for repair soon after diagnosis. They may be repaired either open or laparoscopically, and it is critical to mark the skin at the site of the epigastric hernia preoperatively to allow easier identification intraoperatively. The author does not usually operate on these hernias if they are asymptomatic given the exceedingly low risk of intestinal incarceration.

Direct Inguinal Hernia

Direct inguinal hernias are rare in the pediatric population, estimated between 0.2 and 4.5% [59]. These hernias are repaired primarily with or without the use of mesh, in a similar technique that is used in adults.

Femoral Hernia

Femoral hernias are also rare in children and comprise less than 1% of all hernias, with an incarceration risk between 15 and 20% [60]. They are often incorrectly diagnosed and repaired as an inguinal hernia, and the true diagnosis is not made until the patient presents with a recurrence. These hernias may be repaired open, using the standard McVay approach or laparoscopically using the mesh patch and plug technique [60, 61].

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Herniorrhaphy in Cirrhosis: Operative Approach and Timing

47

Sara P. Myers, Shahid M. Malik, Amit D. Tevar, and Matthew D. Neal

Risk Assessment

Many providers hesitate to proceed with elective hernia repair in patients with established cirrhosis in view of high complication rates, deferring surgical management until compelled to do so by complications such as incarceration, strangulation, and spontaneous or threatened rupture [1]. Rupture is precipitated by increased tension on the abdominal wall (e.g., ascites, trauma) with devascularized skin over the hernia at particularly high risk of scarring and necrosis [2]. Indications for emergent repair include evisceration, gangrenous skin changes, and secondary peritonitis [3, 4]. Elective repair should be considered in individuals who present with thinning of skin overlying the hernia and leaking of ascites fluid as these may portend rupture [5]. Non-operative treatment of complicated ventral hernias (those

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with skin disruption resulting in leaking ascites or exposed bowel) carries a 60–88% mortality which outweighs the substantial perioperative risk, and surgery is therefore recommended [6, 7]. Any attempt at medical optimization and reduction of perioperative risk entails a thorough understanding of risk assessment which begins with the etiology of liver dysfunction. Chronic liver disease and cirrhosis are the results of a variety of conditions, the most common of which include hepatitis C virus (HCV), nonalcoholic fatty liver disease (NAFLD), and alcohol liver disease. The rates of these illnesses are increasing within the United States, and an increasing number of individuals presenting with hernias will have cirrhotic physiology [8].

Various risk factors have been identified that increase the likelihood of poor operative outcomes in patients with cirrhosis. These include intraoperative blood transfusion, coagulopathy, ascites, gastrointestinal bleeding, hypoalbuminemia, and pulmonary dysfunction [9]. Because each patient presents with a heterogeneous set of comorbidities, scales for perioperative risk assessment have been created (Table 47.1) [10]. The two most commonly utilized are the Child-Turcotte-Pugh (CTP) score and the Model for End-Stage Liver Disease (MELD). CTP, initially developed in 1973 as predictive model for mortality after esophageal surgery for

Table 47.1 Child-Turcotte-Pugh (CTP) and model for end-stage liver disease (MELD) classification systems

Clinical/lab criteria	Cirrhosis classification systems			
	Child-Turcotte-Pugh (CTP) classification			Model for End-Stage Liver Disease (MELD)
	Add individual points for total score: *Class A = 5–6 points* *Class B = 7–9 points* *Class C = 10–15 points*			*6.43 (constant) + 3.78 $\log_e$ serum bilirubin + 9.57 $\log_e$ serum creatinine + 11.20 $\log_e$ INR*
	One point	*Two points*	*Three points*	
Prothrombin time (seconds prolonged)	<4	4–6	>6	
Ascites	None	Mild to moderate (responsive to diuretics)	Severe (refractory to diuretics)	
Encephalopathy	None	Mild to moderate (grade 1 or 2)	Severe (grade 3 or 4)	
Albumin (g/dL)	>3.5	2.8–3.5	<2.8	
Serum bilirubin (mg/dL)	<2	2–3	>3	For values less than 1, use 1
International normalized ratio (INR)	1.7	1.8–2.3	>2.3	INR value
Serum creatinine (mg/dL)				Use 4.0 as creatinine level if patient has been dialyzed twice in the last 7 days

variceal bleeding [11], incorporates serum bilirubin, albumin or prothrombin time, degree of ascites, and hepatic encephalopathy. Criticisms of CTP score stem from the subjectivity with which ascites and encephalopathy are graded. In contrast, objective measures such as bilirubin levels, serum albumin, and prothrombin time are direct markers of hepatic function. Other direct assays of liver synthetic function include the indocyanine green clearance test [12] or hepatic uptake of technetium-99m-galactosyl-human serum albumin [13]. Unfortunately, these are not practical tests for the rapid and frequent assessment of liver dysfunction and are not routinely used.

Unlike CTP, the MELD score is a completely objective scoring system. This score utilizes the international normalized ratio (INR) for prothrombin time, serum creatinine, and total bilirubin. Recently, serum sodium has been added for a more complete evaluation; however the MELD-Na has yet to be studied as a predictor for hernia surgery, and thus this chapter will discuss the literature surrounding the use of standard MELD. Though initially generated to evaluate short-term mortality after transjugular intrahepatic portosystemic shunt placement [14], studies have investigated the appropriateness of MELD score for mortality risk assessment in patients with cirrhosis [15]. Though several retrospective studies have been performed comparing MELD and CTP scales, a definitive standard to guide preferential use of one over the other is lacking. In patients' status postabdominal surgery, a MELD of 14 more accurately predicts overall morbidity and mortality than CTP class C [16]. Attempts to equate the two systems demonstrate that in terms of 1- and 3-month mortality rates of patients undergoing both elective and emergent operations (including abscess incision and drainage, liver resection, cholecystectomy, amputation, bowel resection, inguinal and ventral herniorrhaphy, and other intervention), CTP class A is considered analogous to MELD $\leq$ 8, class B to MELD 9–16, and class C to $\geq$17 [17]. Although there are no comparisons of the two classification systems for risk assessment post-herniorrhaphy specifically, MELD score has been shown to predict postoperative complications after inguinal hernia repair (IHR) and umbilical hernia repair (UHR). A study analyzing data from the National Surgical Quality Improvement Program Database (NSQIP) database (2008–2012) demonstrated that every 1 point increase over a mean MELD score of 8.6 points for individuals undergoing IHR and 8.5 points for UHR bestowed a 7.8 and 13.8% increase in postoperative complications (e.g., surgical site infection, dehiscence, urinary tract infection, pneumonia, sepsis, thromboembolism, renal insufficiency, cardiovascular events such as myocardial infarction, and bleeding) [18]. A summary of CTP and MELD mortality risk assessments can be found in table 47.2 [17, 19, 20].

Another helpful instrument is the American Society of Anesthesiologists (ASA) classification. A large retrospective study from the Mayo clinic indicated that ASA class is the strongest predictor of mortality during the initial postoperative period. After postoperative day 7, MELD becomes the best predictor of mortality [21]. Application of these risk assessment tools highlights the fact that operative decision-making must take into account the type of procedure, extent of liver dysfunction, and the patient's overall functional status.

Table 47.2 Mortality rates stratified by MELD and CTP risk assessment

	1-month mortality (elective)	1-month mortality (emergent)	3-month mortality (elective)	3-month mortality (emergent)
Farnsworth et al. [22] *investigating surgeries requiring general anesthesia*				
CTP A	17%	0%	17%	0%
CTP B	9%	9%	18%	45%
CTP C	100%	50%	100%	50%
MELD ≤ 8	10%	0%	10%	10%
MELD 9–16	17%	0%	25%	44%
MELD ≥ 17	50%	60%	50%	60%
Andraus et al. [23] *investigating abdominal ventral hernia repair*				
CTP C	–	OR 2.6 (95% CI 0.63–10.82, p 0.188)	–	–
MELD ≥ 20	–	OR 4.35 (95% CI 1.03–18.45, p = 0.049)	–	–
Cho et al. [24] *investigating umbilical hernia repair*				
MELD ≤ 15	1.3%	–	–	–
MELD > 15	11.1%	–	–	–

Suitability for Surgery

The abovementioned classification systems are valuable instruments for risk assessment. The Mayo postoperative mortality risk calculator (http://www.mayoclinic.org/medical-professionals/model-end-stage-liver-disease/post-operative-mortality-risk-patients-cirrhosis) is one validated risk prediction model [22]. Criticisms of this particular instrument include that it is only intended for moderate- to high-risk surgical procedures. Further, while the model incorporates etiology of liver disease, it does so in a limited manner classifying hepatic dysfunction as either the result of cholestasis/alcohol or viral/other. Nonetheless, risk calculators may be used, in general, to guide surgical decision-making with the goal of reducing perioperative mortality [23]. Fig. 47.1 represents an algorithm to guide the decision to proceed with operative intervention. In patients with cirrhosis and high estimated risk or postoperative mortality, transplant candidacy should be assessed. Surgical intervention in these individuals may provoke decompensation of liver disease, and if transplantation is an option, referral to a transplant center for evaluation is critical [24]. Although there are no strict recommendations regarding when to refrain from offering a patient operative intervention, circumstances such as coagulopathy, uncontrolled portal hypertension, and malnutrition are criteria for deferring elective procedures [25]. If the patient is a transplant candidate, umbilical and ventral hernias may be successfully repaired either at the time of liver transplant or after [26, 27]. If there is a high likelihood that a patient will receive a transplant within 3–6 months, recommendations are to perform umbilical herniorrhaphy concurrently with transplantation [28]. Postponing repair after transplant is advised against as there is increased risk of strangulation post-transplant in individuals who have not had repair [29].

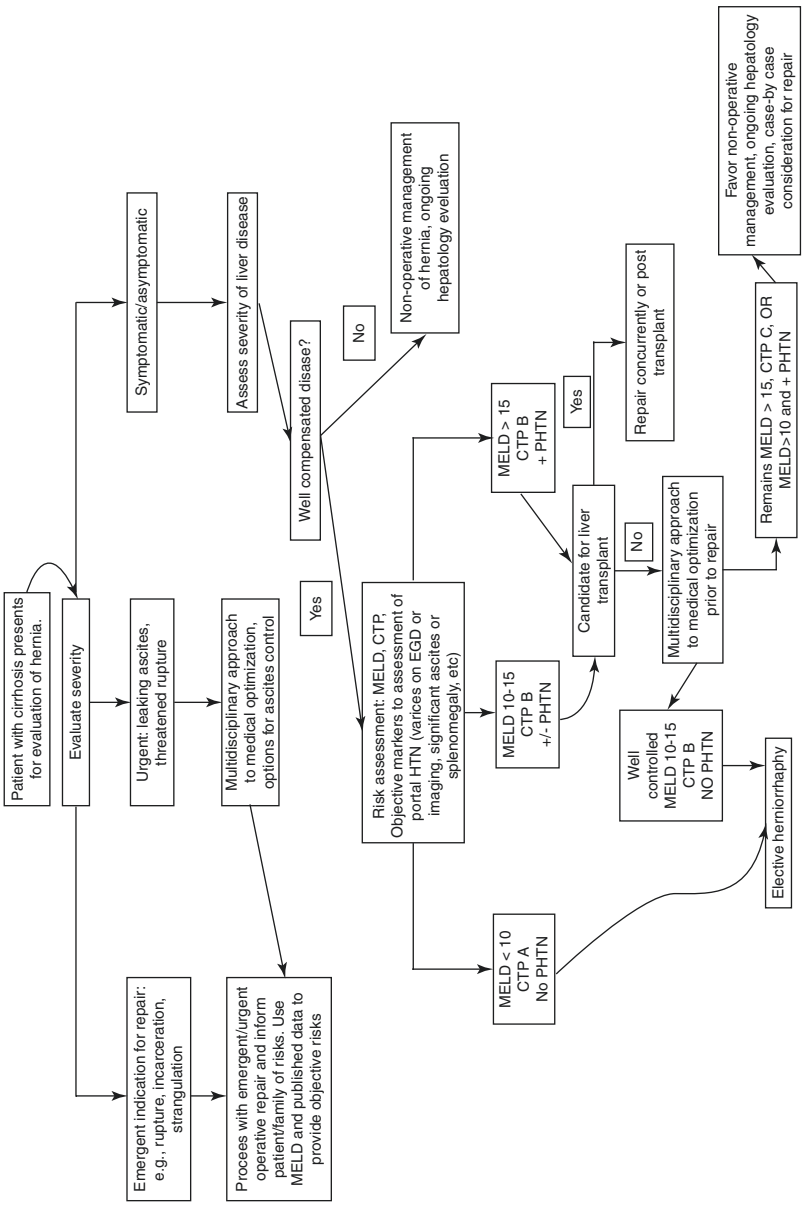

Fig. 47.1 Algorithm guiding decision to proceed with herniorrhaphy in cirrhosis. *MELD* model for end-stage liver disease, *CTP* Child-Turcotte-Pugh, *PHTN* portal hypertension

Preoperative Care of the Cirrhotic Patient

In determining operative timing, one must consider the two distinct phases of cirrhosis—compensated and decompensated. Decompensated status is marked by complications of cirrhosis such as ascites, variceal bleeding, spontaneous bacterial peritonitis, hepatic encephalopathy, and hepatorenal syndrome. Some manifestations may be more ominous than others; for example, the development of ascites bestows a 20% 1-year mortality rate, while variceal bleeding raises this to 57% [30]. Hepatorenal syndrome carries a 30-day mortality rate upward of 70% [31]. Even without a surgical insult, survival differs markedly between these populations, with decompensated patients having a median survival of less than 2 years in comparison with more than 12 years for compensated patients [32]. Consequently, prior to undertaking an elective procedure, efforts aimed at medical optimization [33] should address nutrition, coagulopathy and thrombocytopenia, fluid and electrolyte balance, hepatic encephalopathy, ascites, renal function, pulmonary function, varices, and infection (Table 47.3). This optimization effort should be undertaken in a multidisciplinary fashion, employing the collaboration and expertise of the hernia surgeon, hepatologist, and transplant team.

Malnutrition affects the majority of patients with cirrhosis [34] and is an independent risk factor for mortality [35]. Nutritional status is influenced by the nutrient malabsorption, anorexia, and catabolism associated with chronic liver disease. Several markers including lean body mass, serum albumin/prealbumin, metrics that remain relatively constant despite fluid shifts (e.g., mid-arm muscle circumference), creatinine-height index, and hand strength have been studied. Preoperative nutritional optimization is paramount to improving outcomes including wound healing and reducing delays in recovery and complications such as sepsis [36]. Modifications that select carbohydrate and lipid-rich dietary sources and promote milk- and vegetable-derived proteins and branched-chain amino acids can prevent worsening of hepatic encephalopathy. Emphasis should be placed on correcting vitamin deficiencies. Enteral access is an option for nutrient delivery in patients who have poor oral intake. Alcohol use should be discouraged prior to elective intervention so as to minimize further difficulties with absorption as well as postoperative withdrawal [37].

CTP and MELD scores consider INR as a proxy for coagulopathy in cirrhosis since dysfunction of hepatic synthetic dysfunction leads to lack of both pro- and anticoagulants. Although the INR may be prolonged in a cirrhotic, this does not mean that they are not at risk of thrombosis [38]. This concept is exceptionally important for the clinician to remember. In fact, cirrhosis is an independent risk factor for venous thromboembolic events, and the fallacy of "auto-anticoagulation" should be discarded in favor of a recognition of the complexity of coagulation response that occurs in cirrhotics. In this vein, the use of viscoelastic testing such as thromboelastography (TEG) or rotational thromboelastometry (ROTEM) gives a more complete representation of bleeding risk by assessing all phases of clot generation as well as lysis [25]. Vitamin K supplementation in response to elevated INR is recommended prior to elective surgery as supplementation of fat-soluble

Table 47.3 Diagnosis and treatment for features of decompensated cirrhosis

Features of decompensated cirrhosis	Diagnostic testing	Treatment
Malnutrition • Anorexia/decreased appetite • Impaired nutrient absorption • Catabolic state	• Lean body mass • Serum albumin • Triceps skin fold • Mid-arm muscle circumference	• Nutritional and vitamin supplementation • Diet modification: High carbohydrate, high lipid
Coagulopathy • Aberrant coagulation factors secondary to hepatic synthetic dysfunction • Malabsorption of vitamin K • Thrombocytopenia	• INR • TEG	• Vitamin K administration • TEG-guided transfusion • Fresh-frozen plasma transfusion • Cryprecipitate or desmopressin, lysine analogs, aminocaproic acid, transexamic acid, aprotinin • Platelet transfusion (if thrombocytopenic)
Fluid and electrolyte imbalance • Hyponatremia • Hypokalemia secondary to increased ammonia synthesis in proximal tubules	• BMP • Ammonia level • Urine and serum osmolality	• Oral fluid restriction (hyponatremia) • Limit administration of intravenous fluids • Correct hypokalemia
Hepatic encephalopathy • Malnutrition • Medications, e.g., benzodiazepines, opiates, antidepressants, antipsychotics • Comorbid conditions, e.g., renal insufficiency, gastrointestinal bleeding, infection • Fluid or electrolyte imbalances (e.g., hyponatremia increases blood-brain barrier permeability) • Deficiency of zinc can alter urea cycle and allow for increased ammonia generation	• Mental status assessment (neuropsychological or psychometric testing)	• Lactulose as ammonia cathartic • Correction of electrolyte abnormalities • Zinc replacement
Ascites	• Physical exam • Radiographic imaging	• Diuretics • TIPS for refractory ascites—Paracentesis
Renal insufficiency • Electrolyte and fluid balance abnormalities • Nephrotoxic medications	• Fluid balance assessment • BMP	• Correct electrolyte abnormalities • Avoid nephrotoxic agents • Albumin infusion after large-volume paracentesis

(continued)

Table 47.3 (continued)

Pulmonary insufficiency • Pleural effusions • HPS	• Pulse oximetry • Pulmonary function testing • Arterial blood gases	• Diuresis • Liver transplant • Intravenous epoprostenol to improve pulmonary dynamics (HPS)
Infection • Impaired synthesis of components of innate and adaptive immunity • Spontaneous bacterial peritonitis	• Diagnostic paracentesis (SBP) • Blood culture, urine culture	• Antibiotics • Albumin infusion
Varices • Portal hypertension • Coagulopathy • Volume overload	• Endoscopy	• Nonselective beta blockade as prophylaxis • Normovolemia • Correction of coagulopathy • Endoscopic variceal ligation • TIPS

TEG Thromboelastography, *HPS* hepatopulmonary syndrome, *TIPS* transjugular intrahepatic portosystemic shunting, *INR* International Normalized Ratio, *BMP* basic metabolic panel

vitamins if malabsorption has influenced coagulopathy. Viscoelastic-guided resuscitation [39] is appropriate and beneficial in minimizing unnecessary transfusions along with associated complications and challenges to volume status, and the use of TEG or ROTEM should be considered over the use of conventional coagulation testing in cirrhosis [40]. Thrombocytopenia contributes to coagulopathy in cirrhosis and in many cases is one of the first manifestations of portal hypertension. Thrombopoietin, which is responsible for driving platelet synthesis by bone marrow, is reduced in cirrhosis. Further, splenomegaly allows for segregation and destruction of viable platelets. Platelet transfusion should be done judiciously, and criteria vary depending on indication for procedure (i.e., therapeutic versus prophylactic) and type of intervention [41]. In general, prophylactic transfusion can be justified for patients with cirrhosis when platelet counts fall below $40 \times 10^3/mm^3$, as this threshold is associated with increased risk of hemorrhage, though splenic sequestration and concurrent coagulopathy account for the transient and muted response to transfusion [42].

Recognizing and treating infection prior to undergoing elective surgery is paramount. The liver plays a key role in innate and acquired immunity. Cirrhosis-associated immune dysfunction (CAID) results from systemic inflammation and immunodeficiency [43]. Compared to non-cirrhotic patients, rates of morbidity and mortality are increased if infection is not appropriately addressed preoperatively [44].

The effect of chronic liver disease on other organ systems should be minimized prior to surgical intervention. In particular hepatic encephalopathy, ascites, renal disease, pulmonary dysfunction, and esophageal varices are important considerations. Mild hepatic encephalopathy can be difficult to discern clinically but postoperatively may progress to a more severe form that complicates patient recovery both because of nonadherence and pathologic consequences such as aspiration

pneumonia [45]. Electrolyte imbalances including diuretic-induced hypokalemia and alkalosis can promote hyperammonemia. Hyponatremia can exacerbate the effect of elevated ammonia levels by making the blood-brain barrier more permeable. Fluid restriction, lactulose, and treating precipitating events such as gastrointestinal bleeding can improve encephalopathy.

Ascites is another manifestation of decompensated cirrhosis. Paracentesis allows for evaluation of SBP and can be therapeutic in combination with albumin replacement thereby relieving intra-abdominal pressure and improving pulmonary dynamics. Ascites may be medically managed by low-sodium diets, diuretics, and paracentesis. Transjugular intrahepatic portosystemic shunts (TIPS) should be considered in selected patients (who have no contraindications) with a MELD score less than 15. As TIPS requires 3–4 weeks before it is fully effective for ascites, diuretics many times are used in conjunction with the procedure [46]. If a hernia patient is a candidate for TIPS, elective operative repair may be deferred until this evaluation is complete, as preoperative TIPS has been shown to reduce hernia complication rates in patients with severe ascites [29]. TIPS may also be used as secondary prophylaxis or treatment for refractory variceal bleeding [47]. While a full description of variceal bleeding, management and consequences is beyond the scope of this article, consideration of gastrointestinal bleeding in the cirrhotic patient demonstrates that surgical outcomes require an interdisciplinary approach.

In addition to TIPS, some have advocated for the placement of preoperative peritoneal catheters for ascites drainage [29]. Although this has been shown to be an effective management strategy by some authors, there are multiple concerns with this approach including the risk of infection from indwelling catheters as well as the potential consequences related to rapid ascites removal. Overaggressive removal of ascites is associated with dehydration, acute kidney injury, and acute strangulation [20, 48]. In summary, preoperative optimization of ascites should be guided by a clinician with expertise in managing fluid balance in these complex patients, and strategies can include diuresis, scheduled paracentesis, and preoperative TIPS for the appropriate patient. Close consultation with an expert in hepatology is of paramount importance for a hernia patient with significant ascites.

Repair of Ventral, Umbilical, and Incisional Hernias

Laparoscopic Versus Open Repair

Much of the literature comparing laparoscopic and open approaches in cirrhotic patients is derived from studies of cholecystectomy. Data from these studies support that laparoscopic technique can be employed in patients with moderate cirrhosis of the liver (CTP A and B) with decreased rates of postoperative complication and hospital length of stay [49]. Additionally, a less invasive laparoscopic approach can reduce the postoperative pain and recovery time associated with an open procedure

[50]. Laparoscopic ventral hernia repair has been associated with fewer complications overall when compared with open repair in individuals without chronic liver disease [51]. This may reflect that operative approach is customized based on a patient's history of abdominal surgery, BMI, baseline comorbidities, and hernia characteristics [52]. Studies considering technique in patients with cirrhosis are limited. Patients with cirrhosis who underwent laparoscopy have been shown to have decreased risk of morbidity and mortality [53], reoperation, pneumonia, transfusion requirement, wound infections, and sepsis [54]. Although techniques for hernia repair are evolving, the primary differences in laparoscopic repair are that mesh placement is often intraperitoneal [55] and that primary fascial closure is often not performed [56]. Arguments against a laparoscopic approach in a cirrhotic patient include increased infection risk with intraperitoneal mesh placement in the setting of ascites and immunocompromised state [57], although most of this argument stems from anecdote and case series. Perhaps more pressing is the potential for poor tolerance to anesthesia given the effects of chronic liver disease on cardiopulmonary systems, and as such a clear communication with hepatology and anesthesia is mandatory [58].

In a recent retrospective analysis, patients with chronic liver disease (MELD ≥ 9) who underwent elective laparoscopic or open ventral hernia repair between 2005 and 2013 were identified from NSQIP [59]. The study found that laparoscopic repair is associated with similar short-term outcomes but improved wound complication and shorter length of stay compared to open repair. However, when the sample was sub-stratified based on presence of ascites, there was a significant increase in mortality, rates of sepsis and renal complications, and unplanned return to the operation for patients (Table 47.4). Although MELD score was not significantly associated with outcomes, low preoperative serum albumin was an independent prognostic indicator for all postoperative complications. Unfortunately, how these results are influenced by degree of ascites, the type of mesh used, and other factors continues to be ambiguous. In summary, there are no well-defined contraindications to laparoscopic hernia repair in cirrhotics beyond the inability to tolerate the physiology of pneumoperitoneum, although consideration of the degree of ascites may factor into the decision-making.

Table 47.4 Comparisons of complication rates in open and laparoscopic ventral hernia repairs in cirrhotic patients reported by Juo et al. [59]

Complication	Open ventral hernia repair (%)	Laparoscopic ventral hernia repair (%)	*p* value	Increased odds of perioperative complications in laparoscopic interventions in subgroup analysis for patients with ascites
Mortality	1.6	2.1	0.63	OR 17.97, 95% CI 1.66–94.81, $p = 0.02$
Systemic morbidity	7.8	6.5	0.51	OR 4.99, 95% CI 1.54–16.21, $p < 0.01$)
Unplanned reoperation	5.1	2.8	0.1	OR 13.61, 95% CI 1.99–92.70, $p < 0.01$)

Primary Versus Mesh Repair

In cirrhotic patients, elective repair with synthetic mesh has been shown to be safe and effective [60]. Infection and recurrence rate are two areas of consideration when comparing synthetic mesh to primary repair. In open umbilical hernia repair, the use of mesh has been associated with higher rates of infection than primary repair [61]. A randomized control study of 80 patients (CTP A or B) who underwent open herniorrhaphy for complicated umbilical hernia reported nearly twice the infection rate when using polypropylene mesh in comparison with primary repair [62]. Despite cirrhosis being a known risk factor for infectious complications postoperatively, in this study the rate of surgical site infection was not statistically higher than baseline for mesh repair. The authors posit that this may have been the result of excluding individuals with CTP class C cirrhosis. Importantly, although the rate of surgical site infection was higher in the setting of mesh use, none of the patients in this study required mesh removal, although the longest follow-up reported was only 28 months. This study also echoed existing data [63] that mesh repair boasted a reduced risk of recurrence at 6 months in comparison with primary repair [47]. With respect to biologic mesh, there is a single report of ruptured umbilical hernia being repaired with porcine mesh and fibrin glue [64]. Other studies have explored the use of bioprosthetic mesh in complex reconstructive surgeries with data demonstrating decreased infectious rates [65]. The experience of this approach to patients with cirrhosis is limited to studies with retrospective and small sample sizes [66]. Although there are anecdotal concerns of a higher risk of mesh infection in the setting of cirrhosis (perhaps due to subsequent episodes of spontaneous bacterial peritonitis), there is, in fact, no data to support this observation on a close review of the literature. It is the opinion of the authors that the choice of mesh for hernia repair in the cirrhotic can be driven by standard factors involved in mesh choice (wound class, risk factors for surgical site infection, recurrence risk, etc.) and not influenced by the presence or severity of liver disease.

The vertical Mayo technique, or "vest-over-pants" repair [67], had been recommended as a method of primary repair in patients with ascites and cirrhosis [68] but is now rarely used given its high risk of recurrence [69]. In this repair, the upper and lower boundaries of the defect are overlapped. Interrupted horizontal mattress sutures using a large nonabsorbable suture are placed transversely starting 1 cm away from the defect's lower edge. The suture is then passed under and through the upper boundary approximately 4 cm from the edge of the defect. This repair brings the lower border of the defect under the upper edge and simulates the "vest-over-pants" effect [67].

The anatomical levels for mesh placement include onlay, inlay, retromuscular, pre-peritoneal, and intraperitoneal onlay (IPOM) repair [70]. Reports exist for placement of all anatomic levels in cirrhotics, although there are no well-designed studies to address the optimum location of mesh placement in the setting of severe liver disease. The presence of umbilical varices and the increased risk of bleeding into large potential spaces (i.e., retromuscular or pre-peritoneal) due to impaired coagulation are relevant concerns when choosing a mesh location. There are no

studies to specifically suggest that intraperitoneal mesh placement in the presence of ascites leads to increased rates of mesh infection, although this is a theoretical risk. The IPOM (formerly called underlay) technique, however, has been associated with adhesive disease, obstruction, and fistula [1]. To minimize this, synthetic mesh can be coated or composite mesh can be used. Further considerations include drain placement postoperatively for ascites control. Informal survey of members of the International Hernia Collaboration on Facebook by one of the authors (MDN) reveals a wide variety of practices regarding postoperative drain placement. Options include no drain and management of ascites with serial paracentesis and medical management, short interval drain placement, and chronic, indwelling drains such as peritoneal dialysis catheters. In a recent meta-analysis, control of postoperative ascites reduced hernia recurrence risk from 45 to 4% when pooling data from multiple studies, suggesting the critical importance of postoperative ascites management [71]. However, no standardized management technique exists, and the various options listed above have not been prospectively compared. The elevated risk of infection with chronic catheters is of significant concern, and as such, the authors' practice is to leave postoperative drains for only short intervals (days) followed by interval paracentesis and optimization of medical management to reduce tension on healing wounds.

In cirrhotic patients receiving emergent intervention for ventral hernia complicated by incarceration, obstruction, strangulation, or rupture, one randomized control study demonstrated that there were similar rates of seroma, wound infection, ascites leak, recurrence, and mortality when comparing primary repair with onlay polypropylene mesh repair [72]. In the elective setting, a prospective study of patients with non-complicated umbilical hernias (average defect size 3.05 cm, MELD 18, CTP grade B and C) who underwent IPOM approach used literature comparisons to argue that there was a decreased wound infection and recurrence rate at 6 months relative to onlay and primary repairs [45]. The limitations of this study include lack of an appropriate control population as well as failure to mention type of mesh used [52].

Emergency Surgery in Advanced Cirrhosis

A common scenario presented to the general surgeon is a cirrhotic with severe disease (high MELD, portal hypertension, decompensated state) with a surgical emergency related to a hernia (rupture, incarceration, or obstruction). Decisions regarding the care of these patients are challenging, as the mortality of an abdominal operation in a decompensated Child's C cirrhotic is exceptionally high, but the underlying surgical emergency may have an equal if not worse prognosis. The authors recommend the use of the published reports of outcomes of nontransplant surgery and MELD/CPT scores to provide objective data and a frank discussion with the patient and/or family about operative risks and goals of care, which may include palliative care and comfort measures when appropriate. No absolute cutoff for MELD or mortality risk is utilized in the decision whether or not to operate, but rather a patient-centered and individual decision is made in each case with a clearly articulated set of expectations, understanding of goals of care, limitations, and at times a

time-limited trial of surgery and critical care if consistent with the patient's wishes. The practitioner is also recommended to employ institutional multidisciplinary expertise in both formulation of appropriate operative or non-operative management decisions and discussions with patient and/or family as to the likely outcomes.

Inguinal Hernia Repair in the Cirrhotic Patient

The majority of literature regarding hernia repair in the cirrhotic patient describes ventral and umbilical abdominal wall defects. Perhaps this is in part due to the fact that inguinal hernias in cirrhotics are unlikely to be associated with severe complications such as incarceration and strangulation [73]. The precise incidence of inguinal hernia in this population is unknown but is expected to be more common than in patients without cirrhosis [74]. Several studies note that inguinal hernias can be repaired safely in this setting [75]. Hurst et al. noted that no major postoperative complication occurred in their analysis of 18 patients, representing all CTP classes, who underwent repair for uncomplicated and complicated groin hernia with Bassini or McVay approaches (all but one without the use of mesh). [76]. A more recent retrospective case-control study of 950 patients undergoing elective McVay inguinal herniorrhaphy showed no higher rates of postoperative complications or recurrence in cirrhotic patients irrespective of CTP class [57]. Patti et al. described a cohort of 32 cirrhotic patients undergoing Lichtenstein repair electively with no major complications and improved quality of life [77]. A recent article compared outcomes for elective and emergent inguinal herniorrhaphy (mesh repair) in the setting of cirrhosis. Fifty-six patients with either CTP B or C cirrhosis were distributed evenly among those receiving emergent and elective procedures. Individuals undergoing emergent operations were at significantly higher risk of developing postoperative complications [78]. In summary, there is no consensus as to the technique or type of mesh to use for inguinal herniorrhaphy in the cirrhotic patient, but multiple studies suggest that inguinal hernia repairs are generally well tolerated. No high-quality studies exist to compare open versus minimally invasive repair of inguinal hernias in cirrhotics. As mentioned above, laparoscopy is generally well tolerated in the setting of compensated cirrhosis, but repair of inguinal hernias utilizing a preperitoneal approach must take into consideration the risk of bleeding in the setting of thrombocytopenia and coagulopathy with the creation of this potential space.

Although some experts continue to advise non-operative management over operative intervention in the absence of severe symptoms or incarceration [79], the safety of inguinal hernia repair in the above referenced observational studies suggest that, at least in early-stage cirrhosis without significant portal hypertension, inguinal hernia repair may be a safe option. Furthermore, there is a lack of stratification of anesthesia type for hernia repair in studies focused on cirrhotics. Duration of anesthesia, more than type, affects mortality risk [76]. Anesthetics are usually tolerated well in patients with compensated liver disease; however, in a decompensated state, sedatives, narcotics, and induction agents may lead to overt hepatic

encephalopathy [80]. Specific considerations such as hepatopulmonary syndrome may mandate the need for general anesthesia [81]. Given the elevated risk of complications related to general anesthesia [82], the authors recommend consideration be given to repair of inguinal and selected umbilical hernias under monitored anesthesia care (MAC) and local anesthesia. Although this may limit the surgeon to open as opposed to minimally invasive options, the risks of anesthesia are substantial and must be considered carefully in the risk assessment when deciding on the surgical approach.

Postoperative Management

In patients with cirrhosis who have undergone herniorrhaphy, management requires knowledge of common postoperative complications. These have been referred to throughout this chapter and include surgical site infection, peritonitis, sepsis, respiratory failure, postoperative decompensation of cirrhosis, and impaired wound healing. While there are no recommendations regarding specific monitoring of these patients in the period following hernia repair, the tenets of basic postsurgical care apply. Routine laboratory testing should include complete metabolic and electrolyte panels to monitor for worsening liver function and to correct for common electrolyte abnormalities (e.g., hypokalemia). Close attention should be paid to renal function as an early and sensitive marker of decompensation. Complete blood counts and standard coagulation testing can indicate postsurgical bleeding and aid in correcting coagulopathy and guiding transfusion, although consideration should also be given to the use of viscoelastic testing to guide transfusion if needed. Signs of infection such as surgical site erythema, fevers, hemodynamic instability, and leukocytosis warrant further evaluation and treatment. As mentioned above, studies have demonstrated that postoperative control of ascites is critical to aid in wound healing and prevent hernia recurrence after repair [71, 83, 84]. As in preoperative optimization, postoperative management may require a multidisciplinary approach with the involvement of a hepatologist.

Concluding Remarks

Hernia repair in the context of cirrhosis continues to be a controversial issue. In general, there is convincing evidence that individuals with compensated cirrhosis benefit from early elective ventral hernia repair. Similar recommendations are lacking for individuals with inguinal hernias, although review of retrospective data suggests this to be a safe practice. However, patients who are transplant candidates or at heightened risk of decompensation due to surgical stress or anesthesia may benefit from non-operative management. Further work is necessary to elucidate optimal timing and technique for hernia repair in this patient population. One aspect that is indisputably clear is the need for multidisciplinary care between hernia surgeons, transplant surgeons, and hepatologists which is critical to the care of these complex patients.

Key Summary Points and Recommendations

- The presence of portal hypertension and its sequelae (ascites, varicies, etc.) defines the population at greatest risk for complications from hernia surgery.
- Although no firm cutoff for elective surgery is well established, a MELD>14 has been shown to be a strong predictor of morbidity and mortality in abdominal surgery.
- Identifying decompensated cirrhosis and avoiding elective surgery in this setting is key.
- Elective hernia repair in a patient expected to qualify for and/or receive a liver transplant within 6 months should be deferred until the time of transplant or post-transplant.
- Cirrhotic patients have an increased rate of thrombosis despite abnormally prolonged INR, and risk of both thrombosis and excessive bleeding due to factor deficiency and thrombocytopenia must be considered in the perioperative management.
- The choice of mesh for hernia surgery in cirrhotics should be made by standard factors and not independently influenced by the presence of cirrhosis.
- In the patient with ascites who requires a hernia operation electively or urgently, aggressive postoperative management of ascites reduces the risk of hernia recurrence but must be tightly regulated to control the patient's volume shifts and renal function.
- Multidisciplinary management of cirrhotics requiring both elective and emergent operative repairs is paramount and should include experts in hernia surgery and hepatology.

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Concurrent Hernia Repair with Gynecologic or Urologic Surgery? Pros and Cons

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Michael Choi and Cheguevara Afaneh

Pros and Cons of Concurrent Hernia Repair

Concurrent hernia surgery at the time of urologic and gynecologic procedures avoids the need for a second operation and the associated risks of anesthesia, adds little to the operative time, can often be performed through the same incision(s), and frequently avoids opening a new surgical plane. While the risk of incarceration and/or strangulation related to groin hernias is low (~0.3–3% per year), concomitant hernia repair at the time of urologic/gynecologic surgery also obviates the need for future emergency surgery which carries a risk of mortality ranging from 1.7% to as high as 14% [1, 2]. Additionally, a Veterans Affairs study identified higher complication rates (27% versus 15.1%) for acute hernia surgery when compared with elective surgery and an overall decrease in survival over time for urgent and emergent hernia repairs [3]. Therefore, concurrent hernia surgery can theoretically eliminate the operative morbidity and mortality associated with emergency hernia surgery.

However, the main concerns with concurrent hernia surgery with both gynecologic and urologic surgery are increased infection risks (including wound and mesh infection), hernia recurrence, increased postoperative pain, as well as familiarity with the hernia repair technique. So this begs the question: is concomitant hernia repair with gynecologic and urologic surgery feasible and safe?

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Concurrent Hernia Repair with Urologic Surgery: Historical Perspective

To answer this question, we must first look at the urology literature. Simultaneous inguinal hernia repair at the time of urologic surgery has been well-described and was first published by McDonald and Huggins in 1949 using two separate incisions [4]. The preperitoneal approach to hernia repair was also well-documented in the literature as early as 1876 by Annendale [5]. In 1951, Riba and Mehn described repairing both direct and indirect hernia defects using a preperitoneal approach concurrently with retropubic prostatectomy through a Pfannenstiel incision for benign prostate disease [6].

In 1960, Nyhus popularized a preperitoneal hernia repair technique at the time of prostatic surgery through a vertical lower midline incision that involved high ligation of the hernia sac and suturing of the medial crus of the internal inguinal ring (transversalis fascia) and the lateral crus of the internal inguinal ring (iliopubic tract and femoral sheath-transversalis fascia) lateral to the cord structures for indirect hernias [7]. For direct inguinal hernias, the transversus arch was sutured to the iliopubic tract and/or Cooper's ligament using interrupted polypropylene sutures. Nyhus describes repairing the hernia while awaiting the results of the frozen section on the pelvic lymph nodes so as not to increase the operative time. In this series, hernia recurrence was 6%, and there was also a low incidence of infection [8].

Then, in 1984, Rives and Stoppa described their open preperitoneal, tension-free Dacron mesh repair of the musculopectineal orifice which has become the basis for our current totally extraperitoneal (TEP) and transabdominal preperitoneal (TAPP) hernia repair techniques that are performed laparoscopically or robotically [9]. Since then, numerous studies have demonstrated very low hernia recurrence rates ranging from 0–5% following laparoscopic preperitoneal herniorrhaphy, using either the TEP or TAPP approach; this has become the gold standard for minimally invasive hernia repair techniques [10] (Fig. 48.1).

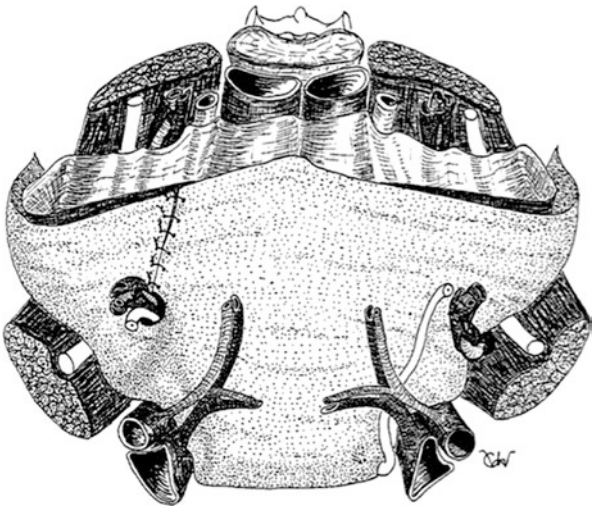

Fig. 48.1 Schematic of the Rives-Stoppa preperitoneal hernia repair using Dacron mesh [9]

Rationale for Simultaneous Hernia Repair and Prostatectomy

Both minimally invasive prostatectomy and inguinal herniorrhaphy involve dissection of the preperitoneal space and familiarity with the relevant anatomy. Moreover, laparoscopic/robotic inguinal hernia repair performed after the patient has undergone a prostatectomy is often infeasible due to significant scarring and distortion of the anatomy. With the progressive adoption of the TEP and TAPP repairs, hernia surgery performed concurrently with laparoscopic/robotic prostate or bladder surgery seemed only natural. An additional benefit of combined preperitoneal surgery is that the tissue planes for a standard open Lichtenstein hernia repair are left undisturbed and can be easily dissected should a hernia recurrence develop.

The prevalence of groin hernias is estimated to be 5–10% in the United States with a similar prevalence of groin hernias in men who are being evaluated for surgical treatment of prostate cancer [11]. However, there is an increased incidence of inguinal hernia formation after radical prostatectomy (~12–15%) which can be clinically identified within 2 years after radical retropubic prostatectomy [12, 13]. Risk factors for post-prostatectomy hernia development include prior hernia repair, constipation, smoking, advanced age, and wound infection. Regan et al. also postulated that the increase in the post-prostatectomy hernia rate was due to injury to the transversalis fascia and internal inguinal ring which normally acts like a U-shaped shutter valve. Disruption of this shutter valve mechanism at the time of radical prostatectomy results in an increased rate of indirect inguinal hernias which is corroborated by the fact that 91% of the post-prostatectomy hernias identified were of the indirect type.

Additionally, Nielsen et al. identified 33% of their male patients had incipient hernias detected intraoperatively at the time of radical prostatectomy, but only 4.4% of men were noted to have inguinal hernias on preoperative physical examination [8]. Due to the increased rate of inguinal hernias following prostatectomy and the high incidence of incipient hernias, this study advocated for concurrent herniorrhaphy at the time of prostatectomy. There were no recurrences of the hernias repaired in Nielsen's study, but 3.1% of the men went on to develop an indirect hernia after a direct hernia was repaired with mesh, emphasizing the need for appropriately sized mesh that covers both the direct and indirect hernia spaces. Moreover, Nielsen and Walsh confirmed that concurrent hernia surgery did not result in higher rates of hematoma formation, infection, fluid collection, or postoperative pain.

Recurrence After Combined Prostatectomy and Herniorrhaphy

Hernia recurrence is one of the main concerns of combined surgery, but numerous studies in the urology literature have shown that recurrence rates are comparable to staged surgery. For example, in 1989, Schlegel and Walsh performed 41 hernia repairs at the time of radical retropubic prostatectomy or radical cystoprostatectomy [14]. There were no postoperative complications attributed to the hernia repairs, and no patient had evidence of a recurrence at a mean follow-up of 28 months. However, the hernia repair performed concurrently with urologic procedures by Schlegel and

Walsh used the same non-mesh technique popularized by Nyhus. Therefore, it is likely that hernia recurrences were either clinically undetected or had a delayed presentation that would have been identified with a longer follow-up.

In 1999, Choi et al. described a large series of inguinal hernias repaired at the time of radical retropubic prostatectomy using an open Rives-Stoppa technique involving preperitoneal placement of prosthetic mesh [15] (Fig. 48.2). In this study, 70 herniorrhaphies were performed in 48 patients (16 bilateral hernias), half of which were repaired with mesh and the other half without mesh. Hernia repair was performed after pelvic lymph node dissection, but most were performed before urethrovesical anastomosis (59 hernias), and this only added 5–10 minutes to the operation. No hernia recurrences were detected in the mesh repair group, but five hernias (14%) recurred in the non-mesh group with a mean follow-up of 24 months. Furthermore, no patients developed wound infections, persistent neuralgia, or ischemia orchitis. All recurrent hernias in the non-mesh group were detected within 1 year of surgery and occurred when the repair was performed before the prostatectomy and urethrovesical anastomosis, which likely placed undue tension on the transversalis fascia.

A preperitoneal Marlex mesh-plug herniorrhaphy was also described by Drachenberg and Bell in 2002 during radical retropubic prostatectomy in 15 patients [16]. In this case series, there were no intraoperative or postoperative complications related to the hernia repair, and there were no recurrences or cases of postoperative orchalgia at a median follow-up of 18 months.

In another large series of 855 consecutive radical retropubic prostatectomies published in 2005, 49 inguinal hernias were identified and repaired simultaneously [2]. Parenteral antibiotics were administered preoperatively and until the indwelling catheter was removed, and the hernia repair was performed after the urethrovesical

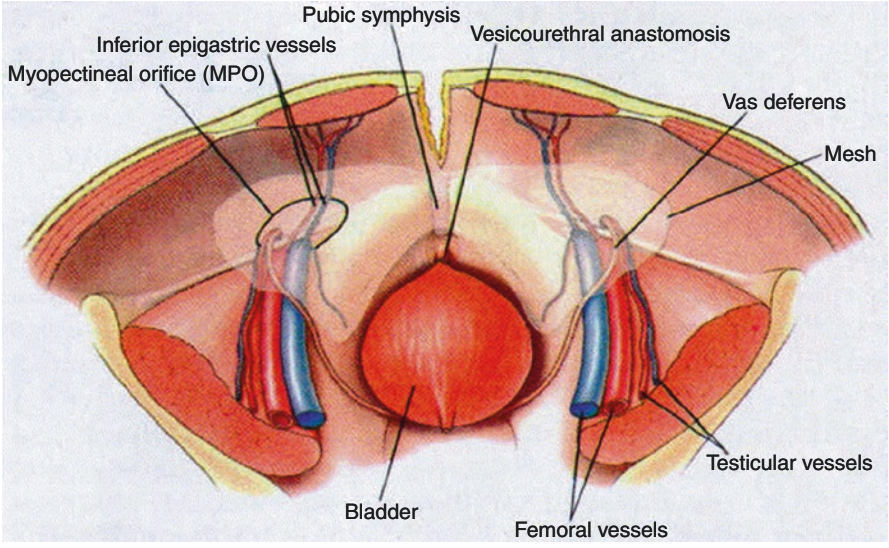

Fig. 48.2 Preperitoneal placement of mesh for bilateral hernia repair after urethrovesical anastomosis as described by Choi et al. [14]

anastomosis using mesh. The Stoppa technique using polypropylene mesh cut with a small slit for the cord structures was used, and care was taken to trim the mesh so as to avoid contact with the urethrovesical anastomosis. The hernia recurrence rate was 4% at a median of 23.1 months of follow-up. Antunes postulated that these hernia recurrences were due to inadequately sized mesh and/or mesh migration resulting from a lack of mesh fixation. Additionally, there were no complications of wound/mesh infection, pelvic fluid collections, or urinary leakage following simultaneous hernia repair with mesh.

Minimally Invasive Prostatectomy and Preperitoneal Herniorrhaphy

Multiple studies have also confirmed the feasibility and safety of laparoscopic hernia repair performed concurrently with radical prostatectomy. A German study reported ten TEP hernia repairs with mesh performed at the time of endoscopic extraperitoneal radical prostatectomy (EERPE) [17]. Mesh placement required an additional 15 minutes for a unilateral hernia and 25 minutes for bilateral hernias, and no patients required conversion to an open procedure. Patients had indwelling catheters placed for a median of 8.3 days, and there were no wound/mesh infections. Lee et al. also confirmed the success and reliability of simultaneous laparoscopic inguinal hernia repair and laparoscopic radical prostatectomy [11]. In their study, 48 hernias were repaired with nonabsorbable mesh, and there were no recurrences at a mean of 10 months follow-up. There were no cases of mesh infection despite two patients developing urine leaks which were managed with drainage and oral antibiotics.

With the advent of the daVinci® robot, the robotic TAPP repair performed concomitantly with robotic radical prostatectomy has also been studied in the literature. In 2007, Finley et al. retrospectively reviewed 49 concurrent herniorrhaphies performed at the time of transperitoneal robotic radical prostatectomy [18]. Only 50% of the patients had evidence of a hernia or weakness of the external inguinal ring on physical examination prior to surgery. Simultaneous hernia repair only added ~10 minutes to the operative time, and only 1 patient (2.0%) had a recurrence at 4 months during a median follow-up of 15.3 months. In this study, a variety of mesh repair techniques were utilized, and there were no mesh-related complications including mesh infection even in the presence of urine leakage.

Concurrent Hernia Surgery, Infection, and Postoperative Pain

The major concern of concurrent hernia repair at the time of urologic/gynecologic surgery is mesh infection. Many surgeons would advise against mesh placement in the setting of rectal perforation or urinary tract infection at the time of prostatectomy. Furthermore, a watertight vesicourethral anastomosis is recommended prior to mesh placement. However, in Schlegel's study, mesh infection was not encountered even in the presence of urinary retention or urinary tract infection when appropriate preoperative antibiotics were administered [12].

This was also confirmed by Choi et al. in which no patients developed infections related to mesh insertion in the setting of concomitant prostatectomy. Unlike patients with benign prostatic hyperplasia, patients undergoing radical retropubic prostatectomy for malignancy are unlikely to have a urinary tract infection, and therefore mesh infection is also unlikely. The authors alternatively suggest that "urine can be sterilized before the procedure with antibiotic treatment of pyuria or preoperative positive cultures. However, it is reasonable to use a modified Nyhus nonmesh technique, as described by Schlegel and Walsh, if there is a high likelihood of wound infection, that is [due to] urinary tract infection, rectal perforation, or urethrovesical anastomosis with a chance of significant urinary leakage" [15].

Ideally, mesh placement should be performed after the vesicourethral anastomosis so as to minimize contamination of the mesh and disruption of the mesh fixation. However, nonabsorbable mesh placement in the setting of clean-contaminated cases such as with bowel resection has been shown to be safe and does not result in an increase in mesh infection [19, 20].

Furthermore, simultaneous hernia repair with radical prostatectomy does not result in increased postoperative pain [21]. Gözen et al. demonstrated that concomitant hernia repair at the time of extraperitoneal laparoscopic radical prostatectomy did not result in significantly higher pain scores or opioid use and did not affect operative times or postoperative complications.

Concurrent Hernia Repair and Gynecologic Surgery

The literature regarding hernia repair at the time of obstetric/gynecologic procedures is less robust than the urologic literature. However, combined Cesarean section and groin hernia surgery has been studied, and the benefits are similar to those of concurrent hernia surgery with urologic procedures. Cesarean section and herniorrhaphy can be performed through the same incision and do not increase operative time/cost or hospital stay. Additionally, simultaneous surgery avoids the need for child care, and the separation of mother from the newborn required for a separate hernia operation and postoperative recovery.

Barber and Graber estimated that 1 of every 1000–3000 pregnancies is associated with a groin hernia with a higher incidence in multiparous women [22]. Many of these groin hernias as well as umbilical hernias become symptomatic during pregnancy due to the increased intraabdominal pressure. This can result in incarceration or strangulation during pregnancy, threatening the life of the fetus and mother.

The first reported elective, symptomatic inguinal hernia repair at the time of Cesarean section was described by Altchek and Rudick in 1987 using a preperitoneal approach [23]. In this case report, a general surgeon performed a preperitoneal inguinal hernia repair after Cesarean section and tubal ligation using the same Pfannenstiel incision. After the vesicouterine peritoneum was closed by the obstetrician, the rectus muscle was retracted laterally, and the preperitoneal space entered by incising the transversalis fascia. A large right direct inguinal hernia sac was reduced, and the hernia defect was closed using #0 Prolene sutures. An ipsilateral femoral hernia was also

identified, and the defect was closed by suturing the iliopubic tract to Cooper's ligament. There was no additional blood loss from the combined operation, and the total operating time was 65 minutes. At 6 weeks follow-up, there was no hernia recurrence.

Elective inguinal and umbilical hernia repair at the time of Cesarean section was also studied by Ochsenbein-Kölble et al. [24] In a small, retrospective comparative study, eight patients undergoing Cesarean section underwent concomitant hernia surgery (five inguinal, three umbilical), and the inguinal hernias were repaired using either the Shouldice or Stoppa technique. Although operative times were slightly longer for combined inguinal hernia repair and Cesarean section when compared with Cesarean section alone, the total operative times remained below the 90-minutes threshold associated with an increase in wound infection rates documented in the obstetric literature. Furthermore, blood loss, postoperative narcotic use, and hospital stay were similar when compared to elective Cesarean section alone. There were no wound infections or hernia recurrences at a mean of 56 months follow-up. Gabriele et al. also published on a series of 28 women who underwent combined Cesarean section and hernia repair and showed no increase in complication rates and no evidence of hernia recurrence at 1 year follow-up [25]. One consideration during combined Cesarean section and hernia repair is the size of the enlarged uterus. This often makes a preperitoneal approach more challenging and some surgeons advocate for the use of an open Lichtenstein hernia repair in this scenario using a separate incision.

Other Combined Hernia Repairs

Other described combinations of urologic/gynecologic/general surgery procedures with herniorrhaphy include inguinal hernia repair combined with orchiectomy, hydrocelectomy, ovarian cyst excision, tubal ligation, and cholecystectomy [26]. These combined procedures offer the benefit of decreased hospital stay and cost, improved cosmesis, earlier return to work, and decreased anesthetic exposure without resulting in increased complication rates or postoperative pain.

Most importantly, if the urologist or gynecologist is unfamiliar with hernia repair techniques, particularly the preperitoneal placement of mesh for inguinal hernias, the patient should be referred to a hernia specialist prior to their planned urologic/gynecologic procedure so as to schedule a combined operation. Otherwise, an intraoperative consultation by a hernia specialist should be obtained in order to properly repair the hernia thereby minimizing the risk of hernia recurrence and postoperative pain.

Technical Considerations

A preperitoneal mesh repair (i.e., Stoppa technique) at the time of combined urologic/gynecologic surgery is the recommended procedure as this avoids the need for a second incision. All patients should receive preoperative antibiotics specific for the combined urologic/gynecologic operation (e.g., second-generation cephalosporin ± metronidazole) that is re-dosed appropriately throughout the operation.

Although mesh can be safely placed in clean-contaminated cases, it is not our practice to insert mesh in the setting of a preoperative infection. For example, if the patient has a preoperative urinary tract infection at the time of prostatectomy or chorioamnionitis at the time of Cesarean section, the inguinal hernia repair with mesh should be deferred until the infection is treated.

When feasible, both patient arms should be tucked at the beginning of the operation in order to provide unobstructed laparoscopic access to the lower abdomen and pelvis. The insertion of the mesh should be performed after the urologic/gynecologic procedure in order to minimize the risk of mesh contamination and the disruption of the mesh fixation.

If a laparoscopic or robotic prostatectomy has been performed, the preperitoneal space has already been created, and the hernia repair proceeds using the transabdominal preperitoneal (TAPP) approach (see Chap. 32, MIS Techniques: Lap TAPP and rTAPP). In short, the preperitoneal space is created by incising the peritoneum from the medial umbilical ligament to the anterior superior iliac spine and bluntly dissecting preperitoneal space until Cooper's ligament is identified medially. The hernia sac is reduced using blunt dissection, and, in the case of an indirect inguinal hernia, the sac is separated from the vas deferens and cord structures. In females, the round ligament may be divided. A macroporous, polypropylene mesh is then positioned over the femoral, direct and indirect hernia spaces and anchored medially only to Cooper's ligament using absorbable tacks or sutures. The peritoneal flap is then reapproximated using absorbable tacks or a running absorbable suture.

For pregnant patients who have undergone a Cesarean section, an open preperitoneal hernia repair with mesh as described by Stoppa is recommended [9, 25]. As previously mentioned, an alternative approach is the open Lichtenstein hernia repair if the enlarged uterus precludes a preperitoneal approach.

Conclusion

In conclusion, concurrent hernia surgery with gynecologic or urologic surgery is both safe and efficacious and does not result in increased complication rates including hernia recurrence, wound/mesh infection, or postoperative pain. With the current pressures of health systems to provide value-based care, combined procedures offer a unique opportunity to optimize patient care while minimizing cost, hospital stay, and resources.

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