Horacio F. Mayer
Editor

Breast Reconstruction

Modern and Promising Surgical Techniques

Foreword by
Peter G. Cordeiro

Springer

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This book is dedicated to my amazing wife, Maria Tereza, and to our wonderful daughter and son, Verena and Ian; to the memory of my parents, Horacio and Yenny, who always encouraged me to pursuit my dreams; and to my mentors in plastic surgery, Ian T. Jackson, Dennis P. Orgill, and Ivo Pitanguy, in memoriam, who have impacted me in ways that have shaped the professional I am today.

Foreword

Breast reconstruction is a field that has evolved in many ways over the past three to four decades. Implant-based reconstruction and autologous tissue-based reconstruction, in particular, have undergone significant advances in the past 5 years. This book is a comprehensive conglomeration of all the newest approaches to breast reconstruction utilizing the entire current armamentarium of techniques. Written by many of the world's experts in breast reconstruction, each chapter covers the basic approaches to reconstruction, including basic anatomy, preoperative planning, surgical techniques, variations in techniques, and postoperative care. There is also a wide variety of case examples illustrated with photographs from actual patients.

Within the field of implant-based reconstruction, major innovations have included the use of acellular dermal matrices and synthetic meshes for both one- and two-stage reconstructions, pre-pectoral reconstruction, and revisionary surgeries. Several chapters cover the essentials as well as the more advanced uses of these techniques.

Within the area of autologous tissue-based reconstruction, the now routinely used perforator flaps, such as the deep inferior epigastric perforator flap, superficial inferior epigastric artery flap, superior gluteal artery flap, and inferior gluteal artery flap, are covered, as are many of the more recent "esoteric" flaps. These include the lateral thigh flap, transverse gracilis flap, profunda artery perforator flap, and lumbar artery flap. The latest robotic and endoscopically assisted techniques round out the autologous reconstructive options.

Finally, lipofilling has had a huge impact on breast reconstruction and has allowed the reconstructive surgeon to refine and improve both implant and autologous reconstructions. It has been utilized for reconstruction of partial mastectomy defects and for whole breast reconstruction. All these approaches utilizing fat transfer are well outlined in this book.

Dr. Mayer has done a superb job of bringing together the experiences of many of the experts in the various areas of breast reconstruction. He has structured the book to make it highly useful, relevant, and current, providing the reader with an excellent overview of the state-of-the-art approaches to breast reconstruction.

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Preface

Breast reconstruction, which is currently considered the last step in breast cancer treatment, has gained recognition as the most aesthetic of the reconstructive surgeries. Having evolved from mere coverage and reconstruction of the thoracic wall to reproducing a naturally looking breast symmetrical to the contralateral healthy breast, several techniques and surgical variations have been described. This book is an attempt to gather internationally respected experts in the field and present their innovative, modern, and promising techniques for reconstructing the breast following cancer.

Traditional techniques have been deliberately excluded, such as the submuscular implant-based reconstruction and autologous reconstructions with the pedicled TRAM flap or the classical latissimus dorsi flap with a skin island. Current techniques include the use of the pre-pectoral plane, synthetic and biologic meshes, and fat grafting alone or with the addition of intratissular or external expansion for improving graft intake. All of these methods are described in detail in the subsequent chapters.

The increasing popularity of breast-conserving surgery has also required the inclusion of a chapter solely devoted to partial breast reconstruction. For total autologous breast reconstruction, the abdominal area continues to be the donor site of choice for perforator flaps that minimize the associated morbidity. Currently, abdominal-based perforator flap breast reconstruction allows lymphatic node transfers, which significantly improve postmastectomy lymphoedema of the upper extremity.

For patients in whom the abdominal region is unsuitable, alternative flaps can be used, such as the lumbar perforator flap, the profunda artery perforator flap, the gluteal flaps, and the musculocutaneous gracilis flap among others. These flap procedures are currently popular options in specialized centers and are covered in this textbook.

Minimally invasive techniques for flap harvesting, such as the endoscopic latissimus dorsi flap and the laparoscopic omental flap, are appealing modern approaches for patients interested in minimizing donor site scarring. The robotic harvesting of the latissimus dorsi flap, which is a natural transition from the endoscopic approach, provides improved visualization and surgical dexterity. None of these scarless techniques are overlooked in this compilation. Finally, scaffold-based tissue engineering that offers a promising future for breast reconstruction surgeries without donor site morbidity is also reviewed.

This is a technique-oriented book that will be valuable for all surgeons involved in breast reconstruction. For didactic purposes, every chapter is well-structured and includes sections on anatomy, patient selection, preoperative planning, surgical techniques, postoperative care, and clinical cases. Most of the chapters also include a supplementary video of the technique to add further instructional value.

It is my sincere hope that this book may be useful for improving clinical understanding and performance of modern breast reconstruction techniques in order to deliver highly satisfactory results for our patients.

Buenos Aires, Argentina — Horacio F. Mayer, MD, FACS

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History of Breast Reconstruction

1

Horacio F. Mayer and Ignacio T. Piedra Buena

Introduction

Along centuries, the evolution in the comprehension of breast cancer biology and behavior has determined the modalities of disease treatment and molded the development and improvement of breast reconstruction techniques. Although the first report of a breast reconstruction procedure dates back to 1895, initially great controversy existed around breast reconstruction after cancer resection. Theories sustained that it could interfere with the adequate treatment of cancer which would finally lead to an illness recurrence [1].

For decades, poor attention was given to emotional and psychological status of the breast cancer patients, and treatments were mutilating in an intent to control what was considered a local affliction that could expand throughout the body and compromise patient's life. In this context there was no place for reconstructive techniques to develop. Although some isolated attempts to perform breast reconstruction were reported in the literature, these techniques did not gain acceptance up to the mid-twentieth century.

Nowadays, breast reconstruction is considered a standard of care and should be offered to every patient facing this diagnosis. It has gained recognition as the most aesthetic of the reconstructive surgeries. Having evolved from the mere coverage and restoration of the thoracic wall, to the generation of a mound that could imitate a natural breast shape when covered by clothes, to the actual possibility to reproduce a naturally looking breast with a nipple areolar complex, seamless scars, and a natural ptosis that shows symmetry to the contralateral healthy mammary gland, breast reconstruction is nowadays considered the final step of breast cancer treatment.

This chapter aims to review the evolution in the understanding of breast cancer and its impact on reconstructive technique development, briefly enumerate the main breakthroughs in both autologous and prosthetic breast reconstruction, and discuss the new challenges in the field.

The Understanding of Breast Cancer Along with Time and Treatment Evolution

The knowledge of breast cancer and advancement on its treatment (as well as society evolution) have determined the application and development of breast reconstruction techniques along history.

The first evidence of breast cancer treatment is documented in Edwin Smith Surgical Papyrus, the oldest known scientific treatise, dating from 3000 to 2500 BC. Along its text, the description of the surgical excision and cauterization of breast tumors is described [2].

Throughout ancient times, Hippocrates identified breast cancer as a frequent disease in women and proposed nonsurgical treatments. He noted women who did not face surgical excision of the tumor had longer life expectancy than those treated by surgical resection [3]. Something could probably be true considering the late time of diagnosis and the poor surgical technologies available at the time, which would make surgery lack of any impact on patient survival.

During the second century AD, in his book titled "Tumors Against Nature," with poor knowledge of cancer pathophysiology, Galen delineated the "humor theory." According to this theory, a breast tumor developed by the accumulation of a coagulum of black bile in the mammary glands. This bile was seen in dark-colored veins around the cancerous tissue which spread to surrounding structures with the shape of a crab legs [4]. Unnoticeably, Galen might have given origin to the word cancer that etymologically derives from its Greek word "Karkinos" meaning crab [5].

Long time passed till there was any medical advancement in breast cancer therapy. During the eighteenth and nineteenth centuries, with the better knowledge of human anatomy, surgeons started to promulgate aggressive surgical

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resections. Jean Louis Petit, director of the French Surgical Academy, was the first to note that enlarged lymph nodes were related to the disease. He described breast cancer as a local illness arising from lymph nodes and promoting en bloc resection of the mammary gland pectoral muscle and fascia together with lymph node resection as the preferred treatment.

It was during the last century that most of the scientific advancements in breast cancer treatment took place. A new era in breast cancer surgery came by the hand of the German pathologist Rudolph Virchow. Through his studies in morbid anatomy of patients that had suffered from breast cancer, he noticed that the illness arouses from epithelial tissue of the mammary gland and then spreads through fascial planes and lymphatic channels.

Virchow's core principles greatly impacted the American surgeon William Halsted, who after traveling through Europe and studying with Virchow's pupils described Radical Mastectomy in 1894 [1]. The procedure attempted to produce local control of the disease and prevention of its dissemination by the complete excision of the mammary gland with its cutaneous envelope, resection of pectoralis major and minor, and axillary lymph nodes up to the third level.

Breast reconstruction was off the table during this period. In his texts, Halsted sustained that any attempt to reconstruct the breast would increase the chances of cancer recurrence and dissemination [1]. Large wounds resulting from surgical excision were closed at a high tension or left to close by secondary intention causing significant morbidity to the patients.

The massive application of this surgical technique to treat breast cancer undoubtedly contributed to save a great number of patient's lives, and not surprisingly, it was proclaimed as the cure for breast cancer at that time, enjoying of great acceptance in the medical community. By late nineteenth century, most surgeons in the United States and Europe had adopted it as the main treatment of the disease, something that would stay unchanged for the next 80 years [6].

Studies performed during mid-twentieth century in London finally gave rise to critics to Halsted's principles and opened the eyes of the medical community. Breast cancers being diagnosed at the moment, where not always large and ulcerated lesions anymore, and even radical and mutilating surgeries were being performed at the time in an intent to cure the illness, a great number of patients continued to die. In 1948, Patey and Dyson described the modified radical mastectomy which, unlike classical radical mastectomy, conserves the pectoralis major and minor muscles resulting in less morbidity [7].

Posteriorly, prospective randomized controlled trials conducted by the American surgeon Bernard Fisher provided additional evidence showing that the extent of the mastectomy does not influence patient's survival. [8, 9] New conservative techniques were proved effective in the management of breast cancer, and radical mastectomy that up to the moment remained "virtually unchallenged and accepted as a standard therapy" was left aside as the primary treatment of the disease [10]. This served as a starting point for the later description of skin-sparing mastectomy and nipple-sparing mastectomy which proved to be safe alternatives to treat a selected group of patients with early-stage disease [11–13].

The advent of sentinel lymph node biopsy as a feasible option for the study of axillary nodes and staging of breast cancer represented another advance in breast surgery. Compared to axillary lymph node dissection, this is not only a less invasive and oncologically safe approach but also helps prevent lymphedema, a frequent and highly disabling complication of axillary lymph node dissection that arises in as much as 30–60% of the patients [14–16].

Moreover, with the evolution of adjuvant therapies, the Italian surgeon Umberto Veronesi proved the safety of breast-conservation surgical techniques such as quadrantectomy and lumpectomy which broke the paradigms of cancer treatment existing at the moment [17, 18]. Breast cancer surgery was now shifting from the "maximum tolerable" to the "minimum effective" treatment [19]. The association of radiotherapy of the breast volume and chemotherapy when indicated made viable a much less invasive treatment where breast anatomy was barely affected.

First Attempts of Breast Reconstruction

As the understanding of breast cancer progressed, so did the interest in breast reconstruction. Although there had been some isolated attempts of reconstruction reported at the time, these were usually nonreproducible and showed variable results. In the context of less aggressive surgical approach to treat breast cancer and with increased knowledge of the disease, interest on patient well-being through reconstruction started to gain ground.

The earliest attempts of breast reconstruction were based on autologous tissues with a variable success rate, which lead to the advancement on the development of prosthetic reconstruction. Better knowledge of the anatomy gave origin to the use of microsurgical techniques, which shade new light to autologous reconstruction providing the surgeon the ability to transfer an adequate quantity of tissue needed to restore the breast shape and volume. The posterior description of perforator flaps further decreased donor site morbidity and promoted the rise in the use of free flaps for breast reconstruction.

Current Scenario in Breast Reconstruction

Surgery always had the primary role in breast cancer treatment. At the present time, we are witnessing that surgical approaches to breast cancer show a tendency to be progressively more conservative. When comparing the rate of mastectomies to breast-conserving therapy, consisting of lumpectomy plus sentinel lymph node biopsy and adjuvant radiotherapy of the breast mound, we can appreciate a 20:80 ratio [9, 20]. This fact is due to an earlier detection of breast cancer produced by screening programs and improvement of diagnostic tools and has a great impact on reconstructive surgery since less extensive surgeries lead to decreased need for reconstruction.

In many cases, the fact that there is less tissue deficiency encouraged breast surgeons and nonplastic surgeons to intend reconstruction with the false expectation that this relatively smaller defects would be easier to restore than mastectomy resections. But the fact that adjuvant radiotherapy administration is needed after the conservative surgical resections to reduce the risk of cancer recurrence usually leads to tissue retraction or necrosis, skin depression, nipple areolar complex retraction, distorted shape, and finally breast asymmetry, resulting in unsatisfied patients.

Plastic surgeons have adapted to smaller resections performed in breast conservation therapy by using surgical techniques they are amply familiar with in order to restore an aesthetically pleasing breast. Large breasts are usually reconstructed using adjacent tissue rearrangement through a periareolar approach or by adapting reduction mammaplasty techniques. When breast volume is insufficient to comply with the tissue deficiency generated by the resection, local flaps like latissimus dorsi or TDAP (thoracodorsal artery perforator) flaps are used. Ancillary procedures such as fat grafting are frequently performed when considered necessary.

As it may be noted, ample knowledge of plastic surgery principles such as flap anatomy, dissection, and manipulation is needed to perform these procedures successfully in the context of an oncoplastic surgery.

The introduction of biological and synthetic meshes may be defined as one of the greatest advancements in breast reconstruction techniques of the twenty-first century. Its employment has shown an increasing popularity in both aesthetic and reconstructive procedures. The use of ADM (acellular dermal matrix) has allowed plastic surgeons to perform prosthetic reconstruction in a prepectoral manner with further preservation of the normal chest anatomy.

During the last century, breast reconstruction surgery has transitioned from being considered a contraindicated procedure due to the belief that it could induce breast cancer recurrence to a standard of care that should be offered to every woman facing this diagnosis, with proven benefits in quality of life and self-esteem [21–23].

Nowadays, we understand cancer, not only breast cancer, as an evolving and systemic disease where its likelihood of development and progression relies on a complex interplay between cancer cells and the local and systemic environment. Tumor cells are in continuous change, a key factor that can provide them the potential to evade the different defense barriers of the body and develop resistance against pharmacologic treatments. When this occurs satisfactorily, it finally leads to the selection of a subset of cells that will survive, grow, and finally metastasize.

We also know that breast cancer is not a unique entity but that it comprises a series of molecular subtypes. Each subtype shows a different behavior, evolution, and prognosis, and as such, each one will have its different treatment.

The main historic milestones in autologous and prosthetic breast reconstruction are summarized on Tables 1.1 and 1.2.

New Challenges and Future of the Breast Reconstruction Field

Since the recognition of breast reconstruction as an integrated part of breast cancer treatment and as a woman right, the field has been in continuous development and evolution. New challenges arise intending to perfect the existing surgical techniques and solve new problems that turn around the topic. Technological advancements played a major role in this process.

Surgical management of breast cancer-related lymphedema with supermicrosurgery has been one of the latest advancements in the field. Axillary lymph node dissection during breast cancer treatment is recognized as the most common cause of lymphedema in developed countries, turning the illness into a major public health issue [55]. On average, about 16% of the women undergoing axillary lymph node dissection and 5–7% of the women undergoing sentinel lymph node dissection as part of their treatment will develop the disease [56, 57].

Upper extremity lymphedema produces high morbidity with psychological, social, sexual, and functional impacts on patients' lives [58]. Until recent years, complete decongestive therapy which consists in manual lymph drainage and the near permanent use of compression bandages and garments, together with a few nonspecific pharmacological treatments, were the only therapeutic available for the management of this condition. These therapeutic options are time consuming, difficult to perform and have limited results which lead to a low compliance and high patient dissatisfaction [59].

Table 1.1 Autologous breast reconstruction milestones

Year	Effector	Achievement
1877	Aristide Verneuil	Breast sharing technique or pedicled contralateral breast flap [24]
1895	Vicent Czerny	First autologous breast reconstruction by the transfer of a fist-sized lipoma from the flank [25]
1896	Ignio Tanzini	First use of the latissimus dorsi myocutaneous flap for the closure of mastectomy defect [26, 27]
1906	Louis Ombrédanne	Use of pectoralis minor flap for the reconstruction of a breast mound [28]
1917	Bartlett Williard	Subcutaneous fat from the abdomen, thighs, or buttocks grafted to the breast defect [29]
1924	Louis Ombrédanne	Axilloabdominal tubed flap in multistage procedures for breast reconstruction [30]
1942	Sir Harold Gillies	Tubed pedicled flap from lower half of contralateral breast, chest, and abdomen wall in multistage procedures [31]
1956	Holdsworth	Tubular contralateral breast flap transfer in four staged procedures [32]
1975	Fujino et al.	First free flap breast reconstruction with superior gluteal artery myocutaneous flap [33]
1976	Nevin Olivari	Rediscovery of the latissimus dorsi myocutaneous flap in patients with radiation damage
1979	Robbins	Pedicled VRAM flap for breast reconstruction [34]
1979	Hans Holmstroöm	First free transverse rectus abdominis myocutaneous flap used for breast reconstruction [35]
1982	Hartrampf et al., Gandolfo	Island TRAM flap for aesthetic reconstruction of the breast mound [36, 37]
1989	Paletta et al.	Free inferior gluteal artery myocutaneous flap for breast reconstruction [38]
1989	Koshima et al.	Introduction of the perforator flap concept [39]
1994	Robert Allen et al.	First report of a perforator flap (DIEP flap) used for breast reconstruction [40]
1995	Robert Allen et al.	First report of SGAP flap used for breast reconstruction [41]
1998	Masuoka et al.	Endoscopic latissimus dorsi muscle harvesting combined with prosthetic reconstruction to avoid additional scars [42]
2002	Wei et al.	First report of ALT flap used for breast reconstruction [43]
2004	Guerra	First report of IGAP flap used for breast reconstruction [44]

Table 1.2 Prosthetic breast reconstruction milestones

Year	Effector	Achievement
Previous to 1950		Report of the use of various synthetic substances (petroleum jelly, glass balls, cartilage, paraffin, vegetable oils, rubber, polyester, Teflon, polyvinyl alcohol sponge for breast augmentation and reconstruction) [45]
1950	Edgerton	Polyvinyl alcohol sponge (Ivalon) used for breast reconstruction [46]
1961	Uchida	The use of injected silicone for breast restoration [47]
1963	Cronin and Gerow	Introduction of silicone implants for augmentation mammaplasty [48]
1965	Arion	The first reported use of a saline-filled implant [49]
1971	Snyderman and Guthrie	The first reported immediate breast reconstruction [50]
1982	Radovan	Introduction of tissue expander and two-stage breast reconstruction [51]
1984	Becker	Introduction of a single-stage expander implant breast reconstruction [52]
1988		Introduction of textured silicone implants for clinical use
2005	Breuing and Warren	The first reported use of acellular dermal matrix (ADM) in immediate implant-based breast reconstruction [53]
2007	Bindingnavele et al.	The first reported use of ADM in two-staged breast reconstruction [54]

In the last decades, reconstructive techniques of the lymphatic system by the use of supermicrosurgery have exploded. The advent of indocyanine green (ICG) lymphography and higher-resolution microscopes with near-infrared illumination systems was necessary for this development [60, 61]. Two main operative techniques were described. Lymphatic-venous anastomosis (LVA) aims to redirect the lymphatic circulation in the obstructed high-pressure lymphatic system of an extremity into the subdermal venous system by the surgical creation of lymphatico-venular shunts. On the other hand, vascularized lymph node transfer (VLNT) consists in the substitution of the previously resected axillary lymph nodes with a free flap containing functional lymph nodes from a nonrisk donor site. To date, there is still no established consensus for type or timing of surgical interventions in the management of lymphedema, but both techniques show promising results in reducing the severity of lymphedema.

Robotic-assisted plastic surgery has made appearance in the last years, inspired by its success in other surgical specialties such as urology where in some procedures it has replaced laparoscopy, its minimally invasive predecessor. Robotic latissimus dorsi muscle flap harvest has been reported in the literature for breast reconstruction in cases in which only vascularized healthy tissue, without skin, is needed as a pedicled flap for implant coverage and in

immediate-delayed breast reconstruction [62, 63]. Advantages of this technique include decreased donor site morbidity, decreased incision, and scar length with improved cosmesis.

Robotic-assisted microsurgical anastomosis has been also reported [64]. Some of the benefits in this technique are the tremor filtration, motion scaling, and better visualization due to optimized magnification and 3D vision. Further improvements to this technology could include augmented reality to the surgical field, the possibility of endoscopic microsurgical instruments enhancing the possibility to perform deep anastomosis, and even remote control of the robot.

Tissue engineering and translational stem cell research are promising fields of investigation. Stem cells are present throughout the body and have the potential to self-renew and differentiate to multiple lineage of mature cells depending on the growth factors they are exposed to. The use of these cells to restore breast volume and shape would not only conserve the benefits of autologous reconstruction but also reduce donor site morbidity to the minimum.

Although glandular tissue may be engineered through correct stimulation of stem cells, there is great concern about the potential risk of malignant transformation. Engineered adipose tissue is an excellent option as it provides volume, acts as an ideal contour defect filler, and represents a minimal danger for cancer development.

Although initial in vitro and animal model research is promising and shows similar results to fat grafting, the maximum difficulty encountered is the possibility to arrange the stem cells into a desired three-dimensional vascularized structure of an adequate size to imitate the breast. In order to achieve this goal, there should be a simultaneous development of the vascular network and the mesenchymal cell maturation into adipocytes; this would avoid problems such as fat necrosis and would increase graft survival predictability. As reconstructive surgery continues, expanding new tools continues to emerge as valuable.

Conclusions

Various lessons may be learnt by the review of breast cancer resection and reconstruction surgery evolution along the years. Our understanding of cancer cell behavior has led us to recognize it as a systemic disease. Although it arises from one organ only, the fact that its development is made possible depends on complex systemic processes not fully clarified to date.

On the other hand, evolution of therapeutic weaponry along the years has minimized the supremacy of surgery as a unique treatment for breast cancer, and the development of new and better adjunct treatments is at its brightest point. Both resection and reconstructive breast surgeries have been continuously adapted to this progress.

Ever since their origins, implant-based and autologous breast reconstructions have been in continuous development with the objective of obtaining more aesthetic results with minimal complication rate. Knowledge of all available reconstructive techniques is imperative for every plastic surgeon, although most complex techniques should be probably performed in specialized, high-volume, reference centers. New horizons on breast reconstruction surgery are exciting.

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Partial Breast Reconstruction

2

Albert Losken and Lindsey N. Urquia

Introduction

With the increasing popularity of breast-conserving therapy (BCT), we have subsequently become increasingly aware of poor cosmetic results following radiation therapy and long term. Up to 30% of women will have a residual deformity following BCT that may require surgical correction [1], which is often challenging following radiation therapy [2]. The oncoplastic approach is subsequently becoming more popular, whereby partial breast reconstruction is performed along with tumor resection, to minimize or prevent these deformities.

The term oncoplastic combines cancer surgery and reconstruction with the two main reconstructive techniques for partial breast reconstruction being volume replacement versus volume displacement. Reduction or mastopexy techniques are common displacement techniques in women with moderate- to large-sized breast. Local flaps are more common volume replacement techniques in quadrantectomy-type defects and in women with smaller breasts. The goals of the oncoplastic approach are to avoid the BCT deformity, minimize positive margins, broaden indications for BCT, avoid full mastectomy, and preserve shape [3].

Anatomy

The tumor size and location relative to the nipple position will often determine the need for the oncoplastic approach or not. Traditionally, women with large or ptotic breasts have been deemed poor candidates for breast conservation surgery, because of reduced effectiveness, increased complications, and worse cosmetic outcome. The post radiation sequela in women with *macromastia* is significantly worse. Radiation-induced fibrosis is thought to be greater in women with larger breasts, late radiation fibrosis is higher, and cosmetic results are also reduced [4]. Tumor location on the breast and relative to the nipple areolar complex as well as the size of the anticipated defect needs to be taken into consideration. Previous breast scars and prior surgery need to be taken into consideration as this may interfere with skin or nipple perfusion. Breast size essentially will often also dictate the type of oncoplastic procedure required. Smaller breasts where tumor resection will result in a deformity more often require a local flap for volume retention. This is especially true for quadrantectomy-type defects. Larger breasts are often amenable to reduction techniques to reconstruct the partial mastectomy defect. When skin needs to be resected with the tumor, the defect is more complex and often requires a flap or rearrangement of both skin and glandular tissue.

Patient Selection

Partial breast reconstruction is indicated whenever the potential for a poor cosmetic result exists, or in patients with tumors in whom a standard lumpectomy would lead to breast deformity or gross asymmetry. The patient initially needs to be a candidate for BCT, and then in a two team model, the ablative surgeon needs to recognize the patient as a candidate for reconstruction and refer appropriately. Another important indication includes concern about the potential for positive margins, or the need for *wider excision*. Additional indications include women who desire breast conservation despite potential adverse conditions, as well as older women with large ptotic breasts in whom mastectomy and reconstruction would be difficult (Table 2.1). Women with central or lower quadrant tumors have also been shown to have a worse cosmetic outcome because of *tumor location*, especially when a significant amount of skin is removed. Lower quadrant lumpectomies have been shown to reduce cosmesis by 50%

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Table 2.1 Indications and goals of oncoplastic surgery

Cosmetic reasons	Oncological reasons
High tumor-to-breast ratio (>20%)	Concern about clear margins
Tumor location – central, inferior, medial	Wide excision required
Macromastia	Poor candidate for mastectomy and reconstruction (i.e., age, breast size)
Large tumor	Patient desires BCT
Patient desires smaller breasts	
Significant ptosis or breast asymmetry	

when compared to other quadrants. A recent study of 350 patients demonstrated that the maximum volumes of tissue resected with lumpectomy without resulting in unacceptable aesthetic and functional outcomes of decreased quality of life (QOL) were 18–19% in the upper outer quadrant, 14–15% in the lower quadrant, 8–9% in the upper inner quadrant, and 9–10% in the lower inner quadrant [5].

The *tumor-to-breast ratio* is one of the most important factors when predicting the potential for a poor outcome. In general, when more than 20% of the breast is excised with partial mastectomy, the cosmetic result is likely to be unfavorable [6].

Contraindications to the immediate oncoplastic technique include those patients not candidates for breast-conserving surgery (BCS), prior history of chest wall irradiation, diffuse multicentric breast disease, and inflammatory breast cancer and those patients without sufficient breast tissue remaining to warrant BCS. If significant resection is required and little breast tissue is anticipated, then either a flap reconstruction would be required or the need for mastectomy should be discussed.

Preoperative Planning

If the oncoplastic approach is deemed necessary for the previously mentioned indications, it is important that the ablative surgeon and reconstructive surgeon communicate and understand the various perspectives. The ablative surgeon must recognize the concept of breast shape, symmetry, and aesthetics and anticipate an unfavorable result without intervention as well as the reconstructive options. It is equally important that the reconstructive surgeon does not compromise the oncologic tenets of cancer management in an attempt to improve breast shape.

Members of the surgical team examine the patient, identify her expectations and desires, and evaluate breast size, shape, and tumor characteristics. A contralateral breast procedure is often required when volume preservation techniques such as flap reconstructions are not used.

Table 2.2 Terminology of partial breast reconstruction

Partial breast reconstruction			
Timing		Technique	
Immediate	At the time of resection	Volume displacement	Volume replacement
Delayed immediate	1–2 weeks following resection (confirmation of margins status)		
Delayed	Following radiation therapy		

It is important to decide the best time to do partial breast reconstruction. When indicated, it is better to perform *immediate reconstruction* at the time of tumor resection (Table 2.2) [7, 8]. This has the benefits of operating on a nonirradiated or surgically scarred breast, resulting in lower complication rates and improved aesthetic results [2]. This is often preferred since it is only one procedure and because of the benefits of operating on a nonirradiated breast. Reduction techniques prior to radiation therapy result in a significantly lower complication rates when compared to performing reductions after completion of radiation therapy (21% vs. 57%, $p < 0.001$), and Kronowitz has shown similar results (24% vs. 50%) [9, 10]. The main concern with immediate reconstruction is the potential for positive margins. When this concern does exist, the reconstruction can be delayed until final confirmation of negative margins (*delayed-immediate reconstruction*). This then allows the benefits of reconstruction prior to radiation therapy with the luxury of clear margins. The main disadvantage is the need for a second procedure, which might be unnecessary in most cases. When a flap reconstruction is required, we prefer to confirm final margin status prior to partial breast reconstruction. There are situations where poor results are encountered years following radiation therapy, which then require correction (*delayed reconstruction*). Since the delayed approach required operating on an irradiated breast, this often has higher postoperative complications, increased need for flap reconstruction, and poorer aesthetic outcomes [7, 8].

Oncoplastic resections tend to be more generous and have been shown to offer a margin advantage compared to lumpectomy alone. Oncoplastic resections in some series have been over 200 grams compared to institutional norms of about 40–50 grams using lumpectomy alone. Losken et al. demonstrated a lower positive margin rate (24.1% vs. 41.0%, $p = 0.01$), fewer surgical reexcisions (12.0% vs. 25.9%, $p = 0.01$), and wider margins from the tumor edge when oncoplastic surgery was performed (4.3 vs. 2.8 mm, $p = 0.01$) [11]. A recent meta-analysis also found a reduction in the positive margin rate for both invasive and in situ disease from 21% with BCT alone to 12% in oncoplastic excisions [12]. Despite the proven advantage over BCT alone, margin

concern is one of the main reasons why partial reconstruction is occasionally delayed. Rather than delaying reconstruction in every patient, we try to minimize positive margins through patient selection and cavity sampling. Characteristics that might make it more difficult to obtain negative margins include younger patients, ductal carcinoma in situ (DCIS), infiltrating lobular carcinoma, prior chemotherapy, or multicentric disease. Preoperative magnetic resonance imaging (MRI), ultrasonography, or mammography is helpful in determining the extent of the disease to guide the necessary resection, although the specificity of MRI has yet to be clearly determined. Another way to minimize the potential for positive margins and the need for reexcision is through intraoperative cavity sampling. Sending separate cavity margins for pathologic examination at the time of lumpectomy significantly reduces the need for reexcision. Cao and colleagues reported that cavity sampling final margin status was negative in 60% of their patients who had positive margins on initial resection [13]. Potential factors contributing to a false-positive margin status included seepage of ink into crevices of the specimen, promoted by excessive inking; tumor friability, promoting displacement of tumor into ink; manipulation of specimens for radiographs; and retraction artifact. Additional intraoperative confirmatory procedures include radiography of the specimen and intraoperative frozen sections for invasive cancer (Fig. 2.1).

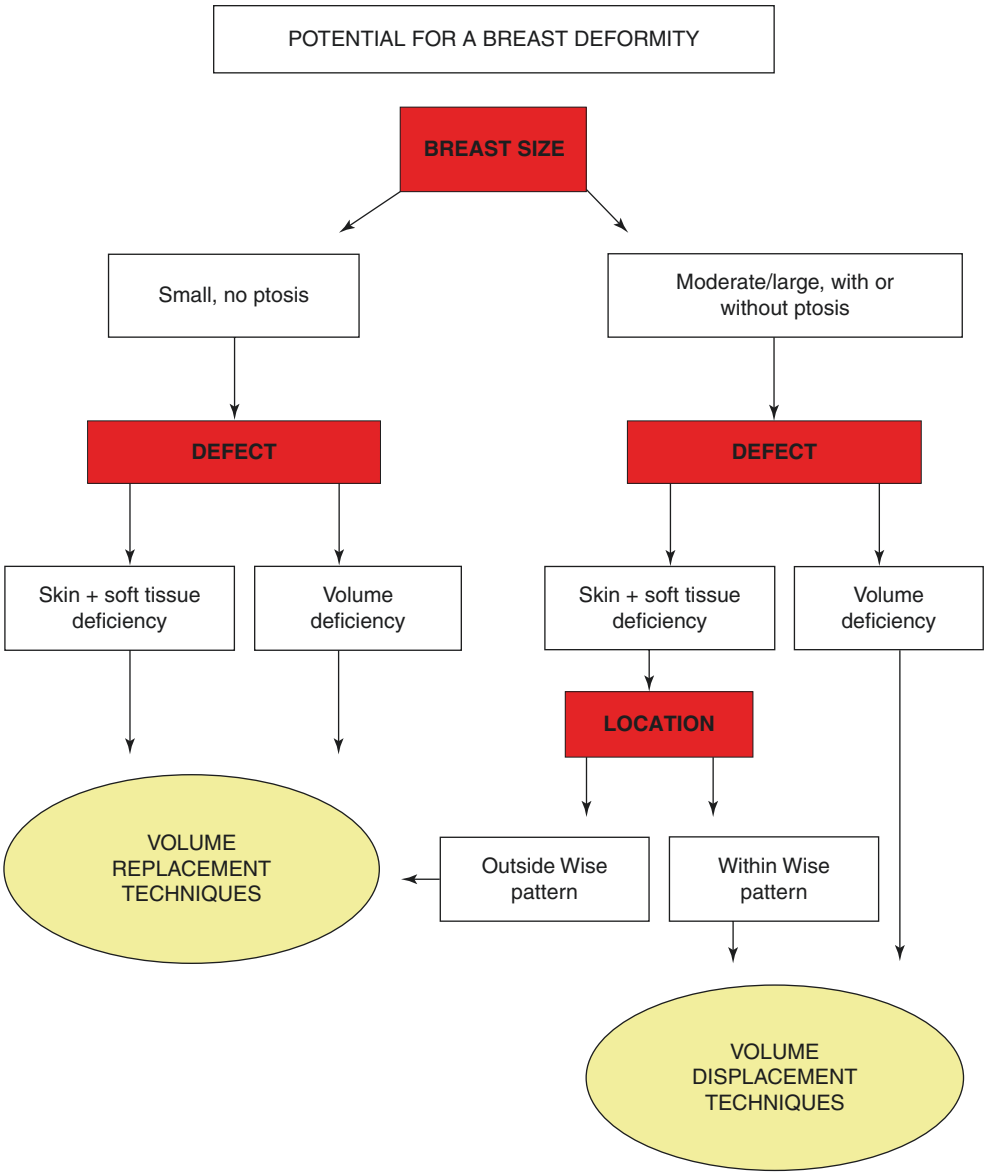


Fig. 2.1 An algorithm demonstrating oncoplastic technique based on breast size, defect size, and location

Surgical Technique

The decision as to which procedure is more appropriate is multifactorial; however, it is ultimately determined by breast size, tumor size, tumor location (Table 2.3). Other factors are also important including patient risks and desires, tumor biology, and surgeon comfort level with the various techniques. Being familiar with the various reconstructive tools will allow reconstruction of almost any partial mastectomy defect.

Volume Displacement Techniques

The breast reshaping procedures all essentially rely on advancement, rotation, or transposition of a large area of breast to fill a small- or moderate-sized defect. This absorbs the volume loss over a larger area. In its simplest form, it entails mobilizing the breast plate from the area immediately around the defect in a breast flap advancement technique. The dissection is over the pectoralis muscle and essentially involves a full-thickness segment of breast fibroglandular tissue advanced to fill the dead space. These procedures are indicated in the type 1 deformities for small- to medium-sized breasts where the resection does not lead to any significant volume alteration that might cause breast asymmetry. A contralateral symmetry procedure is typically not required.

Perhaps, the most popular and versatile breast reshaping options are the mastopexy or reduction techniques. The ideal patient is one where the tumor can be excised within the expected breast reduction specimen, in moderate to large or ptotic breasts where sufficient breast parenchyma remains following resection to reshape the mound (type 2b defects). Any moderate to large breast can be reconstructed using these techniques unless a skin deformity exists beyond the standard Wise pattern (type 2a defect).

In women with large or ptotic breasts, the numerous reduction patterns or pedicle designs will invariably allow remodeling of a defect in any location and any size, as long as sufficient breast tissue and skin are available. Preoperative markings are important, and a decision is made on pedicle design depending on tumor location. Typically, if the pedicle points to or can be rotated into the defect, it can be used. The Wise pattern markings are more versatile allowing tumor resection in any breast quadrant. Once the resection is performed, the cavity is inspected paying attention to the defect location in relation to the nipple, as well as the remaining breast tissue. The reconstructive goals include (1) preservation of nipple viability, (2) reshaping of breast mound, and (3) closure of dead space. The contralateral procedure is performed using a similar technique. The ipsilateral side is typically kept about 10% larger to allow for radiation fibrosis.

When the partial defect cannot be filled with the standard breast reduction techniques in women with smaller ptotic breasts or more peripheral defects, then autoaugmentation techniques can be utilized. These include either extending the primary nipple pedicle to fill the defect or creating a secondary independent pedicle to fill the defect. These techniques have been shown to further broaden the indications for the oncoplastic technique without increasing complications.

Table 2.3 Partial mastectomy reconstruction techniques

Volume displacement techniques	Volume replacement techniques
"Parenchymal remodeling, volume shrinkage"	"Adjacent or distant tissue transfer, volume preserving"
Primary closure	Implant augmentation – rare
Mirror biopsy/excision Batwing mastopexy	Local flaps Faciocutaneous Perforator flaps Latissimus dorsi MC flap
Breast flap advancement technique	Distant flaps
Nipple areolar centralization	
Reduction and mastopexy techniques	

Volume Replacement Techniques

Women with large tumor-to-breast ratios and women with small to moderate breasts who have insufficient residual breast tissue for rearrangement require partial reconstruction using non-breast local or distant flaps. Volume is preserved, and a contralateral procedure is often not required.

Small lateral defects (less than 10% of breast size) can be closed with local fasciocutaneous flaps. Clough described using the subaxillary area as a transposition flap [14], and Munhoz has more recently demonstrated how the lateral thoracodorsal flap (LTDF) is ideal for lateral defects [15]. The latissimus dorsi musculocutaneous flap is a common local option for lateral, central, and even medial defects [16]. It has excellent blood supply and provides both muscle for filling of glandular defects and skin for cutaneous deficiencies. A deinnervated and radiated LD will undergo postoperative atrophy. To compensate for the expected loss in muscle volume, a flap much larger than the defect should be harvested, possibly preserving sub-Scarpa fat on the muscle. Hamdi introduced the concept of pedicled perforator flaps for partial breast reconstruction [17, 18]. A similar skin island to the classical LD musculocutaneous flap can be raised as a perforator flap from either the thoracodorsal or intercostal vessels. By sparing the underlying muscles, the donor site morbidity is less, with fewer seroma formation [17]. Harvesting of pedicled perforator flaps is feasible when the appropriate perforator is chosen, and the dissection is

performed meticulously. The technique becomes more predictable if the surgical algorithm previously outlined is used to select the most appropriate type of flap for the needs of the defect. *The thoracodorsal artery perforator (TDAP) flap* can easily reach defects in the lateral, superolateral, and central regions of the breast. If no suitable perforators are found, the flap is easily converted to a muscle sparing-TDAP or muscle sparing-LD flap. The *lateral intercostal artery perforator (LICAP) flap* is another alternative to the TDAP flap for lateral and inferior breast defects. The lateral intercostal artery perforators are found at 2.7–3.5 cm from the anterior border of the LD muscle. The *anterior intercostal artery perforator (AICAP) flap* is similar to the random-designed thoracoepigastric skin flap; the skin paddle can be harvested as an AICAP flap [18]. The AICAP is based on perforators originating from the intercostal vessels through the rectus abdominis or the external oblique muscles. Since it has a short pedicle, the AICAP flap is suitable to cover close defects that extend over the inferior or medial quadrants of the breast. The *superior epigastric artery perforator (SEAP) flap* is based on perforators arising from the superior epigastric artery or its superficial branch. It has the same indications as the AICAP flap; however, the SEAP flap has longer pedicled and, therefore, it can cover more remote defect in the breast. Large medial defects are more difficult to reconstruct. The superficial inferior epigastric artery free flap has been described for this location [19].

Postoperative Care

The patient is managed postoperatively by both the ablative and reconstructive surgeons. This involves management of complication, positive margins, recurrence, and the final aesthetic result.

If the final pathology report reveals positive margins and additional parenchyma has not been removed from around the tumor site, as is the case in remodeling mammaplasty techniques, there are generally two options: completion mastectomy or reexcision. When margins are involved following oncoplastic techniques with generous excisions, the extent of the disease will often dictate that a mastectomy is the most appropriate treatment option rather than reexcision. The downside to completion mastectomy and reconstruction is minimal in the volume displacement techniques, since the contralateral symmetry procedure has already been performed, and the typical skin removal pattern has also been completed, facilitating easier reconstruction of a smaller breast. However, if a decision is made by the oncology team to perform a reexcision, then this must be performed by the breast surgeon in conjunction with the reconstructive surgeon, since the cavity architecture might have been altered and the reconstructive surgeon was the last one there. Intraoperative cavity clipping with Ligaclips or cavity filling devices will assist with reexcision and guide postoperative surveillance or the need for a radiation boost.

Complications often involve wound healing concerns and are typically managed by the reconstructive surgeon. It is important that complications resulting from oncoplastic techniques do not interfere with the initiation of adjuvant therapy. Careful selection of surgical technique, appropriate patient selection, and meticulous execution will minimize the incidence of postoperative complications. Additional procedures will invariably increase complications; however, most of these are minor. A recent meta-analysis compared 1773 oncoplastic reductions and 1392 oncoplastic flap reconstructions and 5494 BCT-alone patients. The average complication rate in the oncoplastic reduction group was 16%, and in the oncoplastic flap, reconstruction group was 14%; however, there was no delay in the initiation of adjuvant therapy [20]. Early complication rates were not routinely reported in the BCT-alone group, but the complications were on average 25.9% (n = 201/775) compared to 15.5% (386/2482) in the oncoplastic group. Some larger series with volume displacement techniques report complications such as delayed wound healing (3–15%), fat necrosis (3–10%), and infection (1–5%) [21]. Overall complications following volume replacement techniques are slightly higher (2–77%), and this is likely due to the addition of donor site complications and potential flap loss issues [16, 17]. Munhoz recently reported a 33% complication rate using the latissimus dorsi technique for partial mastectomy defects, 65% of which was related to the donor site [16]. The most common complication was dorsal seroma, which occurred in 20% of their patients (50% of their complications).

While complications do exist, they are often managed with conservative treatment and initiation of adjuvant treatment should not be delayed [22]. In a recent oncoplastic reduction series of 353 patients, we identified a complication rate of 16% [21]. These were often minor, and less than 5% required a reoperation. Oncoplastic surgery in one study did not delay the time to delivery of adjuvant chemotherapy (29 days) compared to lumpectomy alone (29.5 days) and mastectomy with immediate reconstruction (31 days) [23]. Radiation therapy has been shown to be delayed in patients with complications further stressing the importance of minimizing them as much as possible.

When it comes to patient-reported outcomes and satisfaction, the oncoplastic reduction technique has been shown to fair favorable compared to BCT alone and compared to mastectomy and reconstruction for women with macromastia [24]. While we often at best wish to preserve satisfaction and quality of life when performing breast reconstruction, this approach does often show improvement. Likely because of the benefit to reduction mammoplasty, these patients in our series reported improvement in body acceptance, feelings of

attractiveness, satisfaction with how their breasts looked unclothed, and satisfaction with sex life. Their improvement in emotional health is likely due to the breast cancer being managed and behind them. Veiga et al. showed a positive impact on quality of life and self-esteem when comparing patients who had oncoplastic surgery compared to BCT alone [25]. Hart et al. have similarly shown that oncoplastic reduction patients reported an unexpected increase in their ability to wear sexually provocative clothing and in their partners' perception of them as womanly [24]. Others have similarly found that self-reported body image scores and patient-reported outcome measures significantly favored oncoplastic surgery to mastectomy with immediate reconstruction (implant or flap) [26].

Massa et al. recently reported an aesthetic comparison between BCT alone, oncoplastic surgery and regular postoperative irradiation therapy, and oncoplastic surgery with intraoperative irradiation [27]. They found that the all groups gave good oncological and aesthetic results with there being some superiority in the intraoperative radiotherapy (IORT) group. However, compared to other cancer operations, oncoplastic surgery is relatively young, and additional future randomized controlled trials with regard to locoregional recurrence rates, role for adjuvant radiation in certain early stage cancers, etc., in addition to patient-centered outcome data with regard to aesthetic self-perceptions are needed.

The benefits oncoplastic procedures might have on recurrence are all related to generous resection and wider margins. Longer-term follow-up studies have shown local recurrence to be 8.7% at 10 years, and the overall survival rate was 82.2% [28], and another study of 545 patients had a 6.7 recurrence rate at an average follow-up of 7 years with a comparable survival at 91% compared to BCT alone [29, 30]. Whether wider margins truly translate into lower recurrence remains to be seen and has not been demonstrated in the oncoplastic data [28]. In an effort to evaluate the oncological safety of oncoplastic surgery, a recent comparison in 980 patients demonstrated similar 5-year recurrence rates with 3.4% in the lumpectomy group, 2% in the oncoplastic group, and 2.6% in the mastectomy and immediate reconstruction group [31]. The groups all had similar histological variables. Another comparison in 801 patients between oncoplastic reduction and lumpectomy demonstrated longer operating time and higher tissue necrosis in the oncoplastic reduction group, with no difference in re-excision or mastectomy rate [32]. They did report improvement in patient satisfaction and QOL in the reduction group with equivalent overall 10-year survival, hence higher local recurrence rates in that group. The oncoplastic approach has also found to be safe compared to mastectomy in tumors larger than 2 cm with similar overall survival rates (87.3% vs. 87.1% at 10 years) [29].

Clinical Cases

Case 1

A 50-year-old female presented with a left lower pole breast cancer. She underwent a generous 120 gram tumor resection including breast tissue and skin. When the defect is below the Wise pattern markings and a reduction is planned, a generous resection is possible. If additional resection is performed by the reconstructive surgeon during the reduction, it is important to mark the specimen appropriately since this would potentially be a new margin if the original margins are positive. A lower pole defect can be reconstructed using any oncoplastic reduction technique except an inferior pedicle. A superomedial pedicle was chosen because it is a relatively short pedicle, and a total of 320 grams was resected on the left including the lumpectomy specimen. The cavity was marked with clips prior to closure. A superomedial reduction was performed on the contralateral side with 360 grams removed. It is common to over resect the contralateral side in anticipation of irradiation fibrosis with time. Her result is shown 5 months postoperatively and prior to irradiation therapy (Fig. 2.2).

Case 2

A 41-year-old female with breast ptosis and moderate volume presented with a 1.5 cm infiltrating ductal carcinoma in the upper out quadrant IDC. A decision was made to undergo breast conservation therapy, and given the size of the anticipated defect, she was referred for reconstruction of the partial defect given concern for a poor cosmetic result. A preoperative decision was made to perform a tissue rearrangement technique given sufficient anticipated breast volume following resection. She underwent wire localization and partial mastectomy removing a 100 gram specimen from the upper outer quadrant. The access incision for the tumor resection was within the proposed mastopexy reduction markings. After examining the defect, it was felt that a standard inferior or central mound reduction or mastopexy would not get enough tissue into the upper outer defect. A decision was made to perform a vertical oncoplastic mastopexy-type procedure using an extended autoaugmentation technique for the defect. A superomedial pedicle was deepithelialized to keep the nipple alive, and the lower pole tissue was also deepithelialized down to the IMF in between the vertical markings. The medial and lateral pillars were created, and the extended pedicle was lifted off the chest wall only enough to allow sufficient rotation of the pedicle. The nipple was then rotated into the proposed nipple location, and the

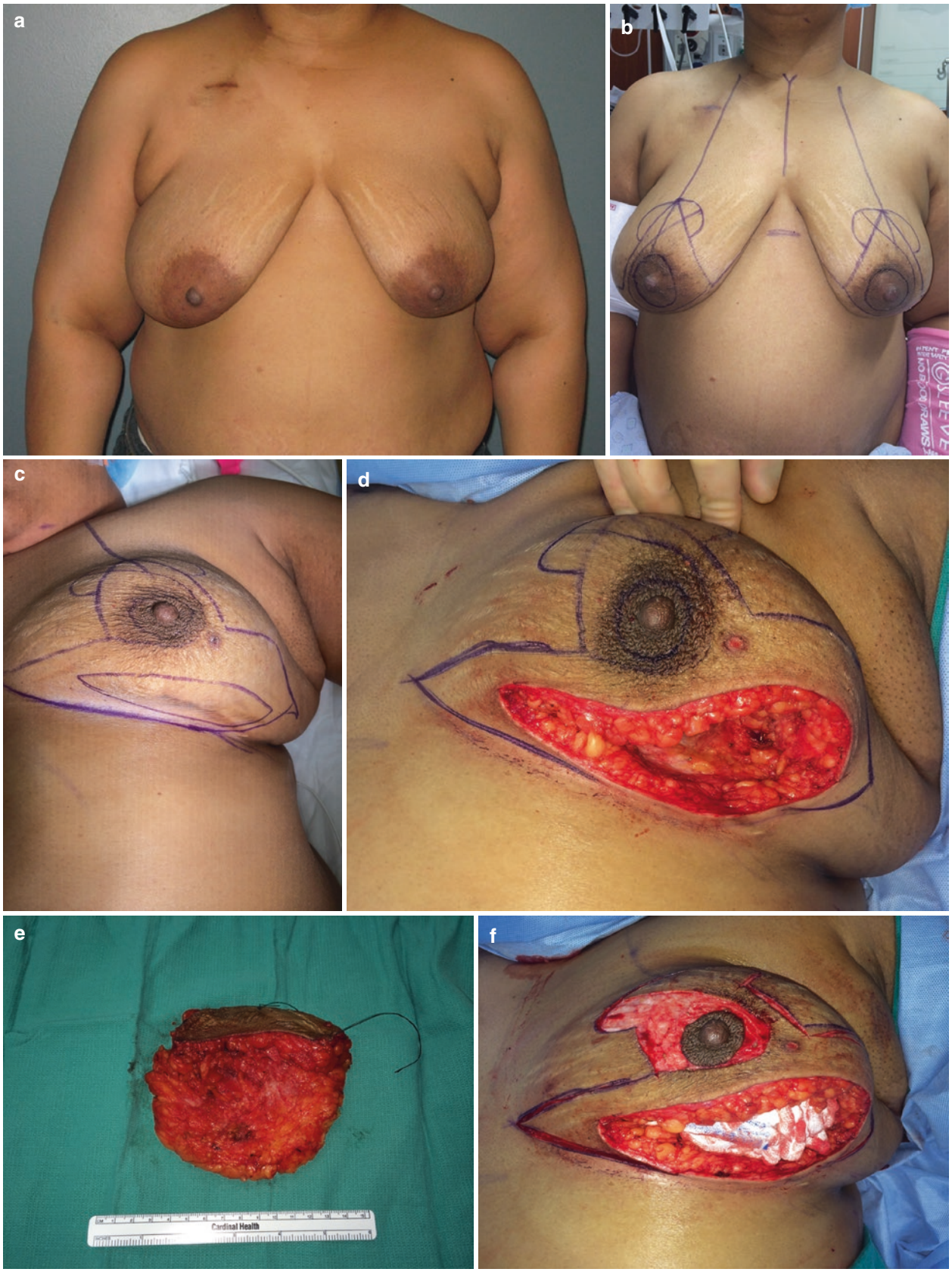


Fig. 2.2 (**a**–**c**) Preoperative view with Wise pattern markings and proposed tumor excision with skin and breast tissue. (**d**, **e**) Post-lumpectomy defect in the lower pole with representative tumor excision. (**f**) Creation of the superomedial pedicle. (**g**) Resection of the additional lower pole tissue. (**h**, **i**) On table result and postoperative view

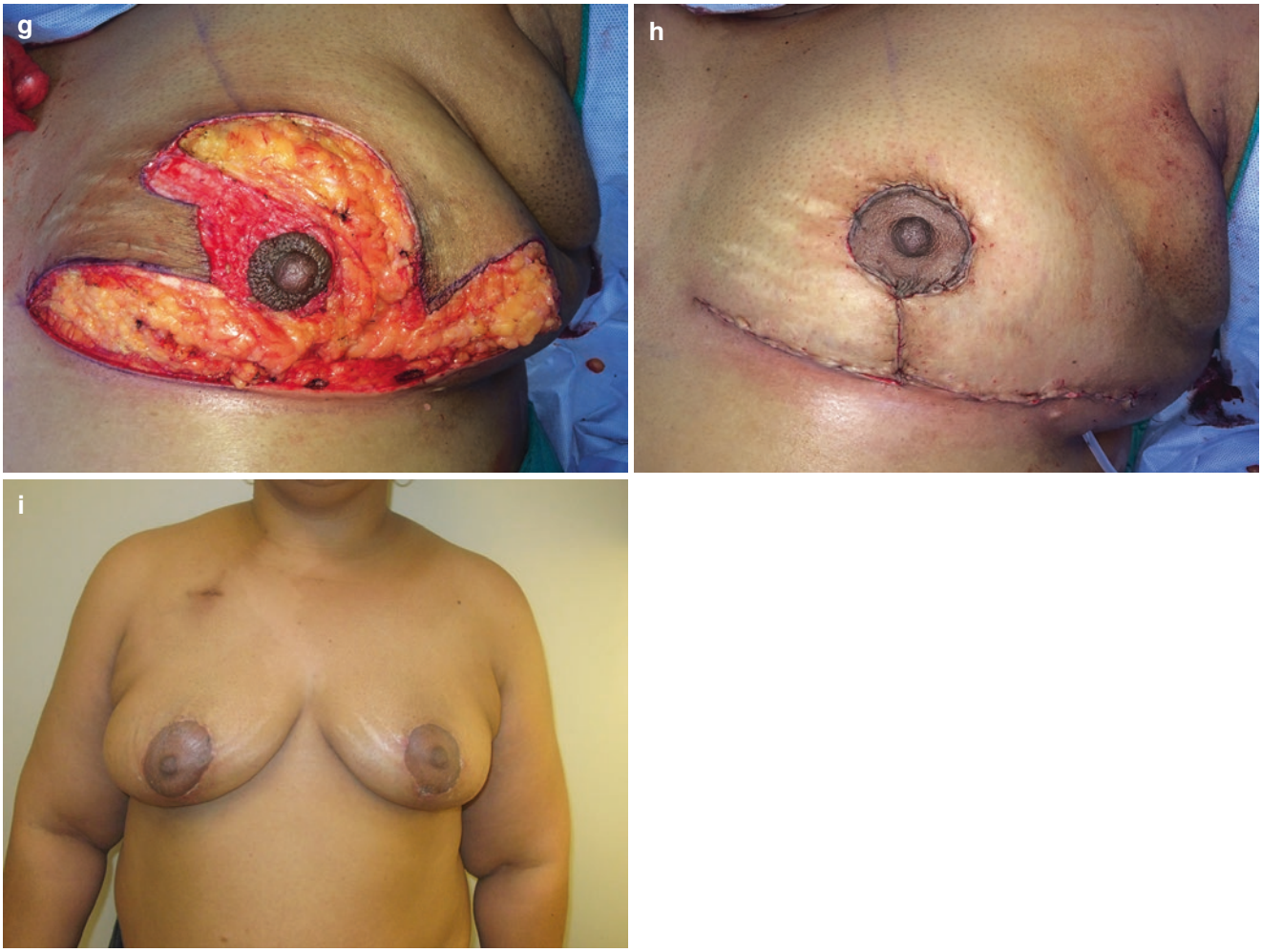


Fig. 2.2 (continued)

extended pedicle was rotated to fill the defect. This provided vascularized tissue into the tumor cavity. No additional tissue was removed. The medial and lateral pillars were plicated and the breast was shaped and closed in a mastopexy fashion. A contralateral reduction of 105 grams was performed using a superomedial pedicle and removing the lower pole tissue. She has decent shape and symmetry 1.5 years following completion of radiation therapy (Fig. 2.3).

Case 3

A 40-year-old female presented with moderate size breasts and ptosis who desires breast preservation. She has an area of DCIS medially on the right. Given oncologic concerns, a decision was made to delay reconstruction until confirmation of clear margins. Her medial defect is demonstrated following tumor resection. Two weeks later once confirmation of negative margins, a decision to proceed with the reconstruction was made. There was still some persistent swelling and bruising. We performed a superolateral pedicle extending the pedicle down to the chest wall by deepithelializing the dermatoglandular tissue and then creating medial and lateral pillars. This extended pedicle was then rotated into the medial defect, and the medial and lateral pillars were plicated. A contralateral symmetry procedure was performed removing additional tissue from that side to preserve long-term symmetry. Her result is shown following radiation therapy with breast edema and size discrepancy. She is then shown 1 year later with good size and symmetry (Fig. 2.4).

Case 4

A 44-year-old patient presented with a T2 tumor in the left breast. She will require a quadrantectomy-type resection and has small non-ptotic breasts. An immediate breast reconstruction was planned because of the expected unaesthetic result after tumor resection in such small size breast. A decision was made to use a pedicled thoracodorsal artery perforator (TDAP) flap to minimize donor site morbidity. Perforators were mapped preoperatively by unidirectional Doppler, and the skin island was drawn large enough to be rotated on the pedicle to fill the upper lateral quadrant defect without too much tension. The TDAP flap is raised on a single perforator and tunneled into the defect. The inset is under no tension in anticipation of radiation therapy. She is shown 1 year after completion of irradiation therapy with preservation of the lateral breast contour and nipple areolar position (case courtesy Moustapha Hambdi MD; Fig. 2.5).

Case 5

A 51-year-old female presented with a recent diagnosis of right-sided breast cancer. Given her ptotic breasts and the size of her proposed lumpectomy, a decision was made to perform an oncoplastic reduction using the Wise pattern and superomedial technique. She had a 63 gram resection from the lateral right breast and an additional 191 gram

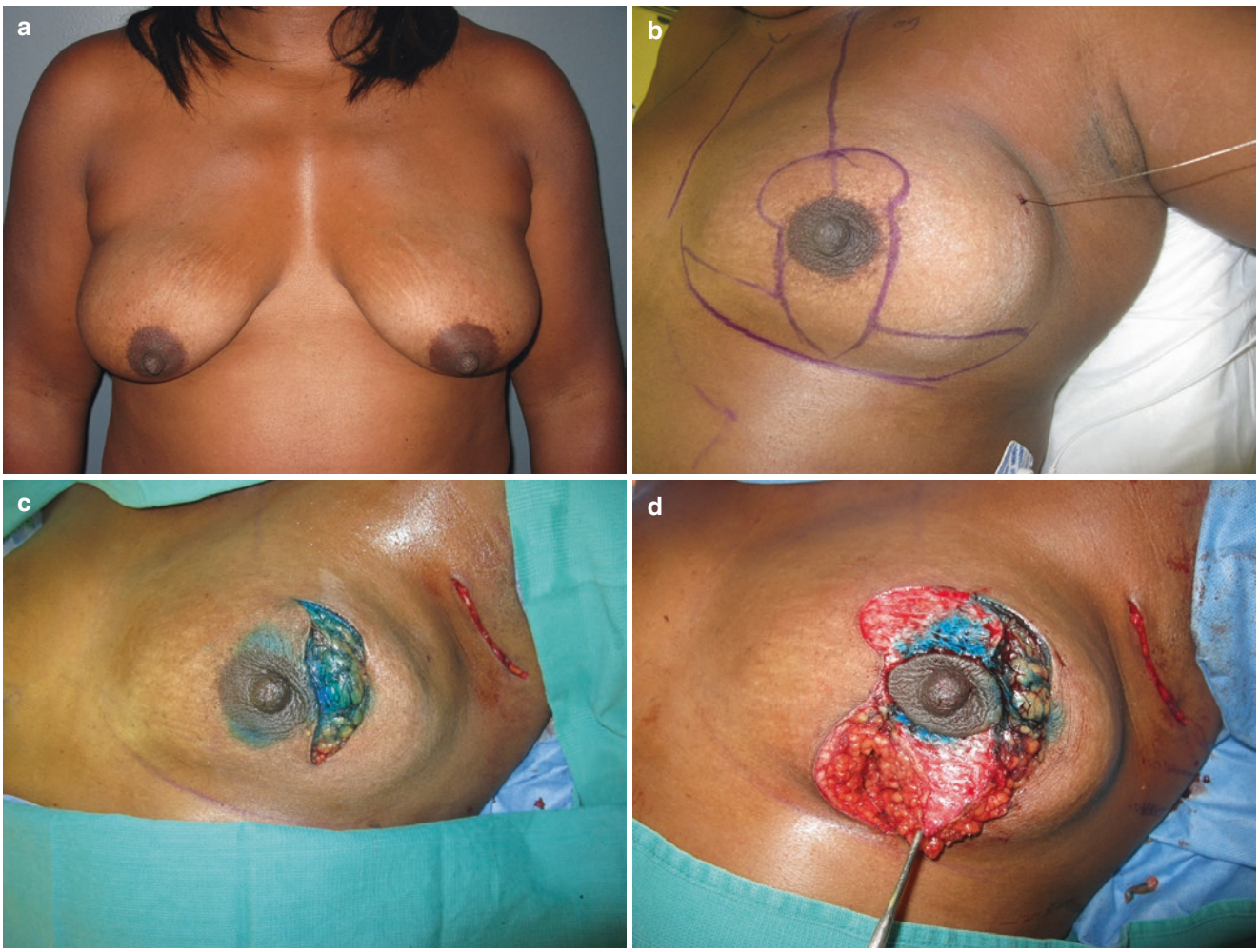


Fig. 2.3 (**a**, **b**) Preoperative view with Wise pattern markings and wire in upper outer quadrant. (**c**) Tumor defect. (**d**) Vertical incision with extended superomedial pedicle. (**e**) Autoaugmentation pedicle rotated into defect. (**f**) On table result. (**g**) 1.5 years following radiation therapy

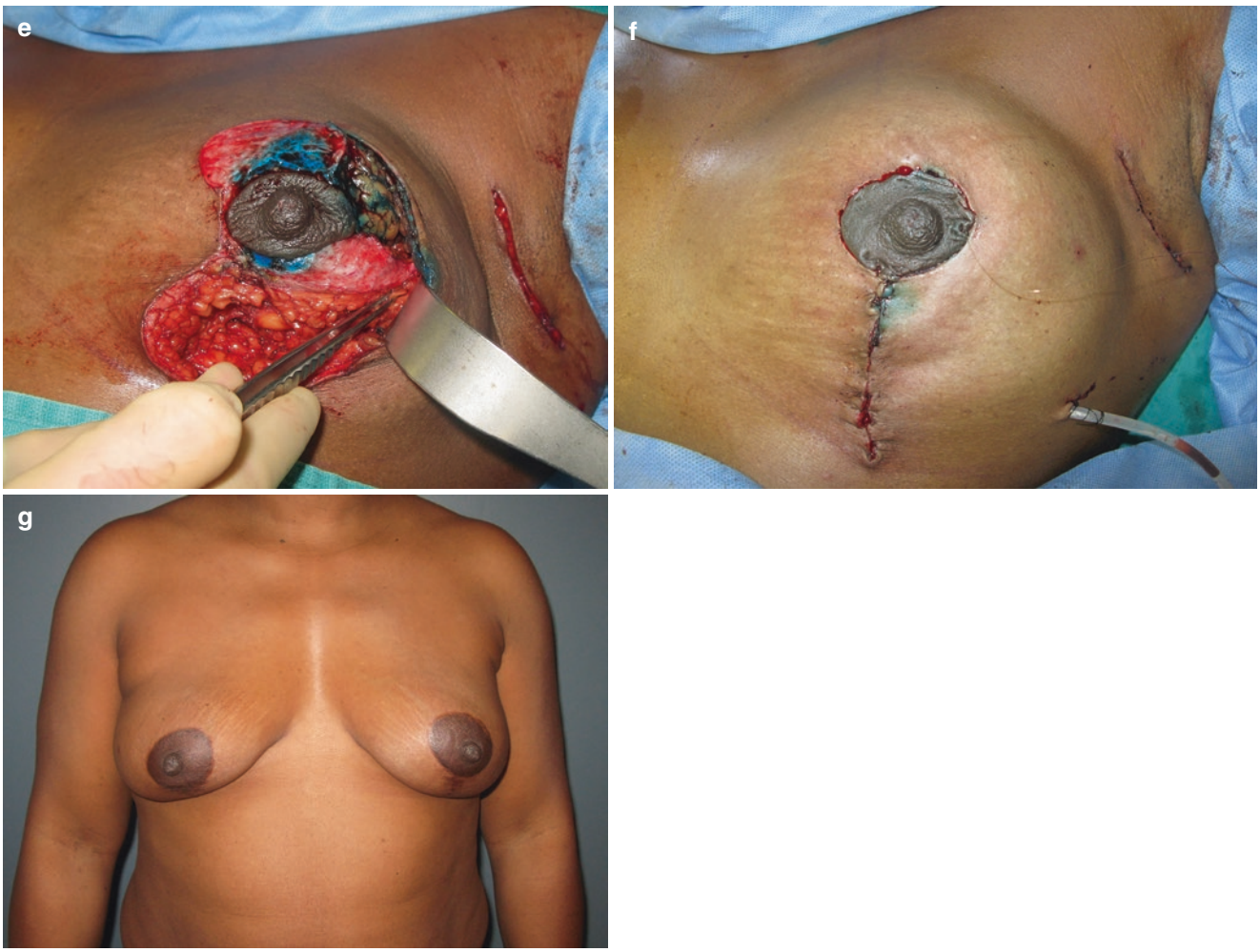


Fig. 2.3 (continued)

reduction. Her resection was performed through the lateral Wise marking. The left breast was similarly reduced with a superomedial pedicle technique removing 222 grams. Her result is shown 1.5 years following completion of right breast irradiation therapy with good shape and symmetry (Fig. 2.6).

Case 6

A 68-year-old patient with large ptotic breasts has a left medial breast cancer. This is a very cosmetically sensitive area, and a large 63 gram resection was performed. A decision was made to perform an inferior pedicle for nipple transfer. This alone would not have filled the medial defect. The entire lower pole was deepithelialized as was the tissue above the nipple for autoaugmentation. An additional 295 grams was removed on that side. The medial portion was back cut and rotated to fill the defect. It was sutured to the upper portion of the pedicle to provide volume. An additional 295 grams was removed on that side. The left side was purposely kept larger intraoperatively with 362 grams removed. She is shown 1 year postoperatively with good symmetry (Fig. 2.7).

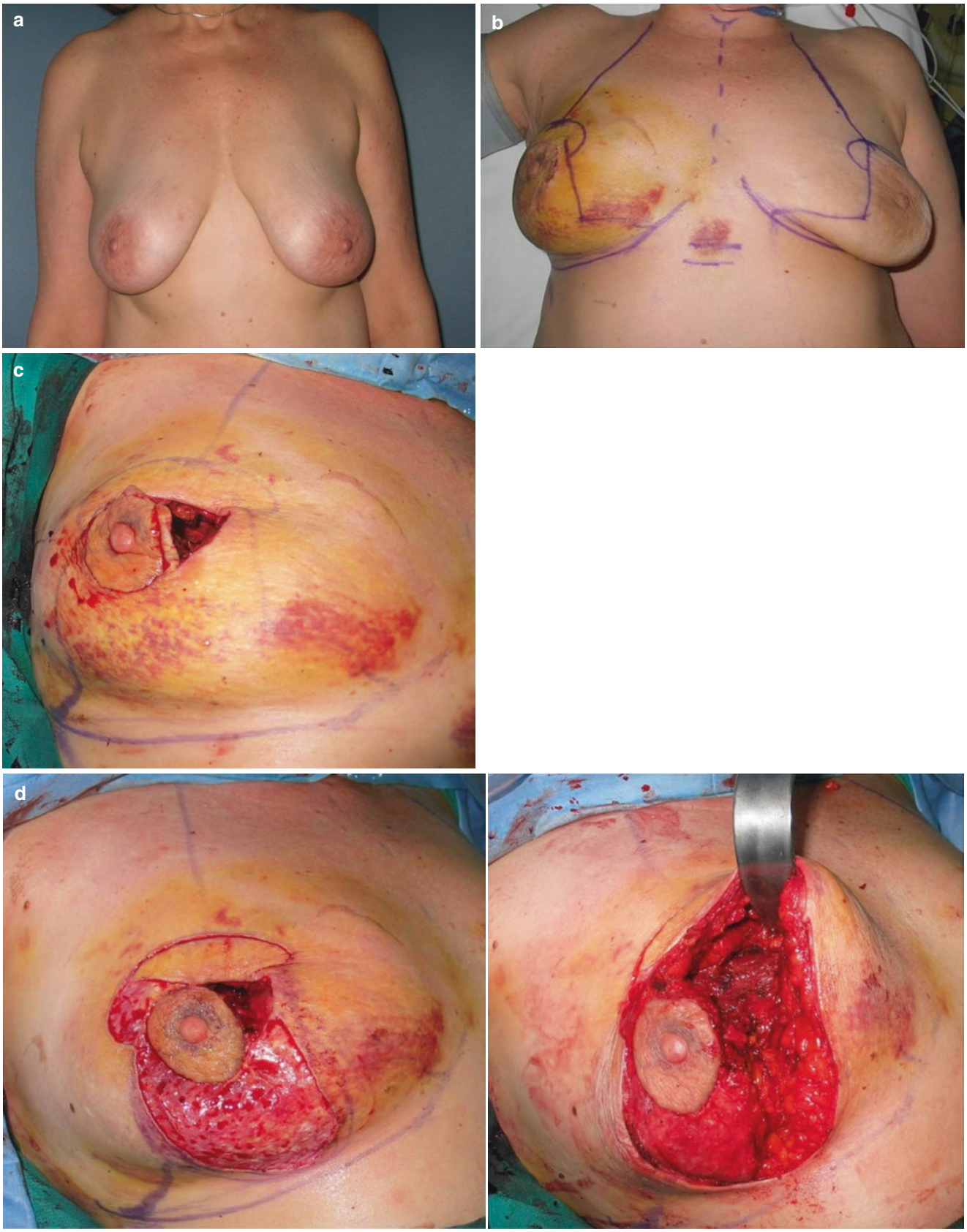
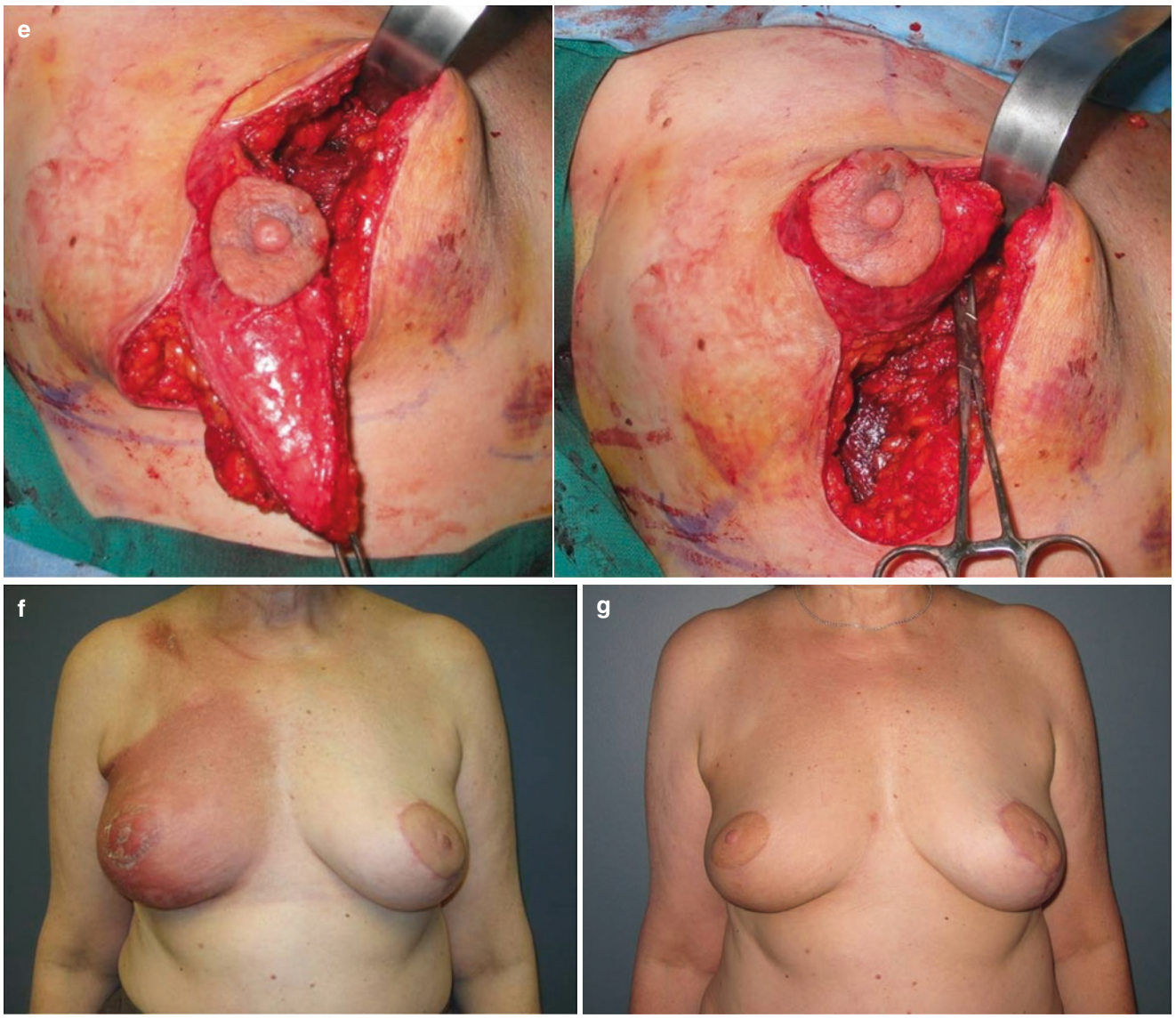


Fig. 2.4 (**a**) Preop view. (**b**, **c**) Post-lumpectomy view with defect shown. (**d**, **e**) Created and rotated superolateral extended autoaugmentation pedicle. (**f**, **g**) Early postradiation therapy and long-term result



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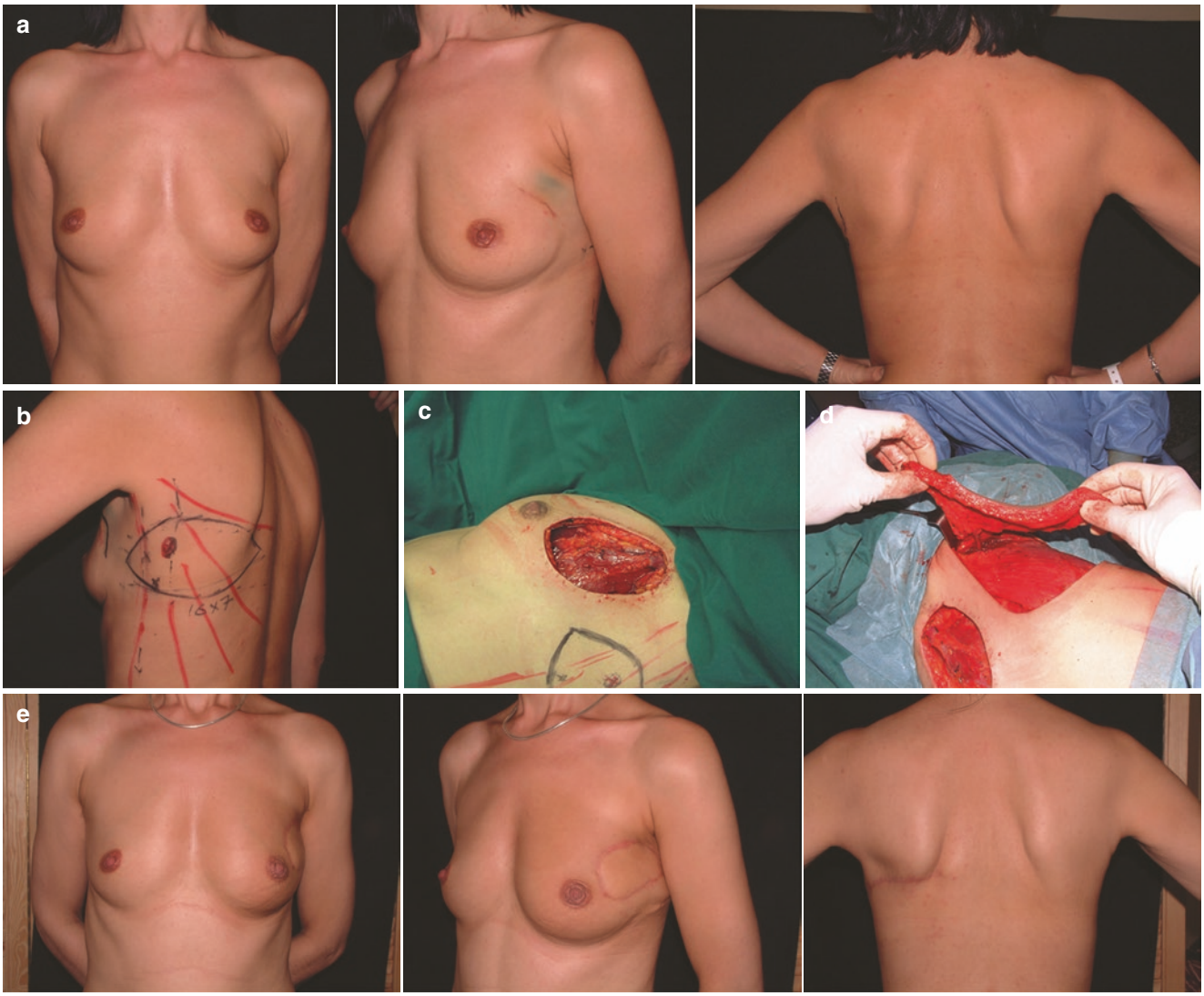

Fig. 2.5 (**a**) Preop view. (**b**) Preoperative markings of the TDAP flap. (**c**, **d**) Tumor defect with raised TDAP flap. (**e**) Final result with preserved contour and shape

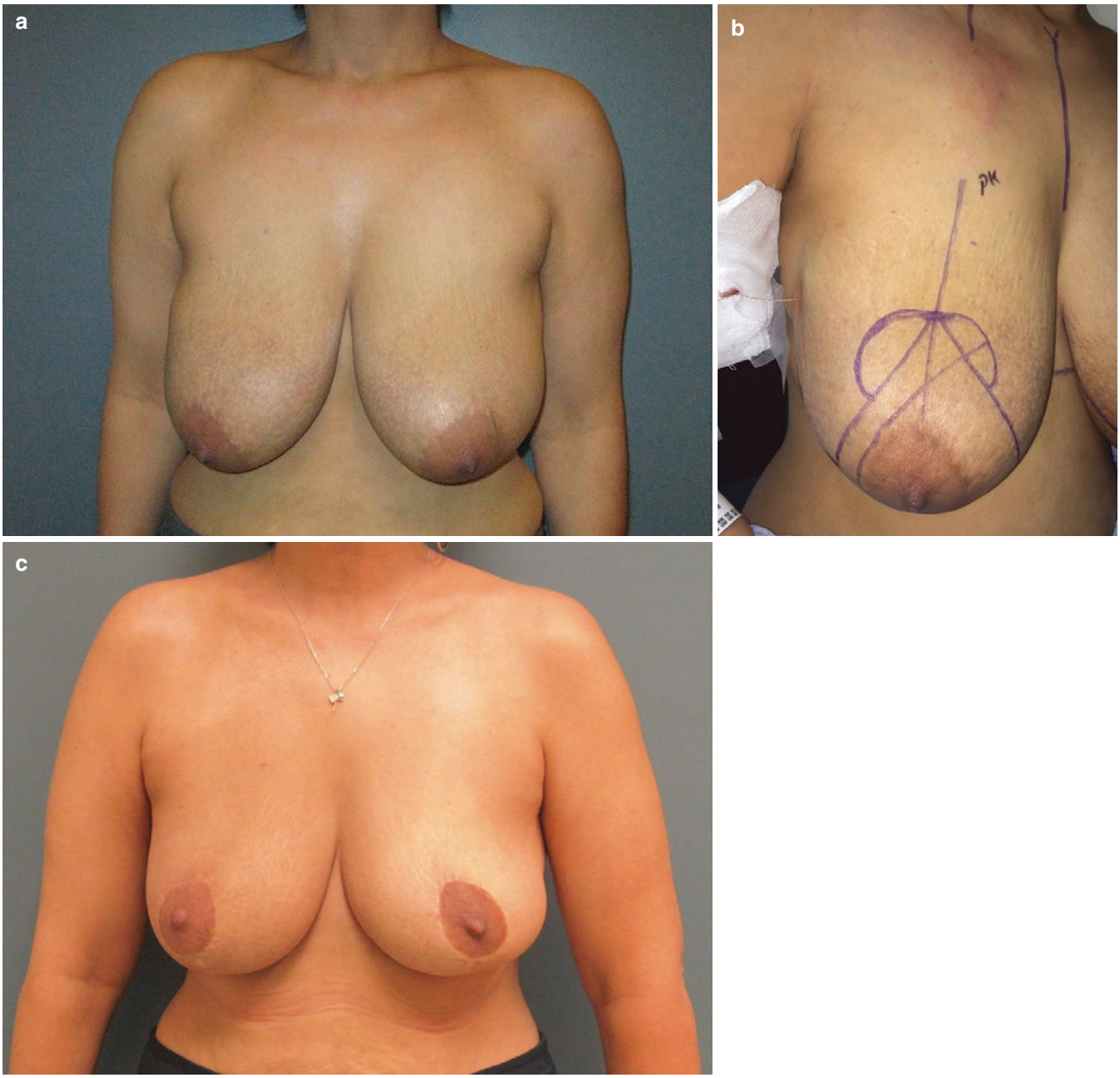

Fig. 2.6 (**a**) Preoperative view. (**b**) Wise pattern markings with wire in outer quadrant. (**c**) Postradiation result

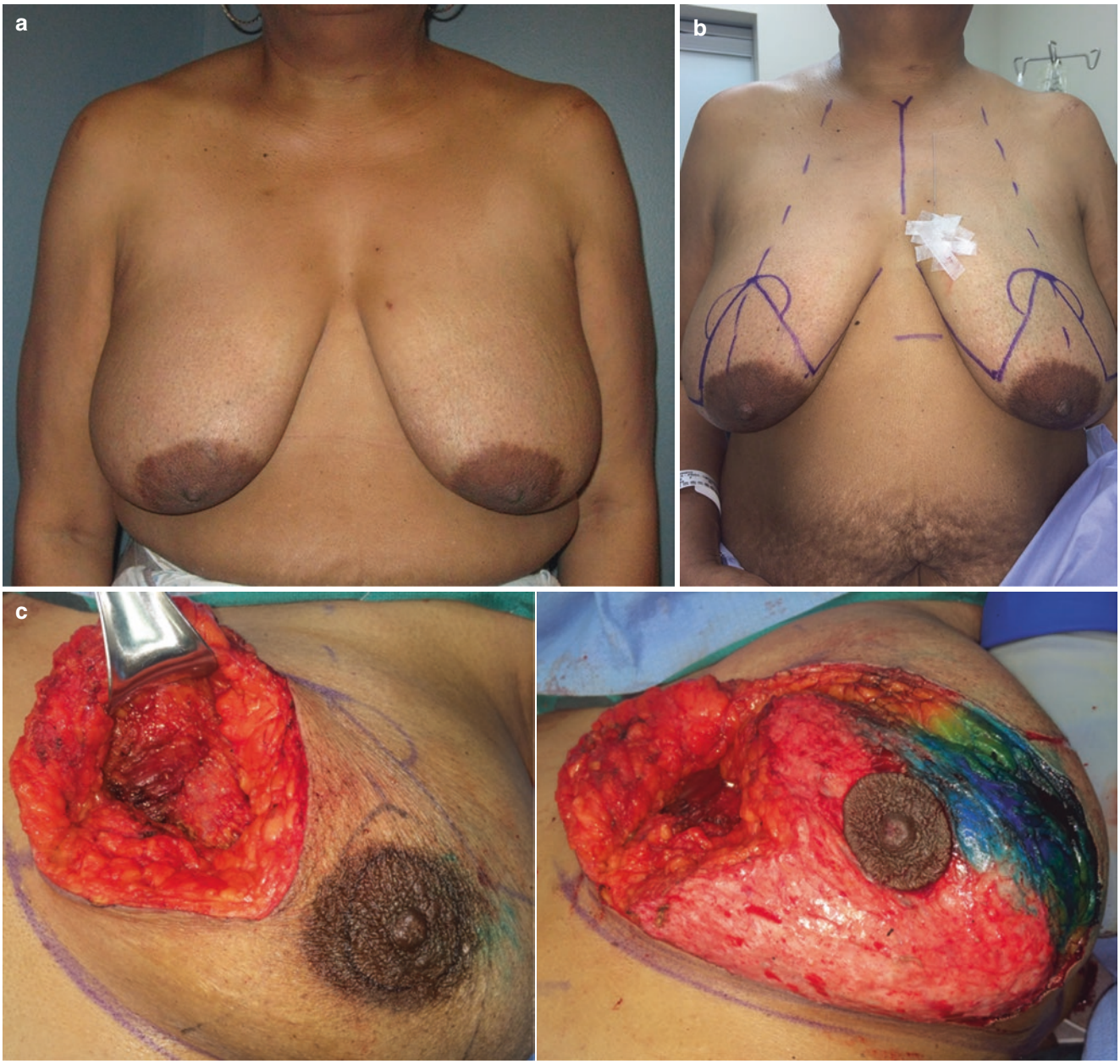

Fig. 2.7 (**a**, **b**) Preoperative view with markings and left medial wire placement. (**c**) Medial defect with created inferior pedicle and deepithelialized portion above the nipple. (**d**) Rotation of extended inferior pedicle with medial inferior pedicle back cut to fill the medical defect. (**e**) Result following radiation therapy on the left

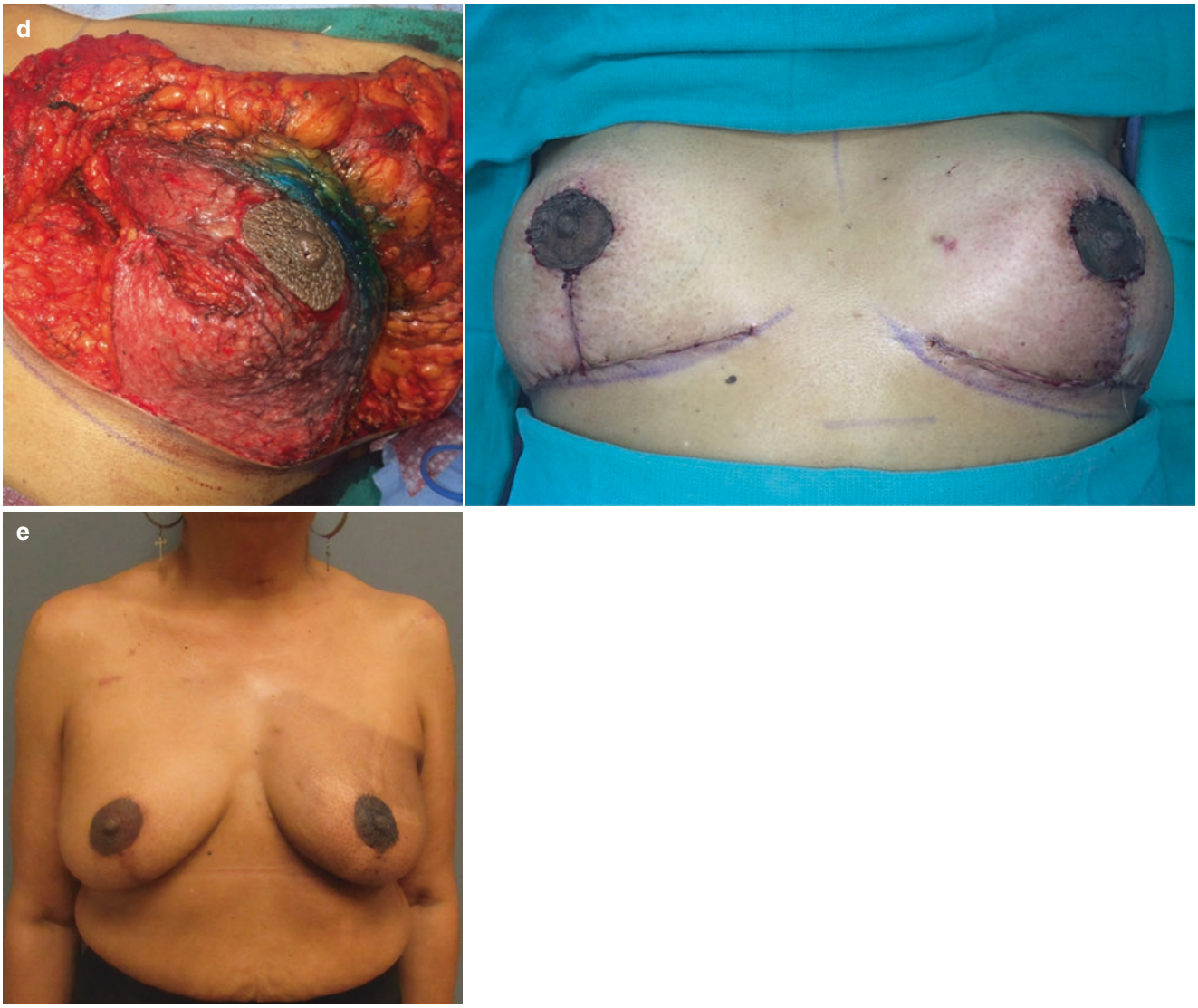

Fig. 2.7 (continued)

Conclusions

The benefits of partial breast reconstruction for women with breast cancer are numerous, and it is not an accepted addition to breast conservation therapy. While the main driving force was to minimize the potential for a poor cosmetic result, the indications have now expanded and so too have the advantages of this approach. The technique will depend on breast size, tumor location, and the amount of residual breast tissue following tumor resection. Flap reconstruction and reduction techniques are the most common reconstructions and are best performed prior to irradiation therapy. Outcomes are favorable from both an aesthetic and an oncological perspective.

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Breast Reconstruction with the Adjustable Breast Implant

3

Hilton Becker

Introduction

The use of tissue expanders has become the most common technique of performing breast reconstruction as evidenced by the 2018 ASPS Plastic Surgery Statistics Report [1]. Chedomir Radovan, a great innovator of the 1970s, is credited with the development of the Radovan breast expander for implant-based breast reconstruction. [2] The expander was originally placed under the subcutaneous tissue and above the pectoralis major muscle for delayed reconstruction. This technique evolved over time leading to immediate breast reconstruction facilitated by the placement of the expander in a submuscular position. Adjustable breast implants were developed shortly thereafter by making the injection port detachable. In this fashion, the expander could be converted to an implant [3]. The initial adjustable implant was a single-lumen saline-filled implant with a detachable injection port. The double-lumen implants were subsequently developed to contain varying volumes of silicone gel in the outer chamber (e.g., 25%, 35%, 50%) with the purpose to provide the implant a more gel-like feel (Fig. 3.1) [4–6]. The Becker 50-50, which contains 50% silicone gel in the outer chamber, is most commonly used for immediate breast reconstruction.

Adjustable implants were originally used for one-stage delayed breast reconstruction. The implant was placed in a complete subpectoral pocket, where the muscle and overlying skin flaps were serially expanded by injecting saline into the injection port. Once the desired volume is obtained, the injection port is removed, leaving the saline-filled implant as the definitive implant. With immediate reconstruction, to facilitate expansion, the muscle can be released along its inferior attachment and elongated with an acellular dermal matrix (ADM) or a synthetic mesh.

With the introduction of skin-sparing and nipple-sparing mastectomies, expansion is rarely necessary. Skin preservation facilitates prepectoral breast reconstruction as the excess skin enables tension-free closure. A full sheet of ADM is commonly used as an adjunct to cover and support the implant to compensate for muscle coverage [7]. Fat grafting can also be used to thicken the skin flap, reducing the need for ADM and thus significantly reducing the cost of reconstruction [8].

Adjustable implants offer solutions for revision reconstruction and complex cases such as radiation problems with poor wound healing, symmastia, and asymmetry.

Anatomy

Adjustable breast implants can be placed either posterior (subpectoral) or anterior (prepectoral) to the pectoralis major muscle. The subpectoral plane is the space beneath the pectoralis major in contiguity with the serratus anterior muscle. The pectoralis muscle can be released at its inferior border to enlarge the subpectoral space. The muscle is then reattached to the inframammary fold with a sheet of ADM. The prepectoral space is the space arising beneath the skin flap following the mastectomy. It usually extends into the axilla and laterally to the latissimus dorsi muscle. The base is the pectoralis major and serratus anterior muscles.

Patient Selection

Almost all patients referred to us for immediate reconstruction are usually eligible for breast reconstruction with adjustable implants. Circulation to the skin flaps is not usually assessed with angiography since even patients with suboptimal circulation can be included.

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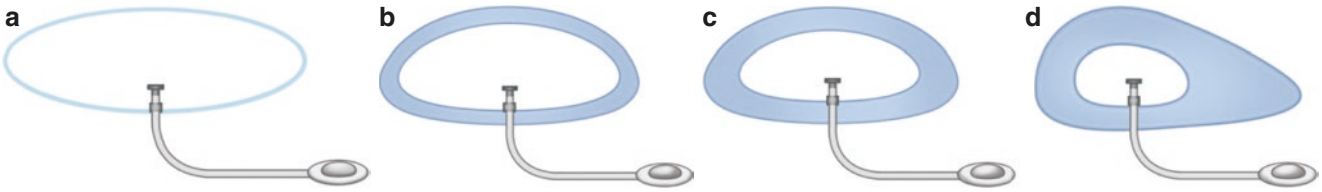

Fig. 3.1 Adjustable breast implants: (**a**) single-lumen saline; (**b**) 25% silicone gel; (**c**) 50% silicone gel; and (**d**) anatomical

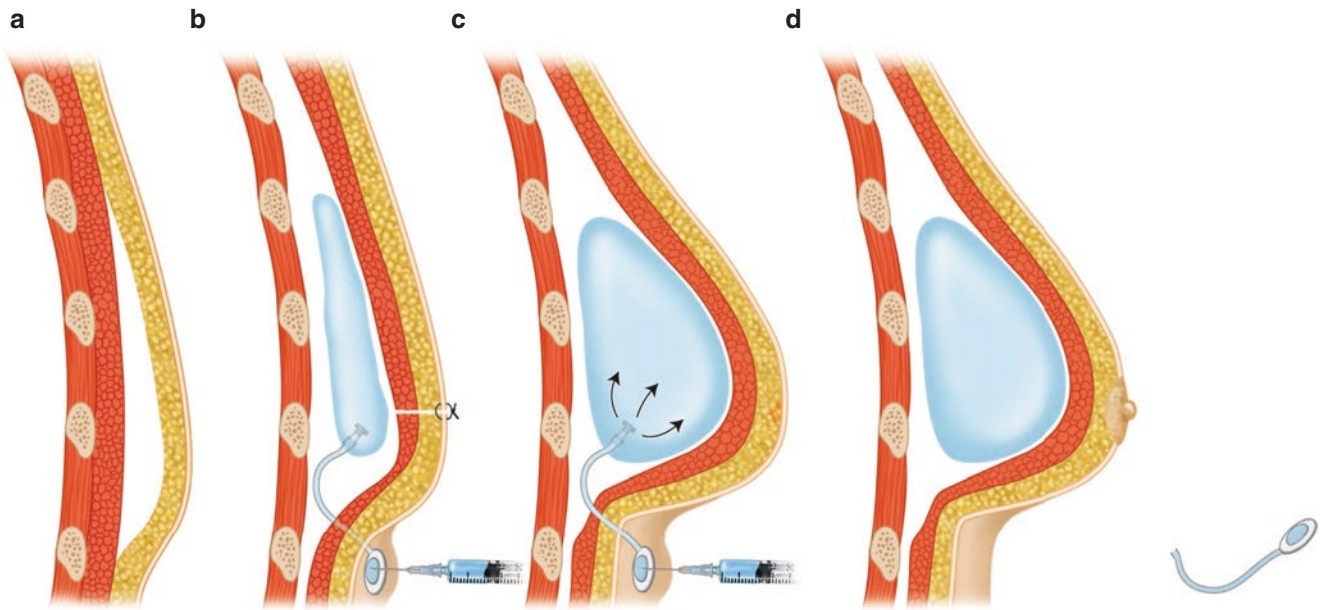

Fig. 3.2 (**a**) Following mastectomy; (**b**) adjustable implant placed beneath the muscle; (**c**) further saline added to expand the flap; and (**d**) injection port removed

Patients with advanced disease or large tumors extending to the muscle are excluded and usually require autologous reconstruction.

Preoperative Planning

The skin incisions are marked by the oncological surgeon together with the plastic surgeon. A decision is made as to the type of mastectomy to be performed (e.g., skin-sparing or nipple-sparing mastectomy). Incision placement is based on the size of the breast, tumor location, degree of ptosis, and whether the nipple will be preserved. The inframammary incision is preferable in smaller-breasted patients. A vertical incision is used in larger or ptotic breasts.

If the nipple is to be removed, in smaller-breasted patients, a circumareolar incision with lateral extension is used, whereas in patients with larger breasts or ptosis, a vertical incision is used [9–11]. A wise pattern is not used in the first stage in order to avoid compromising the nipple areola complex. In cases of moderate ptosis, the vertical incision is deepithelized laterally and the dermal flap is advanced medially, thus lifting the lower pole [12]. Further elevation is achieved by allowing the flap to contract postoperatively over an underfilled implant [12, 13]. In this way, skin contraction reduces the need for mastopexy with skin excision at the time of the initial reconstruction [14]. Further nipple elevation can be achieved during a secondary procedure if necessary.

Depending on the circulation and thickness of the flaps, the appropriate implant is selected. In cases where delayed reconstruction may be considered (e.g., if the skin flaps are thin or circulation threatened), the smooth single-lumen adjustable implant (Spectrum) is used as a spacer. Alternatively, the Becker 25 can be used. In cases where a direct-to-implant breast reconstruction is being considered, the smooth Becker 50-50 is the preferred choice.

Surgical Technique

For delayed reconstruction, the adjustable implant can be placed submuscularly or above the muscle. When placed submuscularly, the pocket is dissected using fiberoptic retraction. A temporary saline breast implant sizer (Mentor Corp., Santa Barbara, CA) is placed in the pocket and overexpanded to assess the pocket. The sizer is then removed, and the adjustable implant is placed in the pocket with the desired volume of saline. A smooth surface is preferable for an adjustable implant as it is softer and more elastic and ripples less. The injection port is placed in a

subcutaneous pocket and sutured into position. The muscle layer is sutured, followed by skin closure (Fig. 3.2).

For immediate reconstruction, the adjustable implant is usually placed above the muscle. In order to place the implant in the correct position, the prepectoral space is adjusted appropriately. The lateral skin flap is advanced medially and sutured to the chest wall beneath the pectoralis muscle with 1 or 2 rows of interrupted 2.0 polyglactin sutures (Vycril®, Ethicon, Somerville, NJ). A temporary saline breast implant sizer is then placed in the pocket and overexpanded. The pocket is assessed, the sizer is removed, and the pocket is adjusted as necessary. If the flap is sufficiently thick, no ADM is used. If the flap is thin, especially with nipple sparing mastectomies, an anterior layer of ADM (FlexHD Pliable MTF Biologics Edison NJ) is used to cover the anterior surface of the implant.

The adjustable implant package is opened, and the implant is irrigated with a triple antibiotic solution. Once the appropriate amount of air is removed, the implant is placed in the pocket (Fig. 3.3).

The adjustable implant comes packaged with two differently sized injection ports: one large and one small. It is the

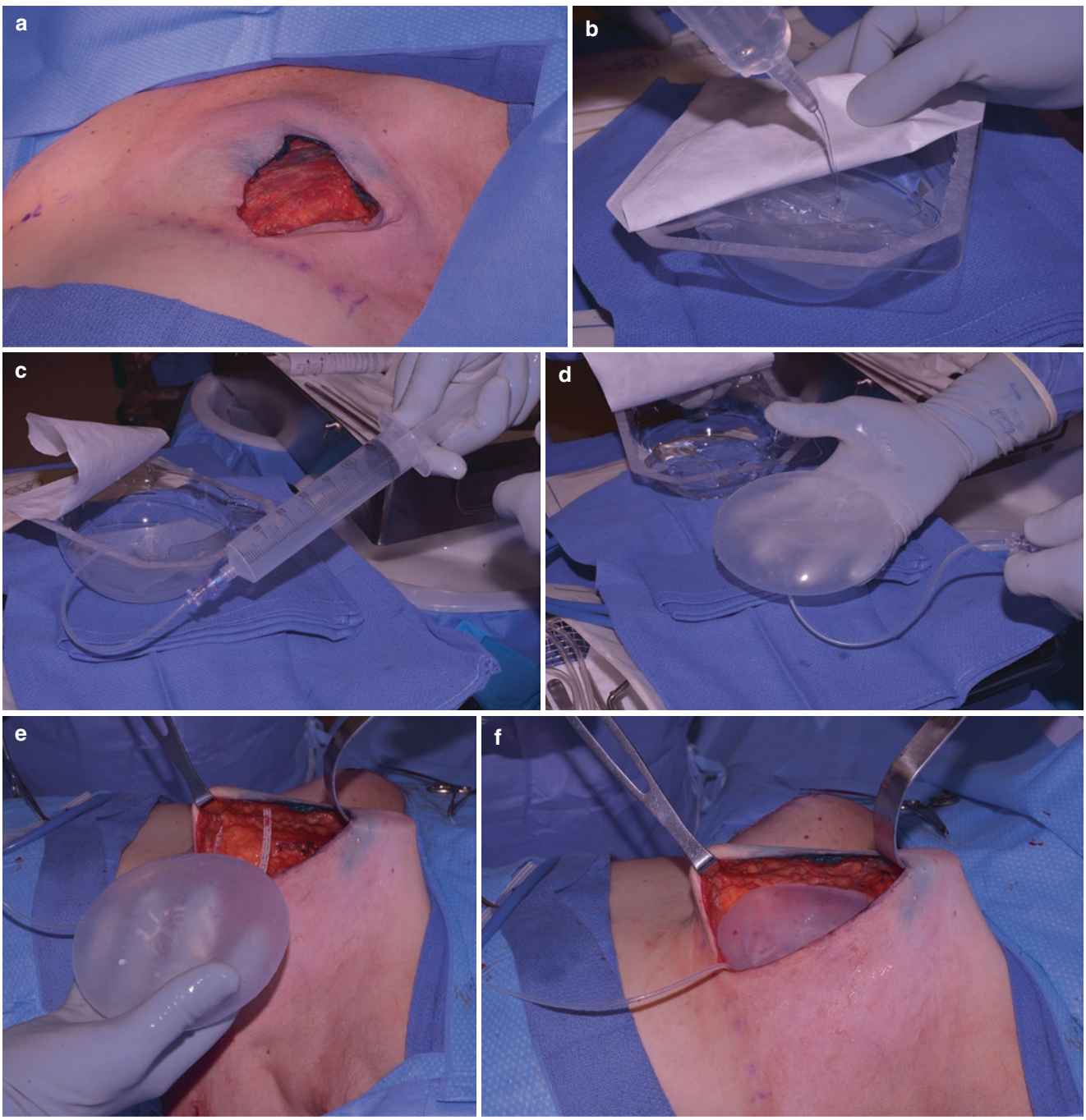

Fig. 3.3 (**a**) Following skin-sparing mastectomy; (**b**) implant irrigated with antibiotic solution; (**c**) air is partially removed from the implant; (**d**) partially air-filled implant; (**e**, **f**) the implant is placed in the pocket

surgeon's personal choice as to which size to use, depending on the size of the patient and thickness of the flaps. There are also two different connectors: a plastic clip-on connector, which is more difficult to use and requires dissection in order to free it on removal, and a steel connector that requires suture fixation with 3.0 silk sutures (Perma-hand®, Ethicon, Somerville, NJ). The advantage of this connector is that the tubing on the injection port can be shortened prior to attachment to the implant fill tube. The injection port is placed in a pocket dissected subcutaneously, usually lateral to the incision, and secured in position with interrupted 3.0 polyglactin sutures (Fig. 3.4). On removal, the injection port can be retrieved by grasping the fill tube beyond the connector, thus avoiding disruption at the connection. Once removed, the implant seals at the self-sealing valve (Fig. 3.5).

The pocket is once again irrigated with triple antibiotic; one or two drains are placed through a long subcutaneous tunnel and sutured to the skin. The incision is closed with a deep row of

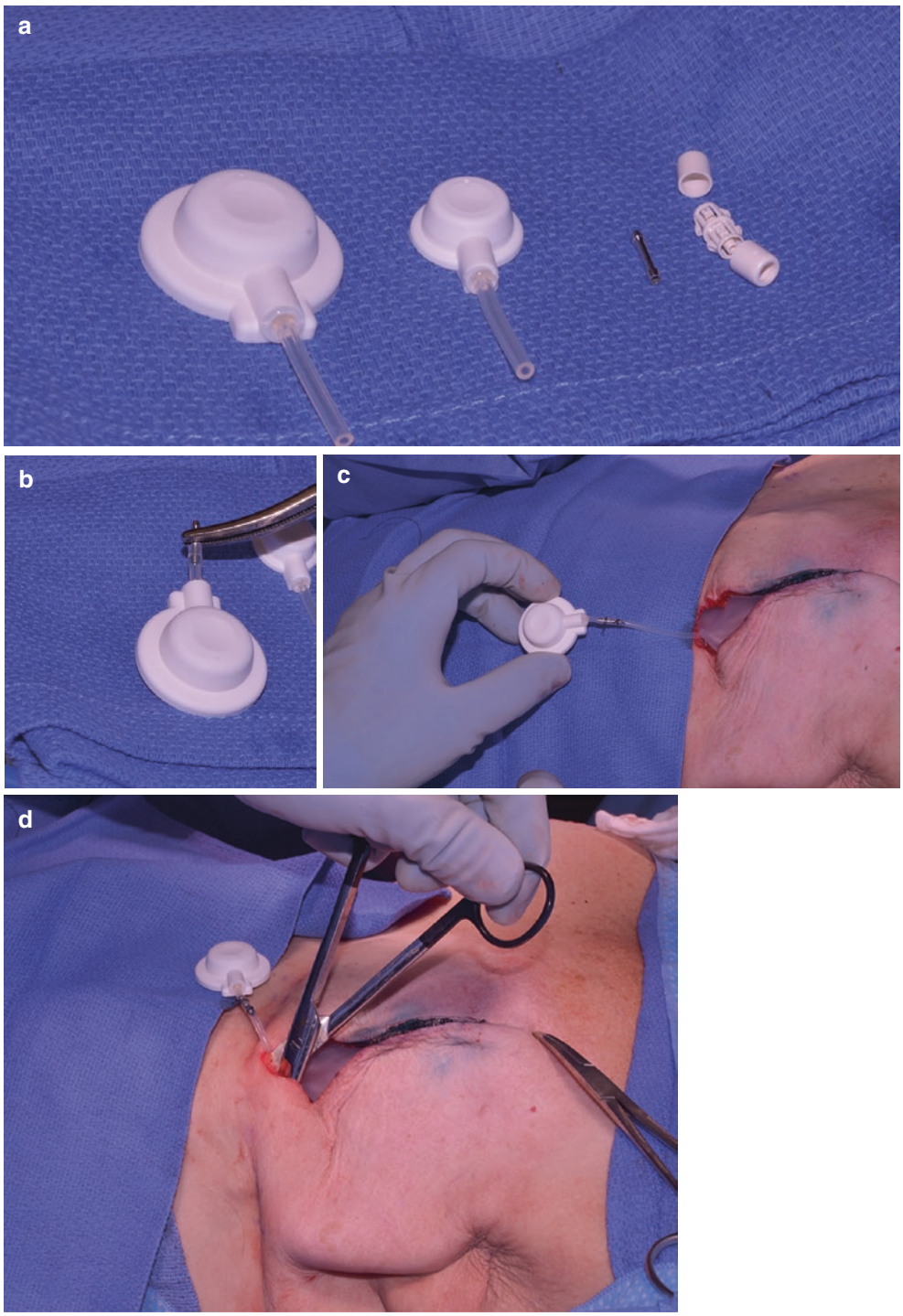

Fig. 3.4 (**a**) Different injection ports with steel and plastic connectors; (**b**) steel connector inserted; (**c**) a 3.0 silk tie is tied around each end of the connector; and (**d**) pocket is made for injection port

interrupted 3.0 polyglactin sutures followed by 2 rows of 4.0 running poliglecaprone sutures (Monocryl®, Ethicon, Somerville, NJ). It is important that closure be completely tension free and water tight. Transparent film dressings (Tegaderm®,3M, Maplewood, MN) are used to help hold the flap in position and then further reinforced with gauze and tape.

When the implant is used as a spacer, it is placed virtually empty, containing only a small amount of air in order to maintain the implant shape (Video 3.1). Postoperatively, once circulation is assured, further air is injected using a 0.20 μm bacterial syringe filter (Cole-Parmer, Chicago, IL).

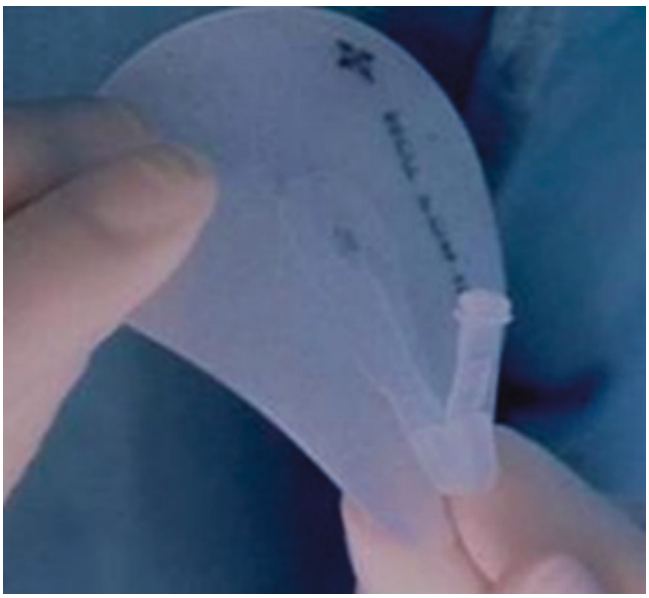

Fig. 3.5 Self-sealing valve

An implant that is underfilled with saline ripples and collapses to the bottom of the mastectomy pocket, resulting in pressure on the inferior pole. We therefore currently underfilled the implant initially with air. This results in a lighter, more uniform surface that does not collapse and exerts less pressure on the lower pole. Furthermore, underfilling the implant with air allows the flap to contract, thicken, and elevate. Fat grafting can also be performed to thicken the flap further, thus virtually eliminating the need of ADM in immediate reconstruction (Fig. 3.6) [12].

If improved soft tissue coverage is desired, further fat is grafted, and the volume of the implant is reduced. Ultimately, sufficient fat can be grafted, enabling removal of the implant and resulting in a total autologous reconstruction. As an additional benefit, the patient is spared the anguish of having a deformed breast during the prolonged fat-grafting procedure without an implant.

The manufacturer of the adjustable implants specifies fill volumes on the instruction brochure. These volumes are not clinically validated. There are however valuable indications for deviating from these volumes (e.g., placing the implant underfilled initially and overfilling if necessary) for symmetry or to correct capsular contracture [15]. Patients are always informed and give consent for off-label use.

Postoperative Care

As the adjustable implant is a dynamic implant, frequent postoperative care is necessary in order to take advantage of adjustability. The patient is seen the day after surgery. All

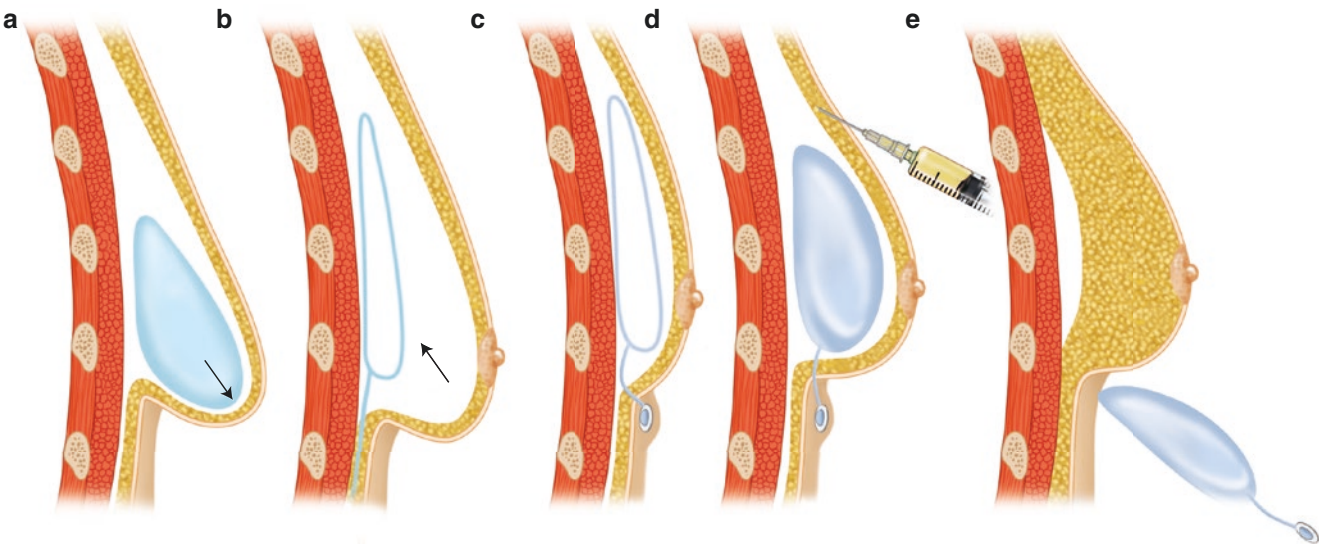

Fig. 3.6 (**a**) Saline-filled implant collapses at the bottom of the mastectomy pocket, and its weight causes pressure on the flap and sagging; (**b**) implant underfilled with air fills the upper pole of the mastectomy pocket, acts as a spacer, and avoids pressure on the flap; (**c**) flap contracts, thickens, and elevates; (**d**) air is replaced with saline and fat grafting is used to thicken the flap further; and (**e**) implant is removed resulting in an autologous reconstruction

dressings are taken down with the patient in the standing position. The position of the implant, and the circulation of the flaps are assessed. Volume may be reduced if there is any concern about circulation. The patient is seen 2 days later, at which stage further adjustments are made.

If the implant is in good position and circulation intact, air may be removed and replaced with saline injected into the injection port using a 23 g butterfly needle. If the implant is sitting too low, further air is injected with a 50 cc syringe attached to a bacterial filter, and an inferior pressure strap is applied. On the contrary, if the implant is too high, saline is added, and a superior strap is applied. The pressure of the strap and the weight of the saline-filled implant will facilitate lowering of the implant. The implant may also be temporarily overexpanded to obtain more ptosis. The patient is then seen every few days, and further saline is added as needed. When the correct size is obtained, the patient is scheduled for removal of the injection port, usually 3–12 months later.

In cases where radiation is required, the volume of the implant can be adjusted to satisfy the needs of the radiation therapist. Furthermore, the implant can be overexpanded soon after radiation before scarring sets in, thus reducing capsular contracture. In the event that an open capsulotomy is needed, the adjustable implant can be overexpanded for several weeks following the capsulotomy. This helps reduce the recurrence of capsular contracture.

Immediate breast reconstruction has a high complication rate [16]. High-risk cases are usually delayed for secondary reconstruction or immediate delayed reconstruction [17]. Alternatively, the smooth adjustable implant can be placed underfilled functioning as a spacer, thus greatly reducing the risk of flap ischemia and extrusion of the implant.

There is a definite learning curve in using adjustable implants; however, when correctly used, complications are relatively uncommon. In fact, the adjustable implants often help avoid complications such as asymmetry and capsular contracture. Complications specific to the adjustable implant include rippling, seroma, skin erosion, premature pocket closure, valve failure, and injection port problems. Rippling is usually more common with the saline adjustable and textured implants. If the incorrectly sized implant has been selected, and it is necessary to lower the volume, rippling occurs, usually requiring replacement with a gel implant. Erosion through skin flaps has been seen in cases where a textured implant is underfilled and forms a fold that can cause irritation to thin skin flaps and eventually erode. Premature pocket closure can also occur if the implant has been left underfilled for too long. Valve failure is very uncommon, yet has been seen where the injection port has been left in for excessively long periods of time. Injection port problems such as rotation, which can lead to kinking of the fill tube, and infection, if the port is placed too close to the skin, have also been described.

Clinical Cases

Case 1

A 46-year-old patient with right-sided breast carcinoma underwent bilateral skin-sparing mastectomy. Reconstruction was performed with a smooth Becker 50-50 silicone gel implant. The implant was placed in a subpectoral pocket and partially filled with saline via a closed system. The muscle was released and reinforced with an ADM. The injection port was placed lateral to the incision. Once circulation was assured 2 days postoperatively, further saline was added. The injection ports were removed at 6 months, and the nipples were reconstructed (Fig. 3.7).

Case 2

A 50-year-old patient presented with carcinoma of the right breast. Following bilateral nipple-sparing mastectomy, an adjustable implant was placed prep-pectorally with full ADM coverage. The injection port was placed in a subcutaneous pocket. The incision was closed tension free. Further saline was added postoperatively until the correct size was obtained. The patient showed good symmetry with no animation deformity (Fig. 3.8).

Case 3

A 43-year-old female, BRCA-positive with large, ptotic, asymmetrical breasts, underwent bilateral nipple-sparing mastectomy with vertical incision and reconstruction with pre -pectoral Spectrum implants initially filled with 100 cc of air. No ADM was used, and the breasts were taped into position to encourage contraction. Good symmetry was achieved without performing a mastopexy. The patient subsequently underwent conversion to silicone gel implants (Fig. 3.9).

Case 4

A 38-year-old patient with carcinoma of the right breast underwent bilateral nipple-sparing vertical incision mastectomy. An adjustable implant was placed prepectorally and initially partially filled with air. The air subsequently replaced with saline. Skin flaps were allowed to contract, and fat grafting was performed. The volume of the implants was reduced, and further fat grafting was then performed. The implants were finally removed. The final result exhibited soft and mobile breasts (Figs. 3.10).

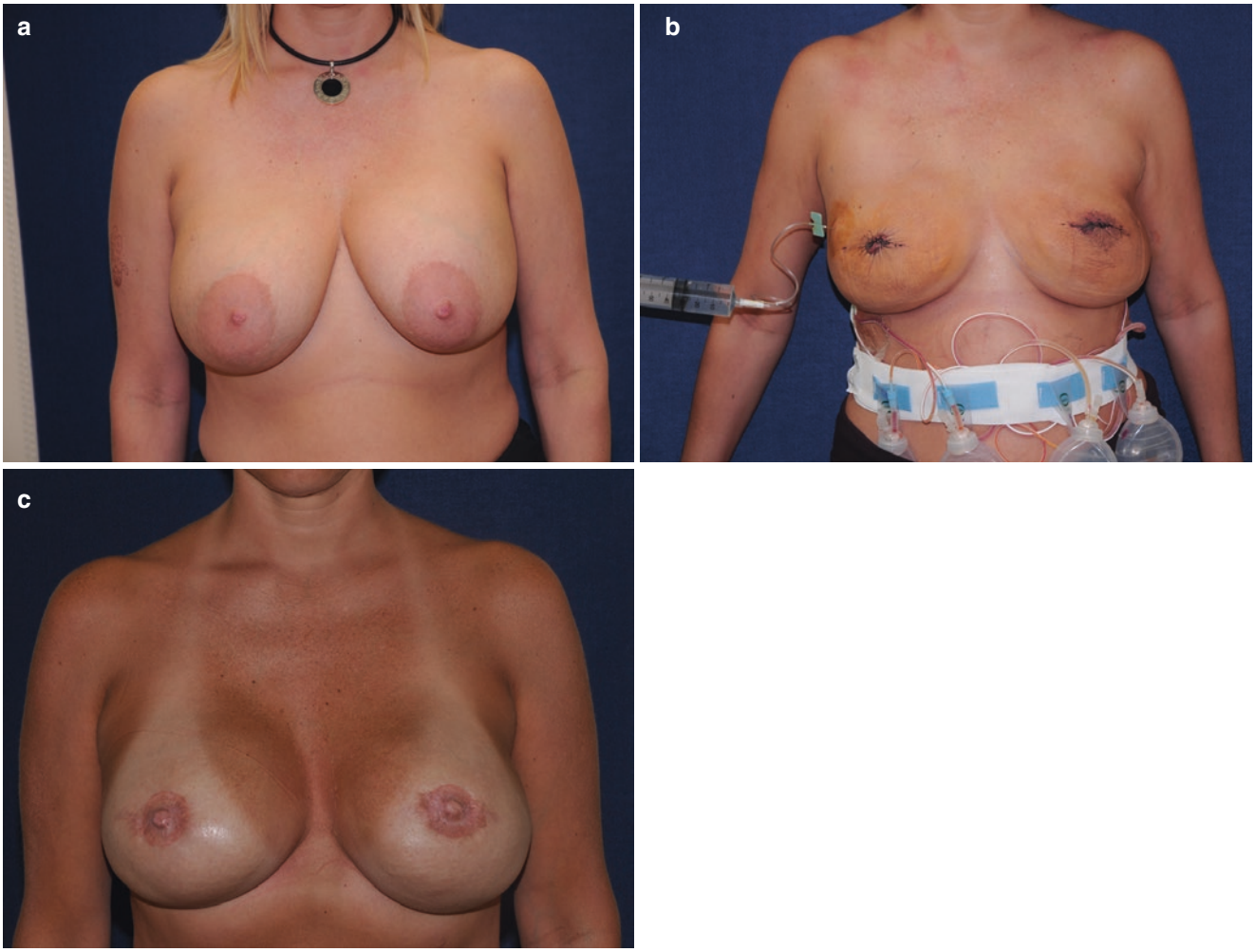

Fig. 3.7 (**a**) Preoperative view; (**b**) implant being filled postoperatively; and (**c**) late postoperative view after removal of injection port and nipple reconstruction

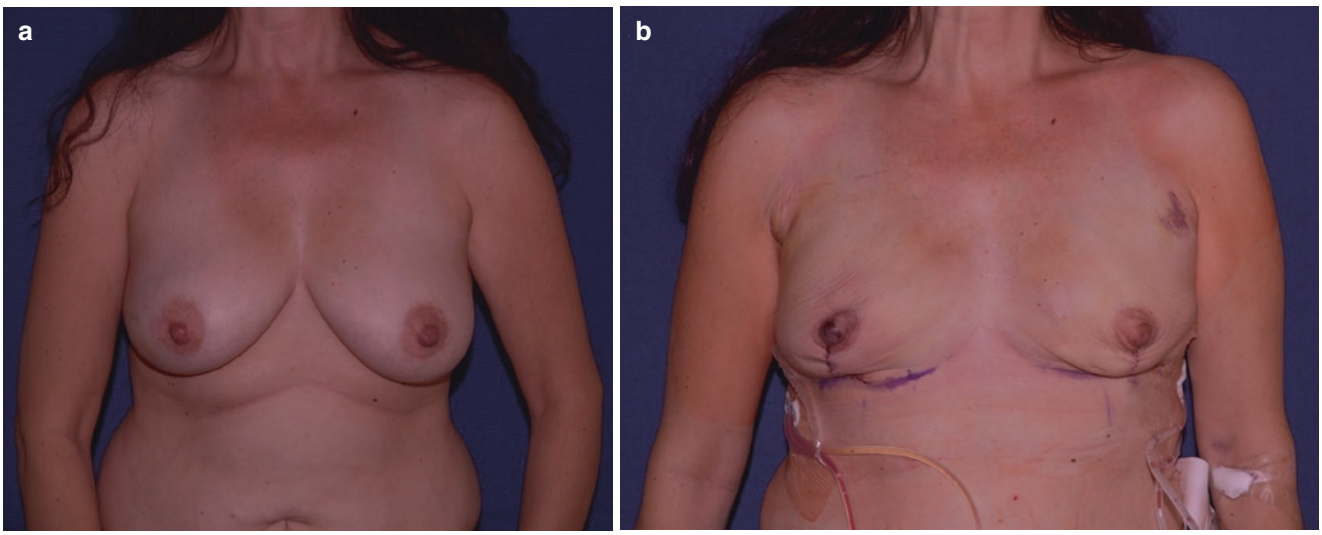

Fig. 3.8 (**a**) Preoperative view; (**b**) immediate postoperative view; and (**c**) long-term postoperative view

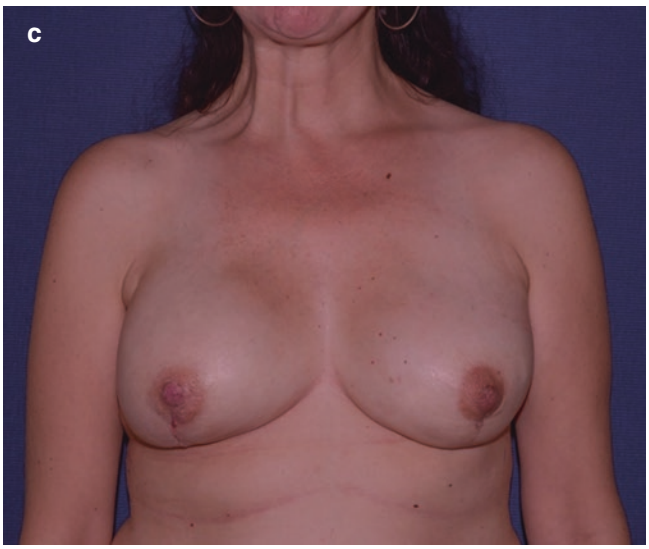

Fig. 3.8 (continued)

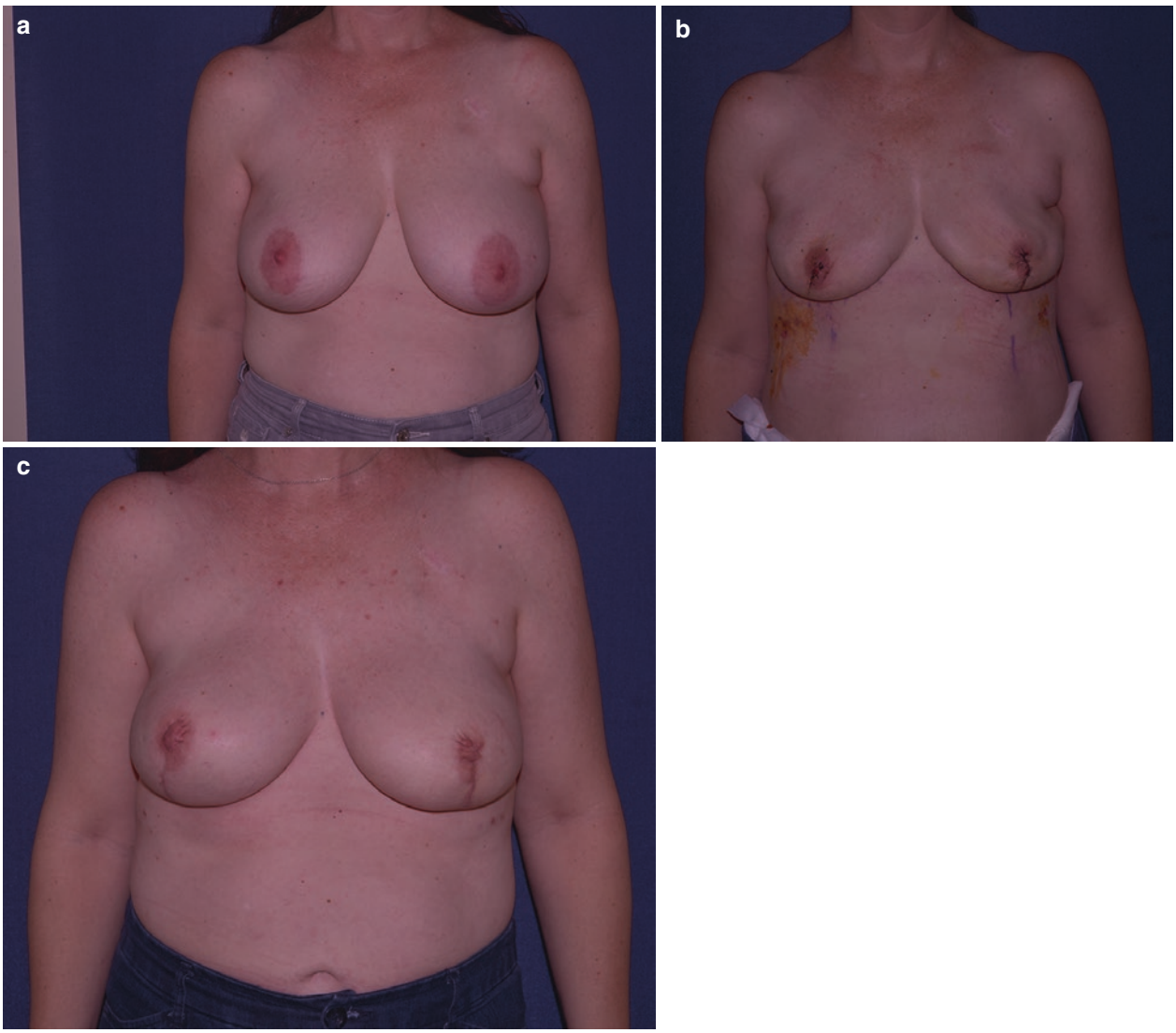

Fig. 3.9 (**a**) Preoperative view; (**b**) immediate postoperative view; and (**c**) long-term postoperative view

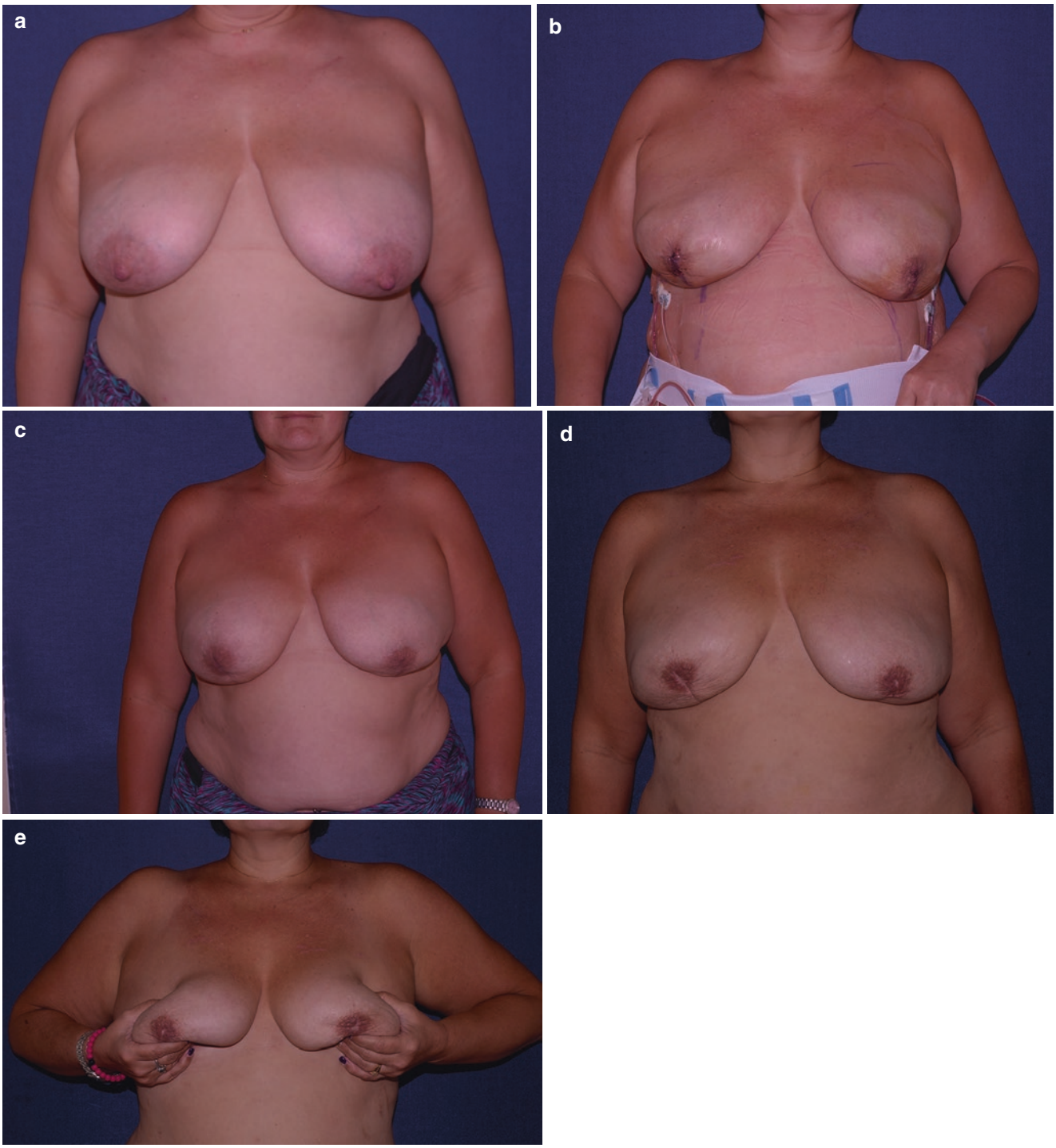

Fig. 3.10 (**a**) Preoperative view; (**b**) immediate postoperative view; (**c**) view after multiple sessions of fat grafting; (**d**, **e**) final result after implant removal

Conclusion

The use of adjustable implants has evolved from delayed to immediate reconstruction and more recently from submuscular to prepectoral implementations. The adjustable implant expands the range of patients that are suitable for immediate prepectoral implant reconstruction by reducing pressure on the skin flaps. Underfilling an adjustable implant with air allows the skin flaps to contract and thicken, reducing the need for ADM coverage. Adjustable implants are beneficial in revision cases and correction of implant complications. In this fashion, better symmetry, with reduced surgical time and cost, is achieved.

Disclosure Dr Becker is a consultant for Mentor Corp. and Surgical Innovation Associates.

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Synthetic Meshes in Breast Reconstruction

4

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Introduction

Implant-based breast reconstruction accounts for more than 86% of breast reconstructions performed in the USA, with two-staged implant-based breast reconstruction and direct-to-implant breast reconstruction representing 86% and 14% of the total procedures, respectively [1]. A similar pattern is seen in other countries [2, 3].

With the evolution of breast cancer resection surgeries into more conservative procedures such as skin-sparing and nipple-sparing mastectomies, the quality of the preserved breast flaps has been improved making total muscle coverage of implants no longer mandatory. In this context, many strategies and adjunct techniques to improve aesthetic result of the reconstructed breast were developed. The tendency for more conservative surgeries, which would respect normal anatomy as much as possible, has further prompted the adoption of surgical devices as a valuable resource in the plastic surgeon's treatment weaponry.

The paradigm of a complete muscular coverage by the creation of a submuscular pocket that would require the elevation of the pectoralis major, anterior serratus muscles, and in many cases the anterior sheath of the rectus abdominis muscle to place the tissue expander or implant has been abandoned. The utilization of meshes and matrices has emerged nowadays as a useful alternative for lower-pole coverage of the tissue expander or implant.

Implant-based breast reconstruction has shown to have multiple benefits. The single elevation of the pectoralis major muscle results in reduced trauma and distortion of the normal anatomy of the chest wall diminishing postoperative pain and risk of bleeding and probably consequent faster postoperative patient recovery. Also, by providing a point of fixation to the lower border of the pectoralis major muscle, the presence of the mesh prevents the cephalic sliding of the muscle once the implant is in position, phenomenon known as window shading.

Creation of the tissue expander or implant pocket is easier for the surgeon as he can establish the height of the inframammary fold (IMF) as desired at the lower fixation point of the mesh. On the other hand, there is a decreased pressure in the pocket after the implant positioning that is achieved by the placement of the mesh in the inferior pole of the breast. This decrease in the retromuscular pocket pressure translates into lower incidence of implant migration and bottoming out phenomena.

The mesh coverage of the inferior portion of the tissue expander or implant acts as the point of lower resistance when compared to the pectoralis major coverage on the superior portion of the implant. This allows for an improved lower pole unfolding and skin expansion in the inferior third of the breast resulting in a higher projection and a more natural breast appearance.

As described before, the mesh acts as an extension of the inferior border of the pectoralis major, providing an ample space for the implant in the partial retromuscular position and allowing the placement of greater intraoperative volume implants. The presence of a spacious partial retromuscular pocket has also allowed surgeons to perform direct-to-implant breast reconstructions. The placement of the larger implants can be performed immediately after the cancer resection procedure with low risk of postoperative complications and achieving a good symmetry with the contralateral healthy breast. This fact can also be advantageous when performing two-stage implant-based breast reconstruction as the achieved immediate postoperative tissue expander volume can be larger, and reaching the desired end point expansion volume can be done in a shorter time period.

The characteristics of the ideal mesh are well described and are summarized in Table 4.1 [4]. Up to date, there is no material that complies with all of these features.

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In 2005, Breuing and Warren first reported the use of acellular dermal matrices (ADMs) in breast reconstruction surgery with promising results [5] that rapidly turned into the center of attention. Soon after, in the year 2007, their use in prepectoral implant-based reconstruction was described making their popularity even greater [6]. Although ADMs were not the only type of biologic meshes being utilized in breast reconstruction procedures, most of their counterparts did not have as much acceptance and successful results, falling into disuse in many cases.

Biological meshes are produced from human cadaveric, porcine, or bovine dermis that are devoid of cells and antigenic molecules through a special processing. Once in the recipient, they act as a scaffold that is rapidly invaded by host cells and revascularized favoring fast tissue regeneration. This produces a genuine integration of the ADM to the host tissue that has been shown to be parallel to normal wound healing process [7].

One major commonly discussed drawback of ADM is its cost. Different reports indicate that the value of every sheet in the UK ranges between $1825 and $4856 depending on the size and type of ADM [8]. A study found a sevenfold price difference ($2527.00 ADM vs. $365.80 mesh) for the billing costs at one institution when compared with polyglactin mesh [9]. Due to this factor, health insurance companies in many countries do not cover the costs derived from its use, and patients must finance the use of the mesh by themselves. Moreover, as with every high-cost implantable device, there is important pressure from the industry in order to promote and universalize its application although to date there is a lack of long-term results and safety reports on their use [10, 11]. Even though there has been an expansion of ADM's authorization by federal laws in many countries, this is not the case for many others where there have been regulatory barriers limiting its utilization, making ADMs not available in every region. Additionally, many patients might show resistance to the use of biologic derive materials due to fear of their animal or cadaveric origin.

Table 4.1 Characteristics of the ideal prosthetic meshes

Biocompatibility, non-immunogenicity and non-carcinogenicity
Resistance to colonization and chronic infection
Ability to maintain adequate long-term tensile strength
Absence of retraction or expansion after implantation
Adequate flexibility to avoid fragmentation or material fatigue
Easy sterilization process without alteration of its properties
Rapid incorporation to the host tissue and promotion of tissue ingrowth
Manufacturing standardization
Low cost
Readily available

Despite the great number of synthetic meshes available in the market, only few of them have been reported as used for primary breast reconstruction procedures [12–19]. Synthetic meshes offer a low-cost alternative to biological matrices with favorable aesthetic results. Their main characteristics are outlined on Table 4.2.

Our preferred synthetic mesh to aid breast reconstruction procedures is polyglactin knitted mesh. Polyglactin mesh has been demonstrated to be a safe product that has been widely used in numerous surgical procedures with a low complication profile for many years. This mesh is widely available and relatively inexpensive, demonstrates little inflammatory response, and is non-allergenic. Nyame et al. used bacterial adhesion assays to demonstrate that synthetic materials such as polyglactin produce decreased rates of bacteria-mediated biofilm formation [20]. It is possible that this resistance to biofilm in the setting of a foreign body implant could have a protective effect on inflammation, infection, seroma, and capsular contracture, but further evidence is needed.

In this chapter, we present the application of synthetic meshes in implant-based breast reconstruction. The proposed technique denominated the ensured subpectoral pocket (ESP), although originally described to simplify direct-to-implant

Table 4.2 Characteristics of the synthetic meshes used for breast reconstruction

	TiLOOP BRA® (PFM Medical, Germany)	TIGR® (Novus Scientific, Sweden)	Breform, Surgimesh-PET® (Aspide Medical, France)	Vycril Mesh® (Ethicon, USA)
Material	Medical titanium coated polypropylene	Fast degrading fibers composed of glycolide and trimethylene carbonate copolymer Slow degrading fibers composed of lactide and trimethylene carbonate copolymer	Polyester	PolyGlactin 910
Structure	Knitted monofilament	Knitted monofilament	Three-dimensional, preshaped, woven mesh	Knitted multifilament mesh
Pore size	1.0 mm	1.0 mm	1.0–2.0 mm	0.4 mm
Weight	16 g/m^2		75 or 130 g/m^2	56 g/m^2
Time for absorption	Non-absorbable	Fast degrading fibers are reabsorbed in 4 months Slow degrading fibers are reabsorbed in 3 years	Non-absorbable	Absorbable in 30–60 days

reconstruction [12], can be modified and applied in two-stage reconstructions as will be furtherly exposed under surgical technique.

Anatomy

The muscles usually involved in the creation of a complete muscular pocket for immediate breast reconstruction are the pectoralis major, the pectoralis minor, the serratus anterior, the external oblique, and the rectus abdominis sheath. The main drawback of this classical approach has been that such muscles, when sutured to create a complete pocket, only allow for the setting of small implants. The ESP technique employs only the pectoralis major and a synthetic mesh as an extension of the subpectoral pocket which allows the setting of bigger implants.

The pectoralis major is a large, fan-shaped muscle that is composed of a sternal head and a clavicular head. The distal attachment of both heads is into the intertubercular sulcus of the humerus. Its clavicular head originates from the anterior surface of the medial clavicle, while its sternocostal head originates from the anterior surface of the sternum, the superior six costal cartilages, and the aponeurosis of the external oblique muscle. It is innervated by both medial and lateral pectoral nerves. Its blood supply is based primarily on the pectoral branch of the thoracoacromial artery. Additional blood supply arises medially from the internal mammary artery and laterally from the long thoracic artery. The main vascular pedicle to the pectoralis major runs deep to the muscle. Other structures lying deep to the muscle include the pectoralis minor, costal cartilages and thoracic rib cage, inferior costal attachment of the serratus anterior muscle, and the superior attachments of the rectus abdominis muscles.

Patient Selection

Candidates for the use of the synthetic mesh-extended pocket for expander or implant placement are women who are suited for an immediate implant-based breast reconstruction after therapeutic skin-sparing or nipple-sparing mastectomy due to diagnosis of early breast cancer (stages I or II), extensive ductal carcinoma in situ (DCIS), or presence of multicentric lesions. Furthermore, the described surgical technique is an excellent alternative for healthy BRCA1 and BRCA2 mutation carriers undergoing bilateral risk-reducing mastectomy.

Exclusion criteria for the use of a synthetic mesh are active smokers and previous radiotherapy history, patients with a positive sentinel node biopsy requiring adjuvant radiotherapy treatment of the breast mound, and patients with thin skin mastectomy flaps after gland resection which the plastic surgeon considers may have compromised irrigation leading to necrosis. Patients with reported allergy to mesh components, a rare condition, must also be excluded.

Preoperative Planning and Patient Preparation

There must be fluent communication between the breast surgeon and the plastic surgeon; thus, evaluation of the patient should be done beforehand. Breast cancer localization, dimensions, and nipple-areola involvement must be cautiously evaluated to decide between skin-sparing mastectomy and nipple-sparing mastectomy. Skin quality, elasticity, and thickness must also be carefully assessed.

Preoperative marking of the incision should always be outlined by the plastic surgeon with the patient in an upright position. Our preferred approach is through an oblique incision which not only places the medial aspect of the scar away from the visible cleavage line but also allows sentinel lymph node biopsy or axillary dissection, when indicated, through the same incision. The borders of the breast must be marked, and special attention must be taken to the marking of the contralateral IMF.

Patients' concerns and wishes regarding implant and breast size and contralateral symmetrization procedures should always be discussed preoperatively. Patients' expectations should be kept real as for every reconstructive procedure.

Surgical Technique

The described technique allows immediate single-stage and two-stage implant-based breast reconstructions. Surgery is performed under general anesthesia; IV antibiotic prophylaxis with first-generation cephalosporin is administered 30 minutes previous to the initiation of the procedure. Patient is positioned in dorsal decubitus with extended arms (at 80°–90° angle from the trunk) if axillary node biopsy is required. Care must be taken of the regions of higher pressure to minimize compression lesions and pressure sores. A urinary catheter may be inserted depending on the planned length of the procedure and may be extracted at the end of it. The use of a warming mattress is recommended.

Skin preparation and surgical field should be delimited at the top of both shoulders superiorly, medial axillary line laterally, and midway from the inferior pole of the breast to the umbilicus caudally. All cords and aspiration tubing should be placed toward the foot of the bed, not to interfere with the patient placing upright.

Three basic steps can be described:

Mastectomy

The mastectomy is usually carried out by the breast surgeon team, but some aspects must be carefully taken into account while removing the breast tissue. It must be understood that the success of the reconstructive procedure starts with and depends on a meticulous glandular resection. Mastectomy flaps should be carefully handled with no excessive traction or compression during dissection. The mastectomy dissection plane should be conducted in the space between the subcutaneous adipose tissue and the glandular parenchyma with special attention not to damage the subdermal vascular plexus of the flaps and jeopardize their blood supply. Preservation of an adequate flap thickness that is homogeneous along its whole extension is intended. The minimum recommended thickness of the skin flaps by some studies is of 0.8 cm in order to reduce the risk of subdermal plexus injury and not to compromise skin vitality [21]. Another key point that must be considered is the preservation of the IMF during glandular resection, a vital landmark whose preservation will further enhance the cosmetic result. When the plastic surgeon is in doubt about the viability of the mastectomy flaps, objective evaluation of the flaps' blood supply may be performed using laser-assisted indocyanine green angiography which offers accurate valuable adjunct information that can guide intraoperative clinical decision-making [22].

In cases where a therapeutic nipple-sparing mastectomy is planned, previous retroareolar biopsy and frozen section pathology analysis are imperative and must in every case rule out malignancy. In the presence of superficial tumors where margins are uncertain, a biopsy of overlying skin is performed. This may probably preclude implant-based reconstruction of the breast. Plastic surgeon must be prepared for this situation, but under no circumstance, the aesthetic result or tissue preservation desire must hinder the oncologic outcome of the resection.

Once the mastectomy is completed, the surgical wound is temporarily draped. Patient's arm position is modified placing them lateral to the trunk with the hands secured on top of the belly. Skin is prepped, temporary draping of the wound is removed, and the surgical field is delimited as previously described.

Creation of the Subpectoral Pocket

A subpectoral pocket is created by undermining the retropectoral areolar space with an electrocautery releasing its costal insertions. The retromuscular pocket dissection begins from its lateral free border and directs toward the midline and then sweeps inferior and laterally along the direction of the pectoralis fibers. The inferior insertion of the pectoralis major is completely released, and medial muscle insertion's origins are partially divided to allow the expansion of the medial pocket (along the border of the sternum). Complete detachment of the pectoralis major insertions on the midline above the fourth interspace is not advisable since it increases the risks of an excessive upward muscle retraction, and implants edge palpability and visibility in the cleavage region.

Successive lavages of the surgical site are performed with triple antibiotic Adams' solution, and careful hemostasis control under direct vision is carried out. Neat hemostasis is performed. In order to promote a complete adherence of the different anatomical layers and minimal dead space, a 15 Fr silicone drain is placed in the surgical bed and extracted through a newly performed 0.5 cm incision at the anterior axillary line at a level inferior to the IMF. If axillary dissection was performed, a second drain will be left in position.

Placement of the Mesh

Meshes, as well as implants, must be handled with maximum care to avoid any risk of contamination. We recommend changing to powder-free gloves prior to manipulation. Mesh tailoring is performed on a side table, and its contact with the skin should be avoided. The mesh width should be that necessary to place the implant on its partial retropectoral pocket without any resistance or traction applied to the muscle after its placement. Usual width with the employed implants volume is of 4–5 cm. Mesh length will be that necessary to cover the implant in its inferior border and usually is between 12 and 15 cm depending on the patient's chest width. Two ribbons of mesh, one lateral and one inferior, are placed mimicking the anatomy of the muscles usually employed in pocket creation: the serratus anterior (lateral ribbon) and the rectus abdominis (inferior ribbon). If the implant is rounded, the ribbon will be placed in an oblique fashion (Fig. 4.1a). Thus, the mesh will exert forces against implant displacement activated by the pectoralis major contraction. If the implant is shaped, the lateral ribbon will be placed at a higher position holding the lateral-superior edge of the implant so as to avoid its displacement and rotation (Fig. 4.1b).

An immediate two-stage implant-based reconstruction may also be performed with the described technique. The synthetic mesh will be used when placing the tissue expander in the same manner as previously described. This approach is preferred when an implant larger than 450 cc will be needed in the definitive reconstruction to achieve symmetry with the contralateral healthy breast. In these cases, the initial tissue expander volume at the end of the surgery is usually higher than the one achieved with the classic retromuscular approach since the pocket has a larger size (Fig. 4.2c). Additionally, the desired end of expansion volume can be achieved in a shorter period of time and with an improved projection of the lower pole.

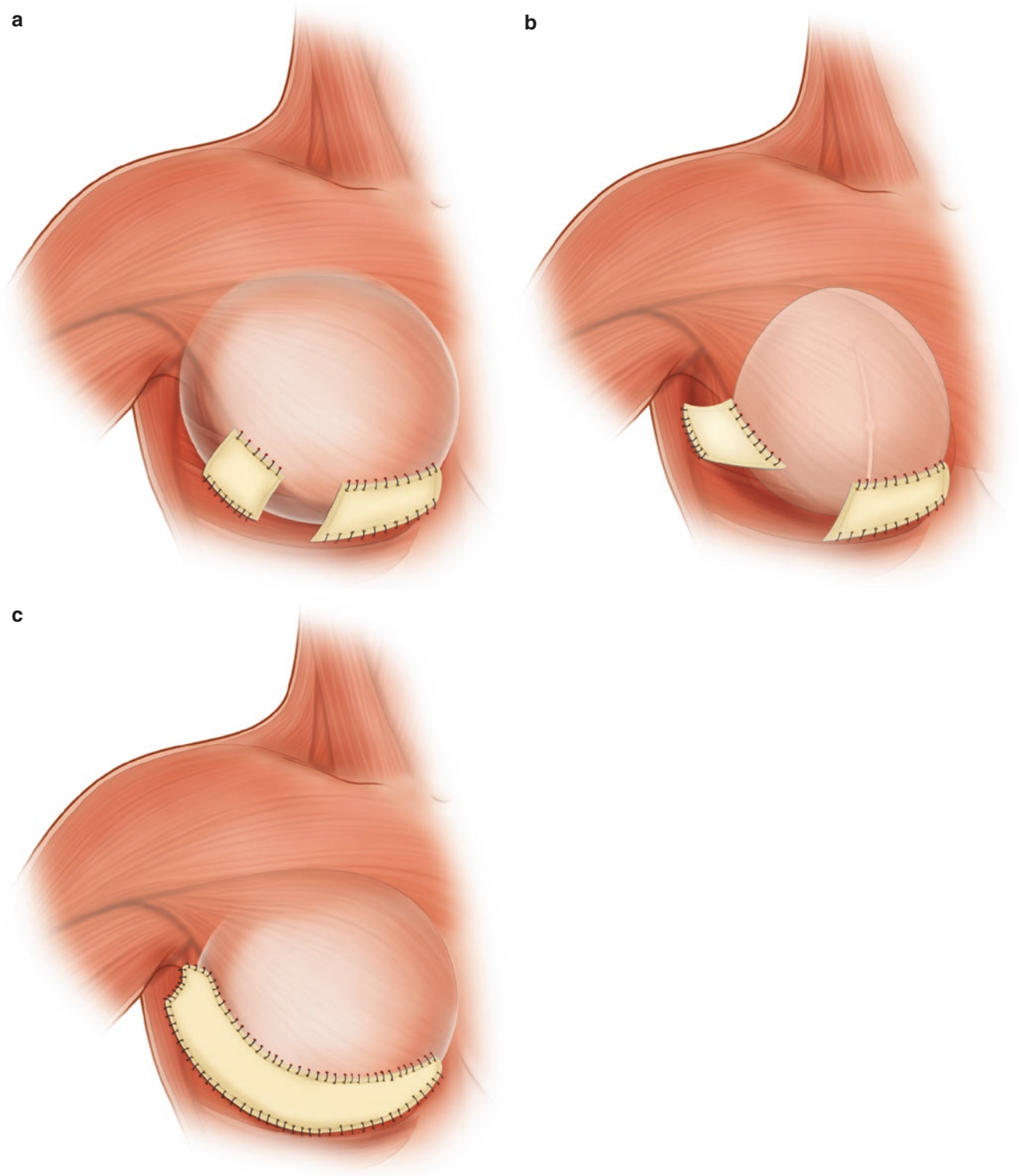

Fig. 4.1 Placement of the synthetic mesh: (**a**) Two ribbons of mesh, one lateral and one inferior, are placed mimicking the anatomy of the muscles usually employed in pocket creation: the serratus anterior (lateral ribbon) and the rectus abdominis (inferior ribbon). If the implant is rounded, the ribbon will be placed in an oblique fashion; (**b**) if the implant is shaped, the lateral ribbon will be placed at a higher position holding the lateral-superior edge of the implant so as to avoid its displacement and rotation; and (**c**) the synthetic mesh can also be placed as an inferolateral sling totally covering the lower pole of the implant

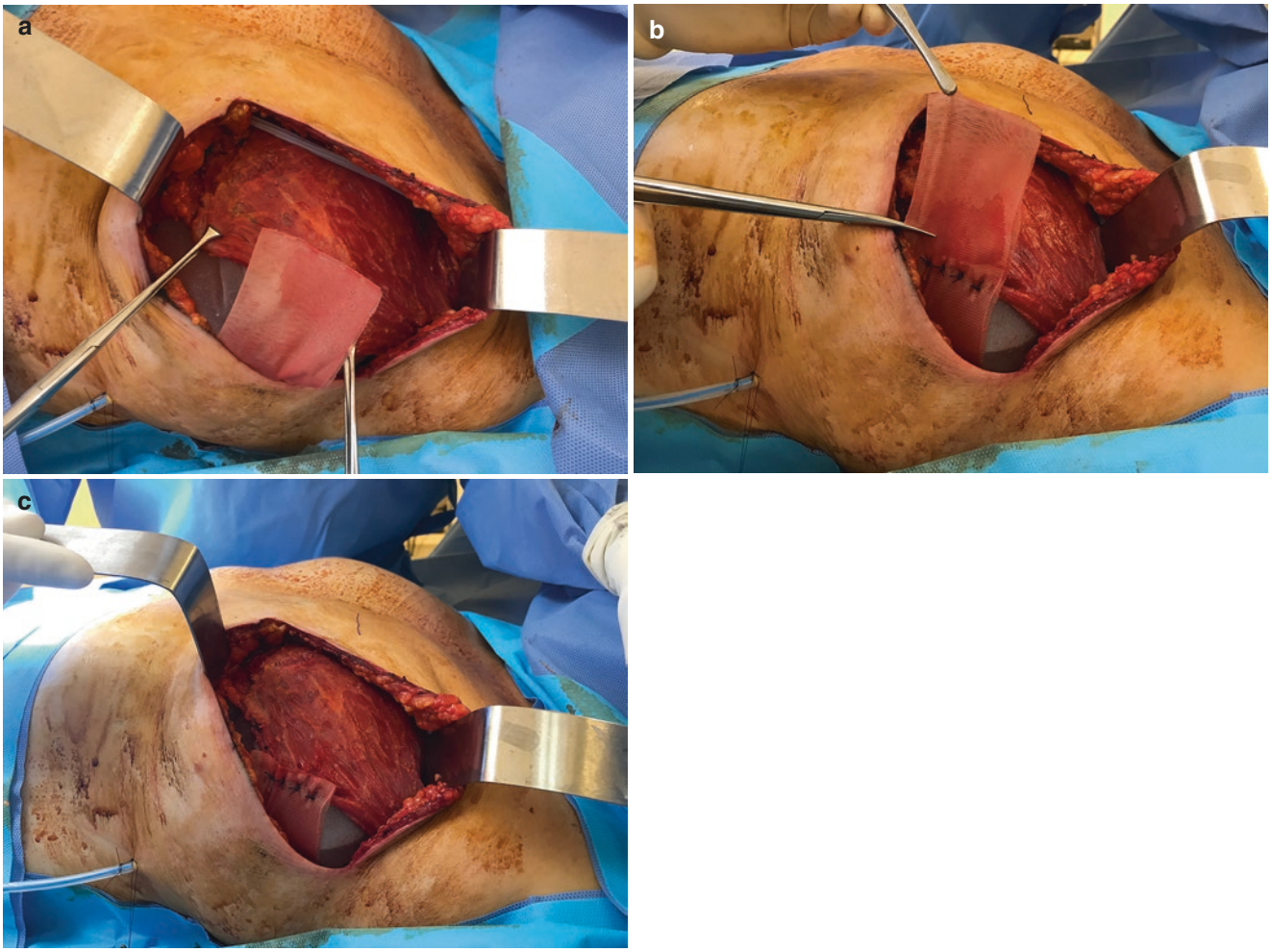

Fig. 4.2 Placement of the mesh with the ESP technique: (**a**) A 550 cc expander is placed in the submuscular space, and the muscle, which is initially partially retracted, is delicately stretched with Allis clamps by the surgical assistant; (**b**) the superior border of the mesh is fixated to the lateral free border of the pectoralis major muscle, generating an extension of the actual muscle, improving in this way the muscle coverage of the expander. The mesh excess is cutoff; and (**c**) since the pocket has a larger size, the initial tissue expander volume at the end of the surgery is 250 cc, a volume usually higher than the one achieved with the classic retromuscular approach

The mesh is first fixed to the chest wall with interrupted polyglactin or polypropylene sutures, depending on the type of mesh being used. Placement of this sutures is of paramount importance since they will determine implant inferior position and consequently recreate the IMF height. Fixation should follow a curved fashion with superior concavity and is performed from medial to lateral. Maximum symmetry with the contralateral healthy breast is attempted. Care to avoid any folds must be taken while fixing the mesh to the fascia and muscle. The selected implant is then placed in the submuscular space, and the muscle, which is initially partially retracted, is delicately stretched with Allis clamps by the surgical assistant (Fig. 4.2a). Once the expander or implant is in position, the superior border of the mesh is fixated to the inferior detached and lateral free border of the pectoralis major muscle, generating an extension of the actual muscle. Stitches are usually placed 1 cm away from the muscles and 0.5–0.8 cm from the mesh free borders. This will prevent potential bulging by the material stacking and excessive tension that may produce muscle laceration. The mesh excess is cutoff (Fig. 4.2b). Closure of the skin is performed by inverted 4.0 polydioxanone stitches (PDS: Ethicon, Somerville, NJ, USA) in a two-plane fashion and completed with an intradermal running 4.0 poliglecaprone suture (Monocryl: Ethicon, Somerville, NJ, USA).

Postoperative dressing is performed with gauze and fixed in position with auto-adherent transparent film (Tegaderm: 3M, Maplewood, MN, USA). No compression garment or elastic bra should be used in the immediate postoperative period in order not to compromise flap vitality.

Technical Variations

Mesh Placement as a Single Inferolateral Sling

The lower border of a full sheet of mesh is sutured inferiorly to the rectus abdominis fascia and laterally to the serratus anterior fascia, along the inferior and lateral mammary folds, creating the boundaries of the implant pocket. After the implant is placed into the created pocket, the mesh is secured to the inferolateral margin of the pectoralis major muscle, and the excess mesh is cut off. In this fashion, the synthetic mesh is sutured in place, as a single inferolateral sling, totally covering the lower pole of the implant (Fig. 4.1c).

Postoperative Care

Drains are removed when their daily output is less than 30 ml. Patients are kept on oral antibiotics (first-generation cephalosporin) until the drain removal, similarly to what is described by many authors when utilizing ADM in primary implant-based breast reconstruction cases [23]. Postoperative pain is managed with oral NSAIDs during a period of 5–7 days and then is usually suspended by the patient herself. The use of a supportive brassiere is recommended from the fifth postoperative day during the first control and should be worn for a 4- to 8-week period.

Complications reported with this approach are identical to those described with the submuscular approach and include hematoma, seroma, infection, skin slough, capsular contracture, and rippling [24]. All of them can be treated in a traditional fashion. In our experience of more than 13 years, the incidence of seroma has been negligible which has been confirmed in a recent study [25].

Infection is one of the most common complications seen with both biological and synthetic mesh use, which often leads to tissue necrosis, and may result in revision surgery or even complete loss of implant [26, 27]. The low incidence of infection seems to be related to the resistance to bacteria biofilm formation of polyglactin meshes [20]. On the other hand, the use of an absorbable mesh, as the polyglactin mesh, implies a reduced risk of extrusion or complications, such as sinus tract formation, usually observed when dealing with their synthetic counterpart [28]. In a recent comparative study by Meyer Ganz et al., they report a similar rate of early and late surgical revisions when performing immediate implant-based breast reconstruction with the adjuvant use of a polyglactin mesh in a partial subpectoral fashion when compared to a total retromuscular pocket [29].

Clinical Cases

Case 1

A 48-year-old woman with right lobular breast carcinoma underwent nipple-sparing mastectomy. Immediate direct-to-implant breast reconstruction was performed with a 465 cc textured shaped silicone gel implant and polyglactin mesh (Fig. 4.3a, b).

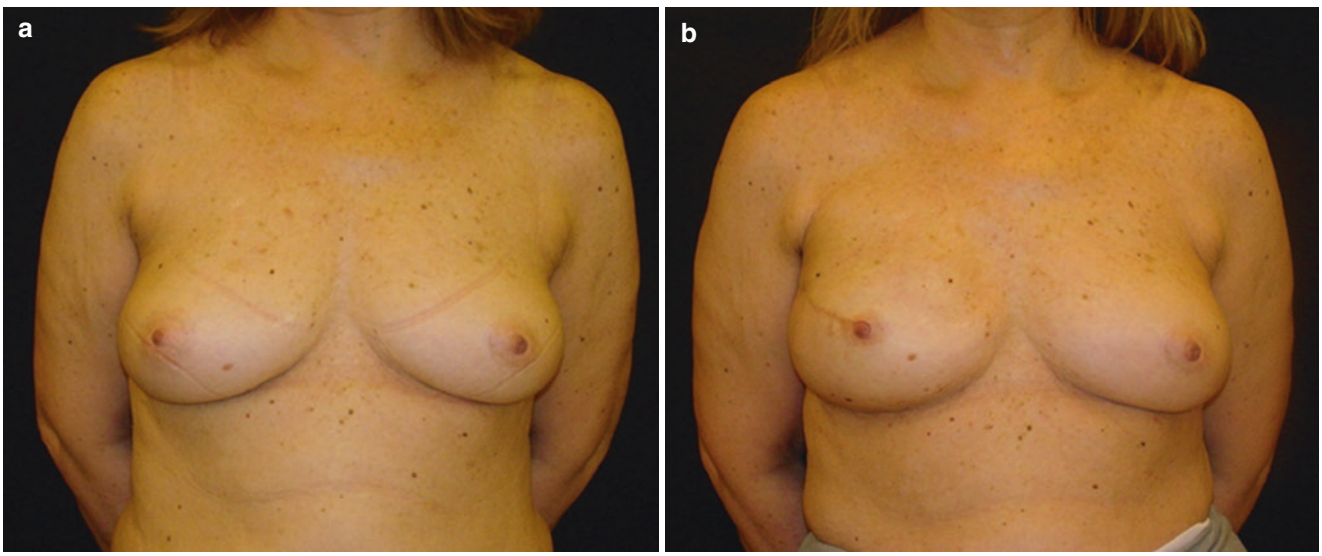

Fig. 4.3 (**a**) Preoperative frontal view; (**b**) postoperative frontal view at 1 year

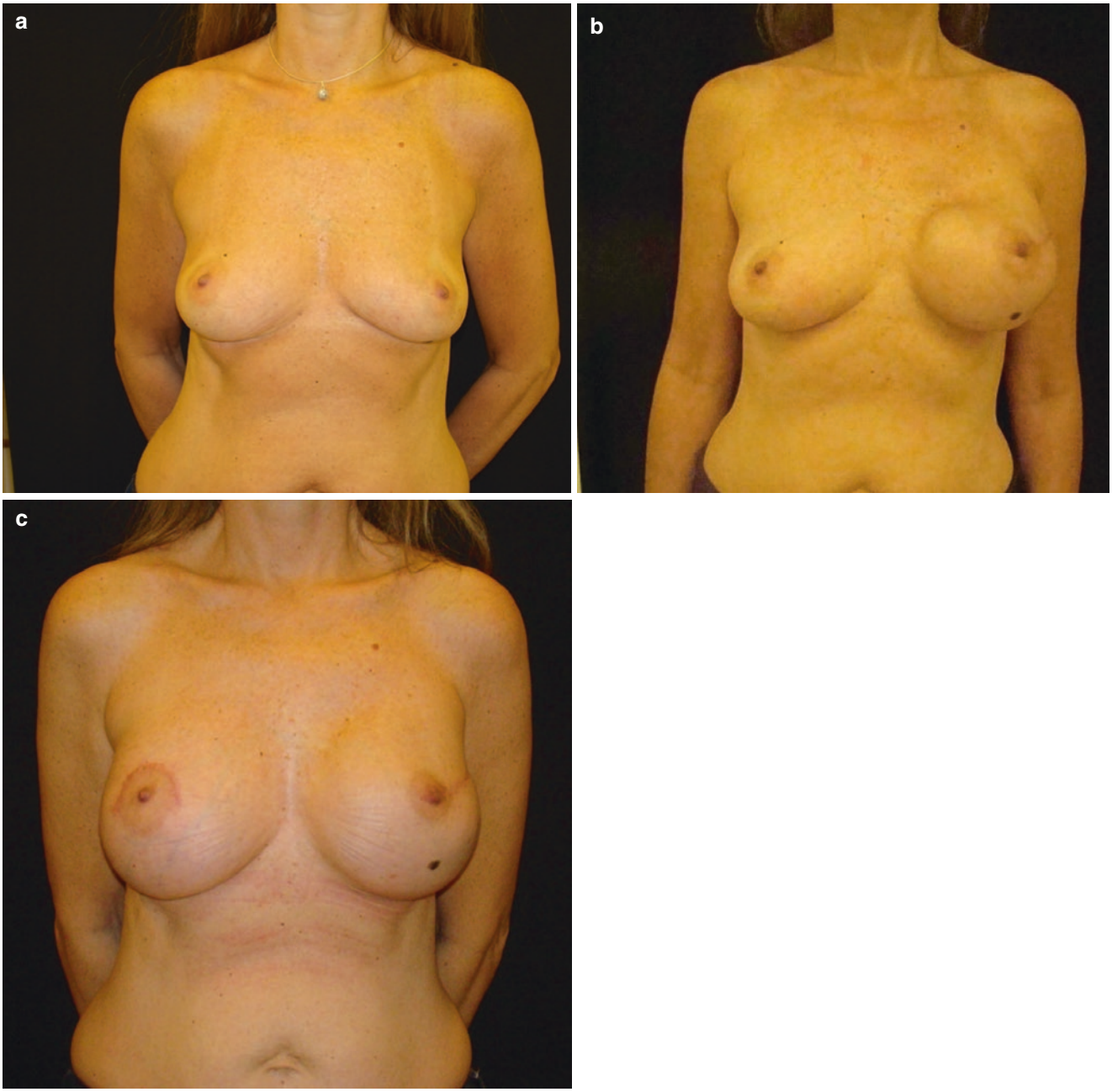

Fig. 4.4 (**a**) Preoperative frontal view; (**b**) following completion of tissue expansion and (**c**) postoperative frontal view at 1 year

Case 2

A 42-year-old patient affected by a left breast ductal carcinoma in situ (DCIS) underwent nipple-sparing mastectomy. Immediate two-stage breast reconstruction was performed with a 550 cc textured shaped expander and polyglactin mesh that allowed a larger intraoperative filling volume. During the second-stage procedure, 4 months later, the expander was replaced by a 555 cc textured shaped silicone implant, and the contralateral breast was augmented with a 225 cc textured round silicone implant for symmetry (Fig. 4.4a–c).

Conclusions

The use of meshes may be defined as one of the greatest advancements in breast reconstruction techniques during the last decade. The use of both biological and synthetic meshes has shown an increasing popularity in breast reconstruction, allowing the performance of some procedures that could not be previously done. Their use is becoming a standard of care in the majority of reconstructive centers due to the overwhelming results.

Although the use of synthetic meshes offers a low-cost alternative to ADMs in implant-based breast reconstruction with favorable aesthetic results, there is still no consensus on whether synthetic or biological matrices have the best outcomes. To make things harder, within each group there is a large list of different materials, biologic origins, and production processing to select from. To date, prospective randomized trials to support the use of any biologic or synthetic mesh or compare the outcomes with the utilization of one or the other to prove superiority are missing. The use of a particular mesh type and material is based predominantly on single surgeon experience or retrospective studies.

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Biologic Meshes in Breast Reconstruction

5

Paolo Persichetti, Barbara Cagli, and Rosa Salzillo

Introduction

Implant-based breast reconstruction (IBBR) is the most commonly used surgical technique after mastectomy. According to the American Society of Plastic Surgeons, in 2017, 81.8% of reconstructions after mastectomy were implant based, whereas 18.2% were autologous reconstructions [1]. Both the expander-implant (EI) two-staged approach and the direct-to-implant (DTI) single-staged approach may present disadvantages: placing a tissue expander in a total submuscular pocket requires an extensive dissection that might be associated with pain during the expansion phase and a flat unnatural look of the breast; on the other hand, placing an implant in a partial submuscular pocket where the inferior pole is covered by the mastectomy flap only puts it at risk of exposure in case of flap necrosis or infection. In both cases, it is hard to control the position of the inframammary fold (IMF), avoid animation deformity and implant displacement, and achieve a natural-looking ptosis of the reconstructed breast.

The introduction of acellular dermal matrices (ADMs) in the clinical practice probably represents the greatest advance in breast reconstruction in the last decade. Biological meshes have been used in soft tissue reconstruction since 1995, when they were first applied for treatment of burns [2] and, in the following years, for abdominal wall, head and neck, urogynecologic reconstruction, hand surgery, and wound healing. The first paper in literature documenting the use of an ADM in breast reconstruction was published in 2005 by Breuing and Warren [3]; however, Salzberg et al. performed the procedure in 2001 but did not publish their findings until 2006 [4].

Biologic meshes can be subdivided in human-derived acellular dermal matrices (hADM) and xenografts, derived from nonhuman sources (porcine, bovine, equine). In the United States, hADMs are sourced by accredited tissue banks that follow the standards for donation set forth by the Food and Drug Administration [5]; concerning xenografts, animal sources must conform to region-specific industry guidance documents, which are meant to address spongiform encephalopathy and other zoonoses [6]. According to the European legislation (European Community (EC) directive 2004/23/EC), companies producing human-derived ADMs (hADMs) outside the EC are not allowed to commercialize them in Europe, hADMs being "human products" and not "medical devices," so being ruled by European legislations on transplants [7]. The Skin Bank of the Bufalini Hospital (Cesena, Italy) obtained in 2009 from the Italian National Transplant Center and National Health Institute the approval for the production and distribution of a new human cadaver-donor-derived ADM named with the Italian acronym MODA (matrice omologa dermica acellulata) that is to date the only human-derived ADM available on the European market [7].

Biologic meshes are processed using different and often proprietary techniques [8] in order to remove donor cells' antigens and potential pathogens while retaining structurally intact ECM. After implantation, the patient's blood infiltrates the matrix, adding host stem cells that adhere to the matrix, differentiate, and promote neovascularization and incorporation into the surrounding tissue [9]. Conversely, synthetic meshes are made of absorbable, long-term-absorbable, or non-absorbable material that promotes a scarring reaction around the mesh resulting in thickening of the subcutaneous tissue underlying the mastectomy flap. After processing, ADMs can be aseptic or sterile. Aseptic ADMs are treated in a disinfection solution that cleans the tissue so that it passes the US Pharmacopeia Chapter 71 (USP 71) sterility test. Many products are treated with an additional terminal sterilization step that provides a sterility assurance level (SAL). Aseptic products have a SAL of 10^{-3} indicating that 1 in 1000 can be potentially infected, whereas sterile products, which are often terminally sterilized through gamma irradiation or e-beam sterilization, have a SAL of 10^{-6} indicating that no more than one in a million products could be potentially infected. Implantable medical devices

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are usually required to have a SAL of 10^{-6}. Many studies attempted to outline the differences in outcomes and infection rates among different ADMs, but reported data are still controversial [10–12].

The first ADMs on the market were frozen or freeze-dried: this implied a long preparatory soak time to thaw the matrix and make it usable in the operatory room. Therefore, they are being supplanted by prehydrated and room temperature stable ADMs that are easier to storage and require a shorter preparatory soak time, hence optimizing time efficiency in the operatory room.

Many ADMs are shaped as an ellipse and are often used as an inferolateral sling for partial submuscular reconstruction; others present more complex shapes for circumferential wrap of implants in prepectoral breast reconstruction.

ADMs can be fenestrated or non-fenestrated: fenestrations allow any fluid accumulation around the implant to drain into the space underneath the mastectomy flap, thus facilitating fluid uptake by lymphatics. It has been shown that they decrease the incidence of seromas, pain, length of stay, and days prior to drain removal [13, 14]. Some matrices have chemically induced collagen cross-linkage to make the collagen more resistant to degradation and consequently more resistant to high-tension exposure [9]. However, cross-linkage prolongs the time of incorporation of the matrix itself because it potentially increases foreign body reaction and encapsulation [12].

Thick mastectomy skin flaps increase the degree of cellular infiltration, neovascularization, and degradation of the biologic mesh [15]. Conversely, thicker matrices have slow neovascularization; therefore, they tend to be incorporated at a slower rate [16]; this translates into higher rates of seroma and increased number of days prior to drain removal [17]. Nonetheless, thicker matrices seem to be less pliable than other matrices; hence, they provide a minor laxity important to achieve a natural lower pole coverage, but they retain a higher tensile strength and might be useful especially in secondary revisions and prepectoral breast reconstructions.

Almost all hADMs have a polarity: they present a basement membrane side and a dermal side containing a vascular network. In breast reconstructions, the dermal side is recommended to face the mastectomy flap [18]. This side is often marked by the company in order to be easily recognizable; if uncertainty still remains after visual inspection, a "blood test" can be performed to clearly reveal the orientation: the physician places a drop of blood onto the rehydrated matrix. The dermal side absorbs blood and will retain a deep red appearance after rinsing, while the basement membrane side of the sheet will repel blood and may only appear lightly pink after rinsing [18]. Conversely, almost all xenografts do not have any orientation. The specific composition, processing technique, and characteristics vary among the several products present on the market and are outlined in Table 5.1 and 5.2.

The purpose of this chapter is to outline the indications, patient selection, surgical techniques, and possible complications deriving from the use of biologic meshes in breast reconstruction.

Table 5.1 hADMs found in the primary implant-based breast reconstruction literature

Product	Cross-linking	Processing	Sterility	Preparatory soak time	Orientation	Shelf life	Contraindications
AlloDerm	Noncross-linked	Sodium chloride, sodium deoxycholate and freeze drying	Aseptic	10–40 min	Basement membrane and dermal sides	2–5 years	Allergy to polysorbate 20 or other antibiotics listed on package
AlloDerm RTU	Noncross-linked	Sodium chloride, sodium deoxycholate, freeze drying and e-beam irradiation	SAL 10^{-3}	2 min	Basement membrane and dermal sides	2–5 years	Allergy to polysorbate 20 or other antibiotics listed on package
AlloDerm SELECT	Noncross-linked	Sodium chloride, sodium deoxycholate, freeze drying and e-beam irradiation	SAL 10^{-3}	2 min	Basement membrane and dermal sides	2–5 years	Allergy to polysorbate 20 or other antibiotics listed on package
AlloMax (formerly marketed as NeoForm)	Noncross-linked	Tutoplast® and Gamma irradiation	SAL 10^{-6}	5 min	Basement membrane and dermal sides	5 years	None stated in instructions for use
CG CryoDerm	Noncross-linked	Sodium chloride, "detergents" and freezing	"Terminally sterilized"	3 min (to thaw)	Basement membrane and dermal sides	5 years	Not available
CG Derm	Noncross-linked	Sodium chloride, "detergents" and freeze drying	"Terminally sterilized"	3 min	Basement membrane and dermal sides	Not available	Not available
Cortiva	Noncross-linked	Tutoplast® and Gamma irradiation	SAL 10^{-6}	30 s	None	5 years	Not available

Table 5.1 (continued)

Product	Cross-linking	Processing	Sterility	Preparatory soak time	Orientation	Shelf life	Contraindications
DermACELL	Noncross-linked	Matracell technology	SAL 10^{-6}	None	Basement membrane and dermal sides	2 years	Allergy to gentamicin or vancomycin
DermaMatrix	Noncross-linked	Sodium chloride, "detergents", acidic/antiseptic agents, and freeze drying	USP 71	3 min	Basement membrane and dermal sides	3 years	Autoimmune CTD
Epiflex	Noncross-linked	Sodium chloride, "detergents", acidic/antiseptic agents, and freeze drying	USP 71	> 30 min	Basement membrane and dermal sides	5 years	Not available
FlexHD pliable/ shaped/ perforated	Noncross-linked	Decellularization in hypertonic bath, and packing in 70% ethanol	USP 71	Soak of unstated duration	None	Not available	None stated in instructions for use
FlexHD pliable	Noncross-linked	Decellularization in hypertonic bath, and packing in 70% ethanol	USP 71	Soak of unstated duration	Basement membrane and dermal sides	Not available	None stated in instructions for use
FlexHD	Noncross-linked	Decellularization in hypertonic bath, and packing in 70% ethanol	USP 71	Soak of unstated duration	Basement membrane and dermal sides	3 years	Autoimmune CTD
hMatrix	Noncross-linked	Amalgatome and saline soaks, "antimicrobial solutions," and freezing	SAL 10^{-6}	15–20 min (to thaw)	None	5 years	Not available
Megaderm	Cross-linked	Alloclean process and e-beam sterilization	SAL 10^{-6}	Not available	Not available	Not available	Not available
MODA (matrice omologa dermica acellulata)	Noncross-linked	Decellularization in 2.5% trypsin 10 in an incubator, washes with sterile 0.9% NaCl for ≥15 minutes, freezing and gamma-ray irradiation (100 Gy)	SAL 10^{-6}	Not available	Not available	Not available	None stated

CTD connective tissue disease

Table 5.2 Xenografts found in the primary implant-based breast reconstruction literature

Product	Source	Cross-linking	Processing	Sterility	Preparatory soak time	Orientation	Shelf life	Contraindications
Braxon	Porcine dermis	Noncross-linked	Withheld as proprietary	SAL 10^{-6}	5 min	Shaped for breast	Not available	Previous radiotherapy, diabetes and CTD
Equity	Equine pericardium	Noncross-linked	"Enzyme deantigenation process" and freeze drying	SAL 10^{-6}	5 min	None	5 years	Sensitivity to equine materials. Not indicated after recent radiation treatment.
Meso BioMatrix	Porcine peritoneum	Noncross-linked	Optrix process	SAL 10^{-6}	Few minutes	None	2 years	Sensitivity to porcine materials.
Native	Porcine dermis	Noncross-linked	Ethylene oxide, freeze-dried	SAL 10^{-6}	5 min	None	5 years	Sensitivity to porcine materials. Do not use Betadine on the matrix and into the surgical field where it will be placed
Permacol	Porcine dermis	Cross-linked	Enzymatic decellularization,cross-linking with hexamethylene diisocyanate, and Gamma irradiation	SAL 10^{-6}	None	None	3 years	Sensitivity to porcine materials
Protexa	Porcine dermis	Noncross-linked	"Enzymatic-chemical-physical treatment at low temperature"	SAL 10^{-6}	15–20 min	None	Not available	Not available

(continued)

Table 5.2 (continued)

Product	Source	Cross-linking	Processing	Sterility	Preparatory soak time	Orientation	Shelf life	Contraindications
Strattice	Porcine dermis	Noncross-linked	Sodium deoxycholate and processed and preserved in patented phosphate-buffered aqueous solution	SAL 10^{-6}	3 min	None	1.5 years	Sensitivity to porcine materials or polysorbate 20
SurgiMend PRS	Fetal bovine dermis	Noncross-linked	Processing withheld as proprietary; ethylene oxide sterilization	SAL 10^{-6}	1 min	None	3 years	Sensitivity to collagen or bovine products
Tutomesh	Bovine pericardium	Noncross-linked	Tutoplast process	SAL 10^{-6}	None	None	5 years	Not available
Veritas	Bovine pericardium	Noncross-linked	Sodium hydroxide, propylene oxide, ethanol and undisclosed irradiation	SAL 10^{-6}	None	None	3 years	Sensitivity to bovine products
XCM	Porcine dermis	Noncross-linked	Optrix process	SAL 10^{-6}	None	None	Not available	Sensitivity to porcine products, patients undergoing desensitization injections to meat products. Rolling, folding, and layering of the product are contraindicated

CTD connective tissue disease

Anatomy

The muscles involved in the creation of a partially submuscular pocket, according to our technique, are the pectoralis major muscle, the pectoralis minor muscle, and the serratus anterior muscle. The pectoralis major is a fan-shaped muscle that lies beneath the mammary gland. Its clavicular head originates from the medial half of the clavicle, while the sternal head originates from the sternum and the first to sixth upper costal cartilages. This muscle inserts on the lateral lip of the intertubercular groove of the humerus and the crest of the greater tubercle of the humerus. When creating a submuscular pocket, the inferolateral margin of the pectoralis major is identified, and dissection starts from here to elevate the muscle. The pectoralis minor muscle lies beneath the pectoralis major. It originates from the external surface of the third to fifth rib and inserts on the coracoid process of the scapula. The serratus anterior muscle originates from the surface of the first to eight rib and inserts along the medial border of the scapula. The lower part of this muscle is elevated, according to our technique, and sutured to the pectoralis major in order to guarantee lateral coverage of the implant.

Patient Selection

Despite several benefits of ADMs' use in IBBR have been thoroughly described, a recent meta-analysis [19] of 23 studies reported that the relative risks for major infection, overall infection, flap necrosis, and seroma are significantly higher when ADMs are used; conversely, ADMs were associated with lower risks of capsular contracture and implant displacement.

Various factors might be responsible for an increased risk for complications following postmastectomy breast reconstruction [20]:

- Patient characteristics: age > 50 years, smoking history, body mass index (BMI) > 30 kg/m^2, and larger breast size
- Medical factors: diabetes mellitus, current steroid use, adjuvant radiotherapy, adjuvant chemotherapy, and history of radiotherapy
- Surgical factors: previous incisions, history of breast reduction, lift and augmentation, previous breast lumpectomy, greater expander fill volume, axillary dissection, longer operative time, nipple-sparing mastectomy, and poor quality of the mastectomy flap (insufficient vascularity, thin flaps, extensive undermining of flaps)
- ADM characteristics: aseptic vs sterile, perforated vs intact, and contoured vs flat

Given the potential risks of seroma and infection, we believe that accurate patient selection is pivotal in the attempt to minimize complications. We hereby analyze, according to our experience, the factors that we consider fundamental when selecting a patient for IBBR (Table 5.3).

Obesity (BMI > 30 kg/m^2) has been linked to surgical and medical complications in the perioperative period [21] because it affects the normal physiology through several mechanisms. Animal studies have shown that the skin of obese mice is mechanically weaker and unable to generate as much hydrothermal isometric force as the skin of lean mice, believed to be due to a mismatch between the increase in skin surface area and collagen deposition [22]. Decreased collagen deposition results in impaired wound healing in obese mice [21]. Additionally, obesity is associated with a

Table 5.3 Patient selection criteria for DTI IBBR with ADMs

Nipple sparing (NSM) and skin sparing mastectomy (SSM)
Minimal or absent ptosis of the contralateral breast
Good quality of the mastectomy skin flap
Adjuvant radiotherapy
BMI < 30 kg/m^2
Nonactive smoker

chronic, low-grade systemic inflammation that displays minimal increase in circulating proinflammatory factors and lacks the typical clinical signs of inflammation and may play a role in decreased flap survival [23]. The increased rate of infection and necrosis might be due to poor perfusion of the edges further from the vascular inflow leading to relative hypoxia of these tissues [24]; furthermore, hypoxia impairs collagen synthesis resulting in deficient wound healing. Therefore, we tend not to choose a DTI approach with ADM in obese patients; in these cases, we rather perform a two-staged breast reconstruction taking advantage of the possibility of deflating the tissue expander if signs of hypoperfusion of the mastectomy flap arise.

Smoking is known to reduce the oxygen supply to peripheral tissues that might lead to infection and necrosis of the mastectomy flap, with potential implant exposure, especially if other risk factors coexist in the same patient. We strongly discourage patients from smoking and exhort them to quit smoking at least 4 weeks prior to the scheduled surgery.

Despite the protective effect of ADMs against radiation-induced capsular contracture [4, 25], the proinflammatory effect of radiation therapy may disrupt normal ADM remodeling and affect its integration with the mastectomy flap [26]. We tend to use a DTI approach with ADMs in patients who undergo adjuvant radiotherapy rather than patients who received neoadjuvant radiotherapy. In this way, the radiation damage hits the breast when the ADM is already integrated with the mastectomy flaps and is therefore able to exert its protective effect against capsular contracture.

Poor perfusion of the mastectomy flap is the main reason for early complications following nipple-sparing mastectomy (NSM) and skin-sparing mastectomy (SSM) [27]. Hence, an adequate perfusion of the mastectomy flap is an important predictor for a successful breast reconstruction. Perfusion of the mastectomy flap can be assessed through clinical observation (flap temperature, tissue color, capillary refill, and dermal bleeding) alone or paired with the use of devices such as laser Doppler, transcutaneous oxygen (TCO_2) measurement, fluorescein-based angiography, or indocyanine green (ICG) laser angiography [27]. Particularly, ICG laser angiography has the advantage of allowing repeated evaluations during the same surgical procedure, thanks to its short plasma half-life (3–5 minutes), and its use has been associated with reduced rates of necrosis and flap loss [27].

Considering the anatomy of the vascular network nourishing breast skin, the mastectomy skin flap thickness is relevant to prevent and reduce necrotic complications, as preserving a flap thickness of more than 1.5 cm, when oncologically safe, allows the NAC to base its vascular supply on the subcutaneous plexus as well as on the dermal and subdermal plexus [28]. While performing the mastectomy, it is critical to follow the plane between the breast gland and subcutaneous fat in order to maximize the blood supply to the mastectomy flaps and NAC [29]. The thickness of the subcutaneous layer is not related to BMI, breast size, or age [30]. Rancati et al. [28, 30] reported that it is possible to determine the thickness of the breast subcutaneous tissue using preoperative digital mammogram and introduced a breast tissue coverage classification (Table 5.4) aimed at foreseeing the postmastectomy flap viability and consequently choosing the best reconstructive option. Thin flaps may implicate a high risk of tissue suffering, and immediate reconstruction might not be safe. Otherwise, a flap thickness of 2 cm or more provides a reliable coverage. In these cases, DTI reconstruction could represent a good option [28]. We find this classification very helpful during the preoperative planning, but always check intraoperatively the viability of the mastectomy skin flaps.

Table 5.4 Breast tissue coverage classification according to digital mammogram [28, 30]

Type 1	Up to 1 cm	Poor coverage
Type 2	Between 1 and 2 cm	Medium coverage
Type 3	More than 2 cm	Good coverage

ADMs have several applications in both primary and revisional implant-based breast reconstruction such as expanding the submuscular pocket to enhance both EI and DTI breast reconstruction, correct symmastia, camouflage surface irregularities and rippling, correct inframammary pole malposition, and provide interface when performing capsulotomies or capsulectomy for recurrent capsular contracture.

Primary Implant-Based Breast Reconstruction

When IBBR is planned, it is pivotal to guarantee a good and reliable soft tissue coverage over the implant in order to prevent infection, extrusion, or displacement. IBBR with ADMs can be performed in a subpectoral or prepectoral plane and, in either case, it can involve an EI two-staged approach or a DTI single-stage approach that is chosen considering several factors such as viability of the mastectomy flap, degree of mastectomy skin sparing, and desired postoperative breast volume. The subpectoral approach is the most widely used among surgeons worldwide and represents the standard of care in IBBR.

Placing a biological mesh to bridge the gap between the inferolateral edge of the pectoralis major muscle and the inframammary crease allows inferolateral implant coverage, potentially reducing infection and implant loss, avoids superior migration and window shading of the pectoralis muscle,

enables better projection of the inferior pole and better definition of the IMF, and increases control over the implant pocket size and location, hence reducing the risk of implant displacement [18] (Fig. 5.1). This leads to a more natural-looking breast with low complication rates.

ADMs may have a prohibitive cost for developing countries and they might not be commercially available in others. Autologous tissues can be used in selected patients as a valid alternative to ADMs [32, 33].

Despite its advantages, submuscular implant placement has been associated with several complications such as breast animation deformity on contraction, pain, and functional impairment of the pectoralis major muscle. Hence, some surgeons have recently adopted a prepectoral approach that consists in placing the implant completely covered with ADM in a prepectoral plane. They suggest that the ADM provides an excellent aesthetic outcome by camouflaging upper pole irregularities and avoids implant displacement by creating a well-defined pocket while sparing the complications associated with the detachment of the pectoralis muscle [34]. Prepectoral implant positioning can lead to the development of traction rippling, especially in patients with naturally thin mastectomy skin flaps. Outcomes and complication rates vary among the various papers present in the literature, and prepectoral breast reconstruction is considered a viable alternative to the subpectoral approach in both two-staged and DTI [35] approach when an adequately perfused mastectomy skin flap is present [36].

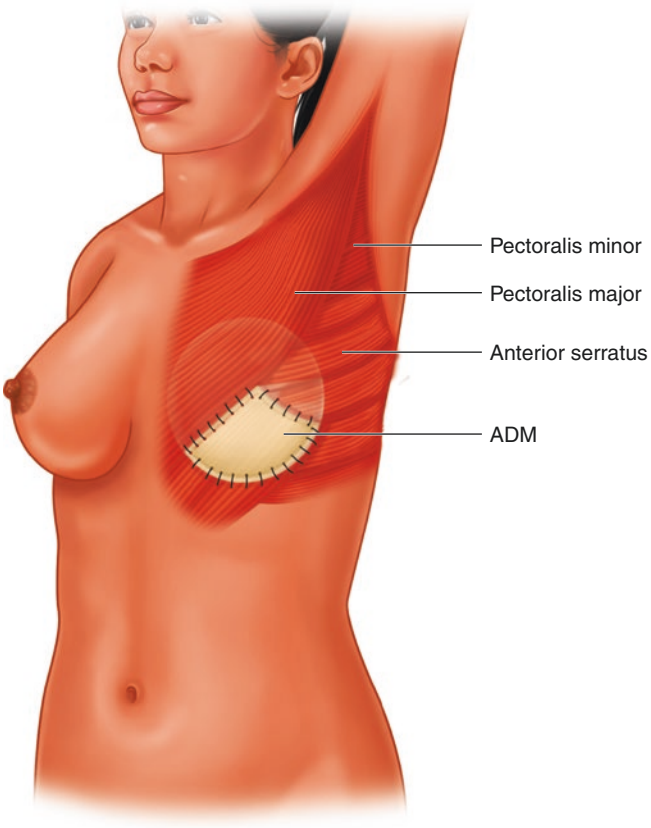

Fig. 5.1 Inferolateral implant coverage with ADM in dual plane IBBR

Revisional Breast Reconstruction Surgery

Implant-related complications vary from capsular contracture to implant rippling and displacement, and revisional procedures can be as frequent as 34–52% within 3–6 years after the primary procedure [37, 38]. The advent of ADMs in breast reconstruction fostered their application in treating implant-related complications, and several studies have demonstrated ADMs' efficacy in correcting implant displacement and capsular contracture and rippling with lower reported recurrence rates and improved cosmesis [39, 40].

Correction of Implant Displacement

Several techniques have been suggested to correct implant displacement [41, 42], but the pillar of corrective surgery is represented by capsulorrhaphy. The efficacy of this technique has been widely demonstrated; however, it does not always prevent the implant from falling against the suture line or moving across it. A well-defined inframammary fold (IMF) is of paramount importance in providing an aesthetically pleasing breast [43]. The "slingshot" capsular flap described by our group [44] proved to be effective in redefining and repositioning the IMF and achieving aesthetically adequate and stable results. This is a very versatile flap, and it was also shown to be a very good option for salvage of exposed breast implants [45]. However, capsular flaps are not applicable in patients with thin capsules and inadequate tissues. Recently, ADMs [25, 42]have been suggested as an alternative to capsular flaps in reinforcing the capsulorrhaphy suture lines and correcting implant displacement. This approach has been proved effective, with good aesthetic results and minimal complications, recurrences, and failures.

Correction of Capsular Contracture

Capsular contracture is the most common complication associated with breast implant placement [46]: it causes hardening of the breast leading to discomfort, pain, and poor aesthetic outcomes, often requiring revisional surgery. Surgical approaches aimed at correcting capsular contracture involve partial or total capsulectomy followed by implant pocket change, open capsulotomy, and implant exchange, but are not always able to prevent recurrence. It is

well known that irradiation before or after mastectomy is a strong predictor for the development of capsular contracture and significantly increases the likelihood of worse clinical outcomes [47]. With the introduction of ADMs in IBBR, surgeons have reported lower rates of capsular contracture [4, 25, 48, 49]. It has been suggested that ADMs minimize the inflammatory response, hence reducing capsule formation around implants [50]. These encouraging data led many surgeons to use ADMs for the correction of capsular contracture, and it has been reported that more than 90% of Baker III–IV capsular contractures have been successfully treated with ADMs with no recurrences in a mean follow-up time of 9–21 months [25, 42]. However, capsular contracture rates are known to increase over time; therefore, comparative studies with a longer follow-up are needed in order to assess the efficacy of ADMs in the treatment of this complication.

Implant Rippling or Wrinkling

Despite the recent development of highly cohesive silicone gel implants, rippling or wrinkling is a possible complication of IBBR, especially in patients left with a very thin mastectomy scar and in prepectoral implant placement. ADMs have been reported to be effective [51] in the treatment of implant rippling or wrinkling because they add volume between the thin mastectomy flap and the implant, making the borders of the implant less visible.

Animation Deformity

Animation deformity is a possible complication of subpectoral implant positioning, and it consists in implant displacement during pectoralis major contraction. Women with large muscle bellies and thin mastectomy skin flaps are most commonly affected. The most effective technique to treat this complication involves performing a total capsulectomy, suturing the pectoralis major muscle back to the chest wall, and transferring the implant to a subcutaneous plane prior to its complete coverage with an ADM in order to ensure precise and long-lasting positioning and to reduce the chance of implant rippling [51].

Preoperative Planning

After an accurate patient selection, examination of the preoperative mammogram, classification of the breast according to Rancati's scheme [28, 30], and optimization of modifiable patient-related risk factors such as obesity and smoking, we proceed with the preoperative markings.

With the patient in standing position, the midline, the midclavicular line, the inframammary folds – and their potential asymmetry – and the breast footprint are marked.

Surgical Technique

According to our experience, we believe that the ideal candidates for the use of ADMs are patients undergoing DTI breast reconstruction after NSM or SSM with a minimal or non-ptotic contralateral breast, nonactive smokers, BMI < 30 kg/m^2, and planning to receive adjuvant radiotherapy. We are able in this way to position a definitive implant without the need of important adjustment procedures on the contralateral breast, hence performing a single-stage breast reconstruction.

Intraoperative evaluation of perfusion and viability of the mastectomy flap is pivotal in order to confirm or dismiss the DTI approach. If the mastectomy flap is too thin and poorly vascularized, positioning a tissue expander might be preferable given the possibility of deflating it if the skin shows signs of hypoperfusion.

After mastectomy and careful hemostasis, the inferolateral margin of the pectoralis major muscle is dissected off the anterior chest wall using electrocautery. The pectoralis minor and serratus anterior muscles are also elevated to the extent of the previously marked footprint of the breast when the pectoralis major alone is not able to guarantee adequate coverage (Fig. 5.2a, b). The ADM is then prepared according to the manufacturer's recommendations and placed at the inferior pole of the just dissected pocket (Fig. 5.2c). The first polyglactin 2/0 suture is placed between the inferior medial corner of the matrix and the medial border of the inframammary fold (Fig. 5.2d). The lower border of the ADM is sutured along the inferior and lateral mammary folds, defining and recreating them (Fig. 5.2e). A drain is then placed in the implant pocket, deep to the ADM. Afterwards, the superior medial corner of the matrix is sutured to the medial aspect of the pectoralis major muscle (Fig. 5.2f), and the implant is inserted beneath the pectoralis muscles and the ADM (Fig. 5.2g). The pectoralis muscles are then sutured to each other and to the serratus anterior muscle on the lateral aspect. The superior border of the matrix is then sutured to the inferolateral margin of the pectoralis major muscle (Fig. 5.2h). Using this technique, the ADM is curved laterally and cephalad along the lateral border of the breast perimeter in an "inferolateral sling" fashion, to recreate the natural curvilinear origins of the inferolateral aspect of the detached pectoralis muscle and breast mound unit. Care must be taken when placing the ADM in order to prevent any wrinkling of the device. Using this approach, the implant is covered by the muscle superiorly and by the ADM inferiorly. The inferior mastectomy flap is then sutured to the pectoralis

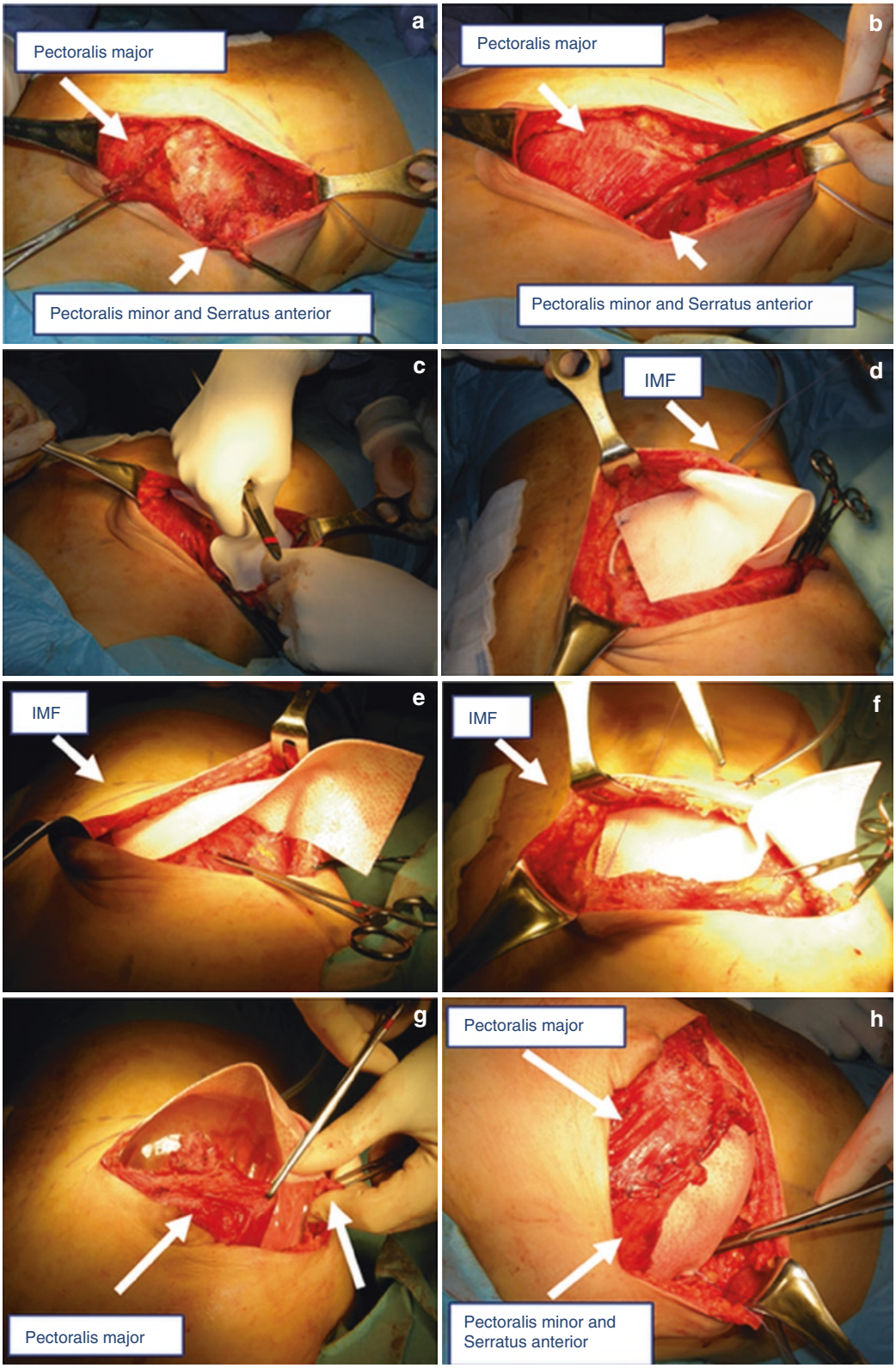

Fig. 5.2 Surgical technique. (**a**, **b**): The submuscular pocket is dissected; (**c**): the matrix is placed in the lower pole of the pocket; (**d**): the first suture is placed between the inferior medial corner of the matrix and the medial border of the IMF; (**e**): the caudal border of the matrix is sutured along the IMF; (**f**): the superior medial corner of the ADM is sutured to the medial aspect of the pectoralis major muscle; (**g**): the implant is placed beneath the pectoralis muscles and ADM; (**h**): the pectoralis muscles are sutured to each other on the lateral aspect, and the superior border of the matrix is sutured to the inferior border of the pectoralis major muscle

major muscle in order to place the cutaneous scar above the muscle; the cutaneous scar should not overly the device in order to prevent ADM exposure if dehiscence or infection of the surgical scar occurs. Subcutaneous and cutaneous sutures are then performed, and compressive dressing is applied to the breast.

Postoperative Management

On first postoperative day, a surgical bra with a full front zip/closure is placed, and the patient is recommended to wear it for at least 8 weeks after surgery. Afterward, the patient is allowed to wear other types of bra, as long as they do not have underwire. Suction drains are removed when they drain less than 50 cc for at least 2–3 days and antibiotics are prescribed until 2 days after drain removal. Sutures are removed 2 weeks after surgery. The patient is recommended to avoid physical activity, especially abduction and weight lifting, for the first 8 weeks postoperatively.

ADMs have several advantages such as enhancing EI and DTI IBBR by expanding the submuscular pocket, guaranteeing good implant coverage in prepectoral IBBR, better definition of the IMF, better inferior pole projection, reduced rates of capsular contracture, and better overall aesthetic outcomes, but they do not come without complications. Complications associated with ADMs in IBBR can be divided as follows:

- Early complications: hematoma, seroma, infection, mastectomy skin flap necrosis, and need for explantation
- Late complications: asymmetry, implant wrinkling or displacement, capsular contracture, and late infection

Complications can delay adjuvant therapy due to non-healing wounds and may require hospital readmissions, pharmacotherapy, and additional procedures; therefore, they can have significant implications for the timing, effectiveness, and overall cost of a patient's breast cancer treatment [26]. Many studies in literature attempt to assess the complication rates associated with the use of ADMs, but the reported data are controversial. The broad diversity of ADM products, patient characteristics, surgical techniques, and study methodologies contribute to a wide variation in the outcomes reported.

Differences between ADMs may influence the rate and extent of host acceptance, inflammation, and organized host response of cell infiltration into the ADM, possibly affecting the risks for infection and seroma formation [20]. Suboptimal decellularization may leave cell remnants that can induce an inflammatory response when implanted. Conversely, excessive damage to the ECM during processing may also increase inflammation while reducing cellular and vascular infiltration of the material, limiting integration [12, 20, 52]. Other studies investigating the complication rates among different ADMs have reported no significant difference among different ADMs [10, 11, 53] and between prepectorally and subpectorally placed ADMs [54].

Several *patient-related factors* can threaten the correct integration of an ADM. Radiation therapy has a proinflammatory effect [55] that may reduce the cellular penetrance into the matrix, disrupt normal ADM remodeling, and affect its integration with the mastectomy flap. Patients irradiated both before and after ADM insertion are at increased risk of poor cellular penetrance and worse integration of the matrix with the mastectomy flap [26].

Exposure of an implanted ADM to chemotherapy is associated with less uniform ECM deposition because these drugs impact ECM protein expression as a mechanism for limiting tumor metastasis [56], and limited vascular penetrance into the scaffold, probably due to chemotherapy-induced downregulation of vascular endothelial growth factor and other molecules resulting in a reduction in angiogenesis. This might translate into alteration of ADM remodeling and limited clinical efficacy [26].

Aging is associated with a reduction in cellular proliferation, particularly fibroblasts [57], putting the matrix at risk for degradation, hence ADM explantation [58]. Smoking limits skin mastectomy flap perfusion and is associated with a less extensive bioabsorption and constructive remodeling of the ADM. Nonetheless, ADM scaffold vascularity in smokers appears to be more widespread, probably as a compensation mechanism for diminished oxygen carrying capacity [26].

Corticosteroid assumption is notoriously linked to delayed wound healing because of downregulation of collagen deposition [59]; ADMs placed in patients taking corticosteroids display a significant reduction in type I and III collagen [26], placing the patient at risk for infection and, eventually, matrix explantation. IBBR with ADMs in patients with large breasts (≥500 g) has been associated with a higher rate of complications, probably because large breasts are less perfused, and this renders ADM incorporation more difficult [54].

Many studies investigated the difference in complication rates between ADM and non-ADM IBBR. A recent meta-analysis [19] of 23 studies reported that the relative risks for major infection, overall infection, flap necrosis, and seroma are significantly higher in ADM IBBR compared to non-ADM IBBR; conversely, ADMs were associated with lower risks of capsular contracture and implant displacement. Consistently with these data, another recently published meta-analysis [60] reported no significant difference in rates of hematoma, seroma, implant explantation, and total amount of revisional procedures when comparing hADM IBBR and subpectoral IBBR without hADMs, but confirmed a higher

rate of infection and risk of mastectomy skin flap necrosis in the hADM group.

It is unclear whether the increased incidence of infection is due to contamination during the manufacturing process, perioperative handling of the biomaterial, or increased susceptibility to infection in the postoperative period [60]. There are certainly several factors that might influence the development of infections, but current evidence supports a trend toward lower infection rates with sterile ADMs, compared to aseptic ones [61–63]. Indeed, aseptic products have a SAL of 10^{-3} meaning that one in a thousand could be potentially infected, whereas sterile ADMs have a SAL of 10^{-6}, indicating that only one in a million could be potentially infected.

Seromas are a commonly occurring complication in IBBR with ADMs. ADMs are scaffolds that require revascularization and repopulation with host cells, but until that occurs they are associated with a normal healing response that includes exudation of fluid [31]. The amount of ADM in a wound has been shown to be correlated with the number of expected seromas [64]; hence, achieving an adequate drainage of the surgical site around the ADM is crucial in order to eliminate dead space between the ADM and the patient's tissues and promote its integration. Some surgeons accomplish this by placing multiple drains, while others prefer to use fenestrated products, which have been associated to a significantly lower rate of seroma if compared to nonfenestrated ADMs [13]. Furthermore, thicker matrices have slow neovascularization; therefore, they tend to be incorporated at a slower rate [16]; this translates into higher rates of seroma and increased number of days prior to drain removal [17].

Mastectomy skin flap necrosis seems to be higher in IBBR with ADMs [19], and it represents a major concern for the surgeon because, particularly full-thickness necrosis with device exposure, it increases the chance of performing an explantation procedure. The increased incidence of mastectomy flap necrosis might be related to the tendency for larger initial fill volumes to be attained in hADM-mediated breast reconstructions, but this has not yet been conclusively validated [60]. Skin flap necrosis can be conditioned by several factors such as the thickness of the mastectomy flap, patient's medical comorbidities, smoking history, and surgical technique; therefore, it is difficult to assess the extent to which ADMs alone play a role in this complication. Since poor perfusion of the mastectomy flap is the main reason for early complications following NSM and SSM [27], it is crucial to thoroughly assess its viability preoperatively and intraoperatively and, if necessary, change the original surgical plan and pursue the safest option for the patient.

Clinical Cases

Case 1 (Fig. 5.3)

A 51-year-old patient affected by left ductal breast cancer underwent left nipple sparing mastectomy and prophylactic right nipple sparing mastectomy. Bilateral DTI reconstruction was performed with 470 cc anatomic silicone gel implants and ADM derived from porcine dermis.

Case 2 (Fig. 5.4)

A 50-year-old patient affected by right ductal breast cancer underwent right nipple sparing mastectomy and prophylactic left nipple sparing mastectomy. Bilateral DTI reconstruction was performed with 420 cc anatomic silicone gel implants and ADM derived from equine pericardium.

Case 3 (Fig. 5.5)

A 45-year-old patient affected by left ductal breast cancer underwent left skin sparing mastectomy and adjuvant chemotherapy and radiotherapy. Left DTI reconstruction was performed with 180 cc anatomic silicone gel implant and ADM derived from equine pericardium.

Case 4 (Fig. 5.6)

A 56-year-old patient affected by right ductal breast cancer underwent right nipple sparing mastectomy and adjuvant radiotherapy. Right DTI reconstruction was performed with 240 cc anatomic silicone gel implant and ADM derived from porcine dermis.

Case 5 (Fig. 5.7)

A 24-year-old patient affected by right lobular breast cancer underwent right nipple sparing mastectomy and prophylactic left nipple sparing mastectomy, followed by adjuvant radiotherapy and chemotherapy. Bilateral DTI reconstruction was performed with 585 cc anatomic silicone gel implants and ADM derived from bovine pericardium. The patient developed capsular contracture after radiotherapy. Lipofilling might be an option in these cases in order to mitigate capsular contracture and breast surface irregularities.

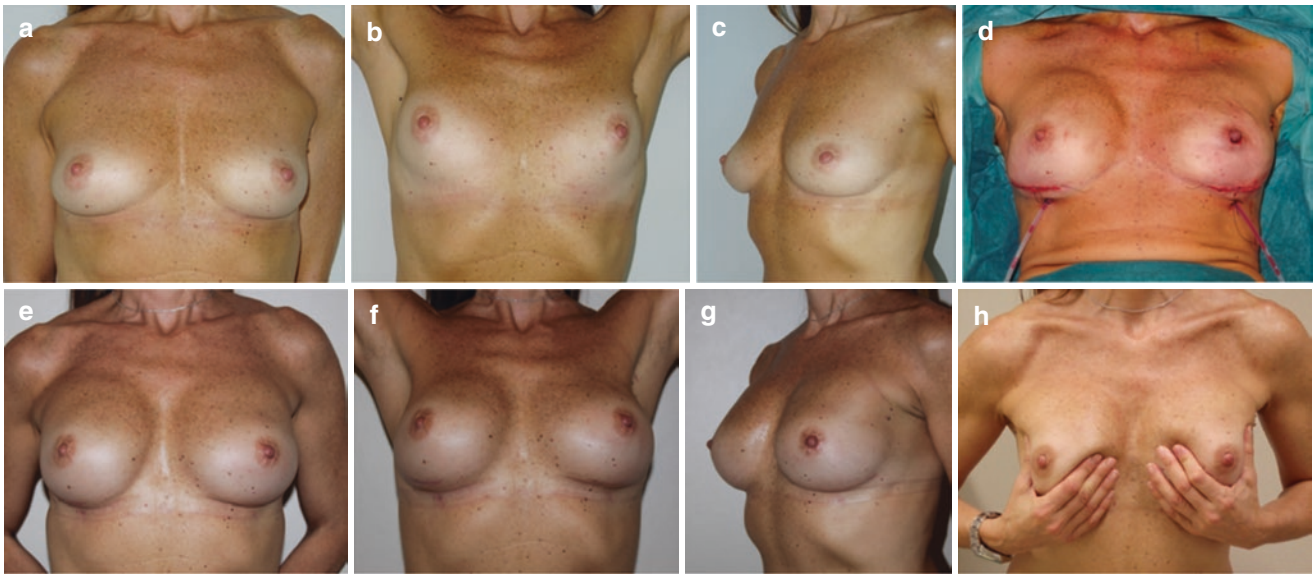

Fig. 5.3 (**a**, **b**) Preoperative anterior view; (**c**): preoperative oblique view; (**d**): immediate postoperative view; (**e**, **f**): 1-year postoperative anterior view; (**g**): 1-year postoperative oblique view; (**h**): patient is highly satisfied with the procedure and refers very natural appearance and feeling of the reconstructed breasts

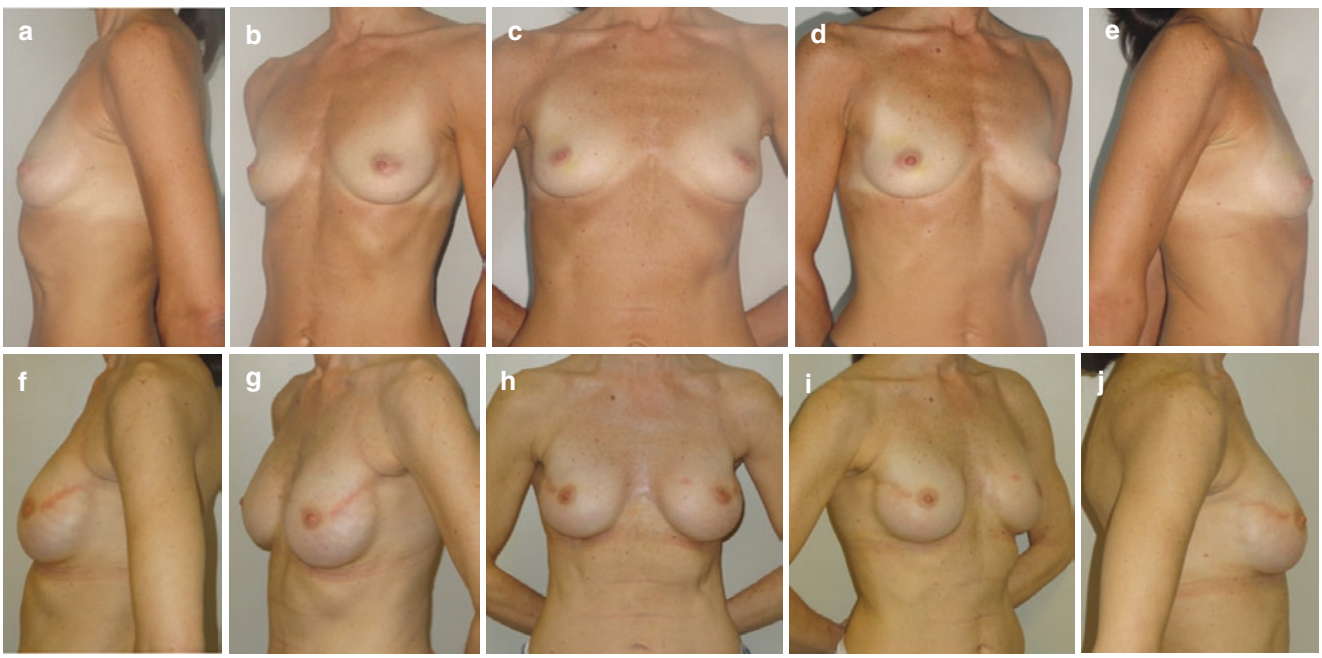

Fig. 5.4 (**a**, **e**): Preoperative lateral view; (**b**, **d**): preoperative oblique view; (**c**): preoperative anterior view; (**f**, **j**): 1-year postoperative lateral view; (**g**, **i**): 1-year postoperative oblique view; (**h**): 1-year postoperative anterior view

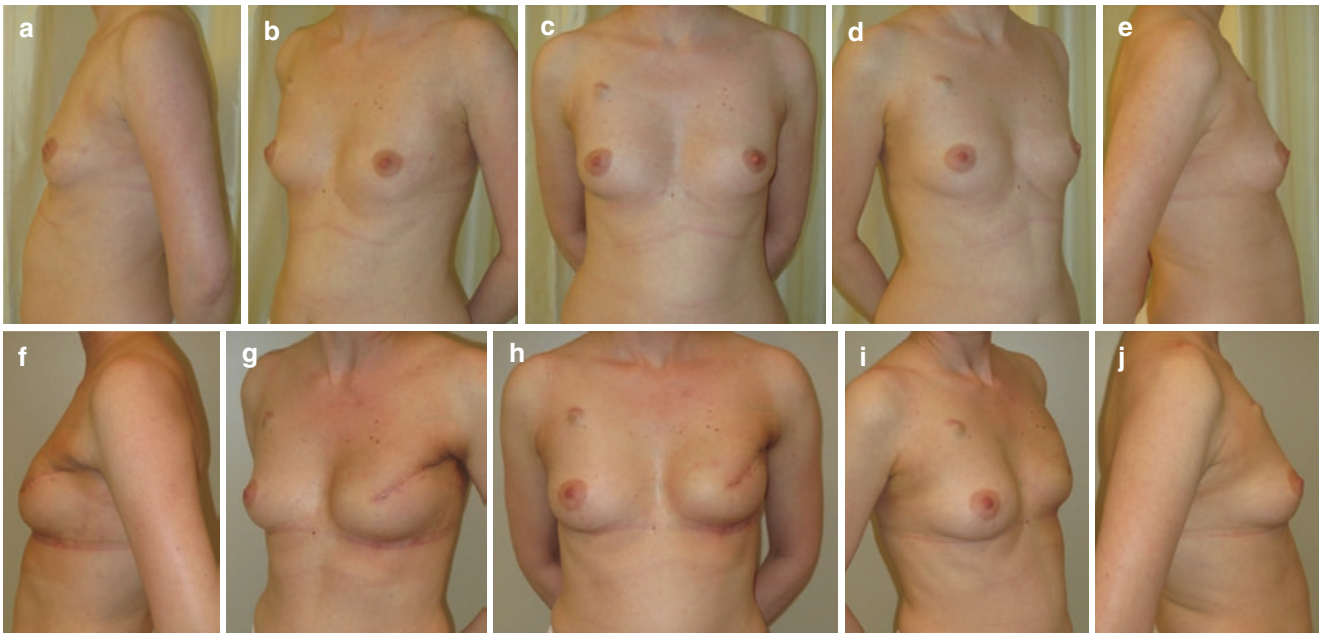

Fig. 5.5 (**a**–**e**): Preoperative lateral, oblique, and anterior view; (**f**–**j**): 1-year postoperative lateral, oblique, and anterior view after completion of radiotherapy

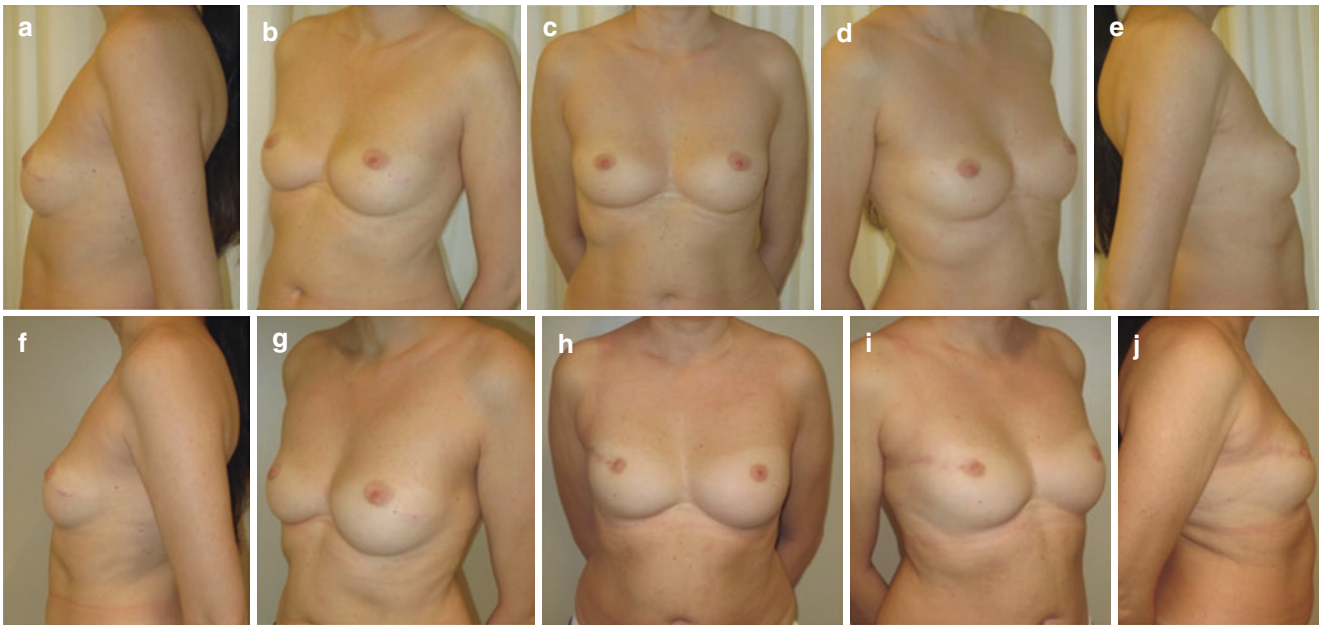

Fig. 5.6 (**a**–**e**): Preoperative lateral, oblique, and anterior view; (**f**–**j**): 1-year postoperative lateral, oblique, and anterior view after completion of radiotherapy

Case 6 (Fig. 5.8)

A 62-year-old patient affected by left ductal breast cancer underwent left nipple sparing mastectomy and prophylactic right nipple sparing mastectomy. Bilateral DTI reconstruction was performed with 470 cc anatomic silicone gel implants and ADM derived from porcine dermis.

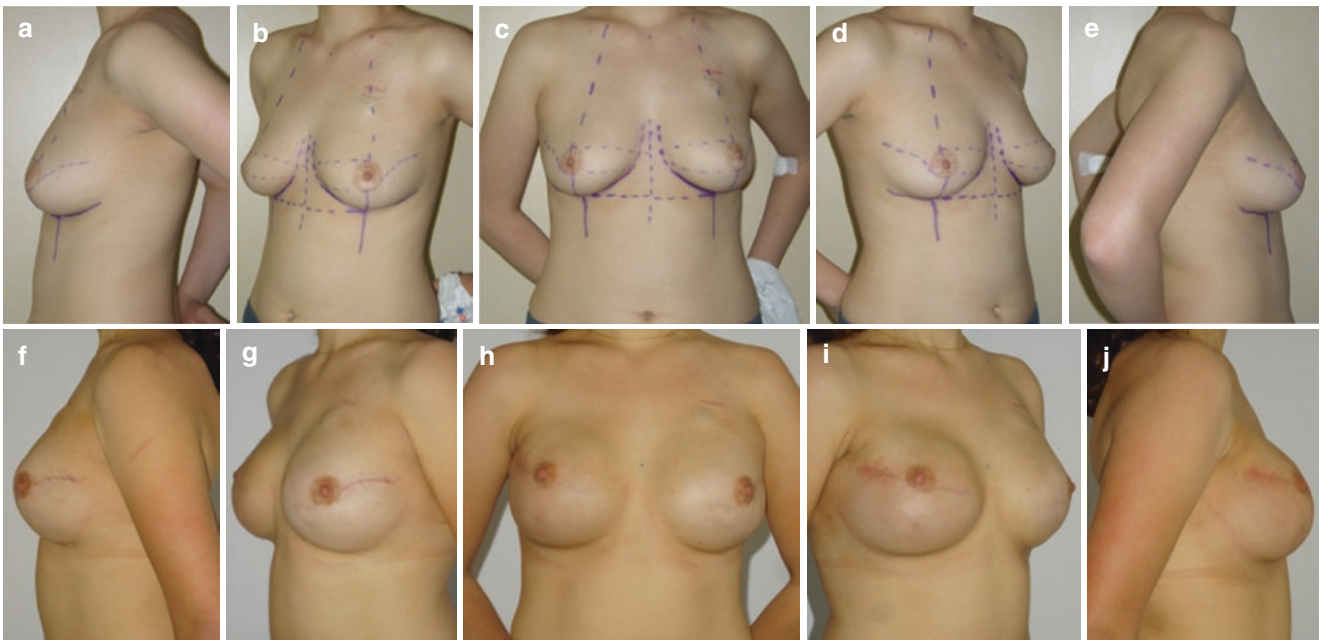

Fig. 5.7 (**a**–**e**): Preoperative lateral, oblique, and anterior view; (**f**–**j**): 2 years postoperative lateral, oblique, and anterior view

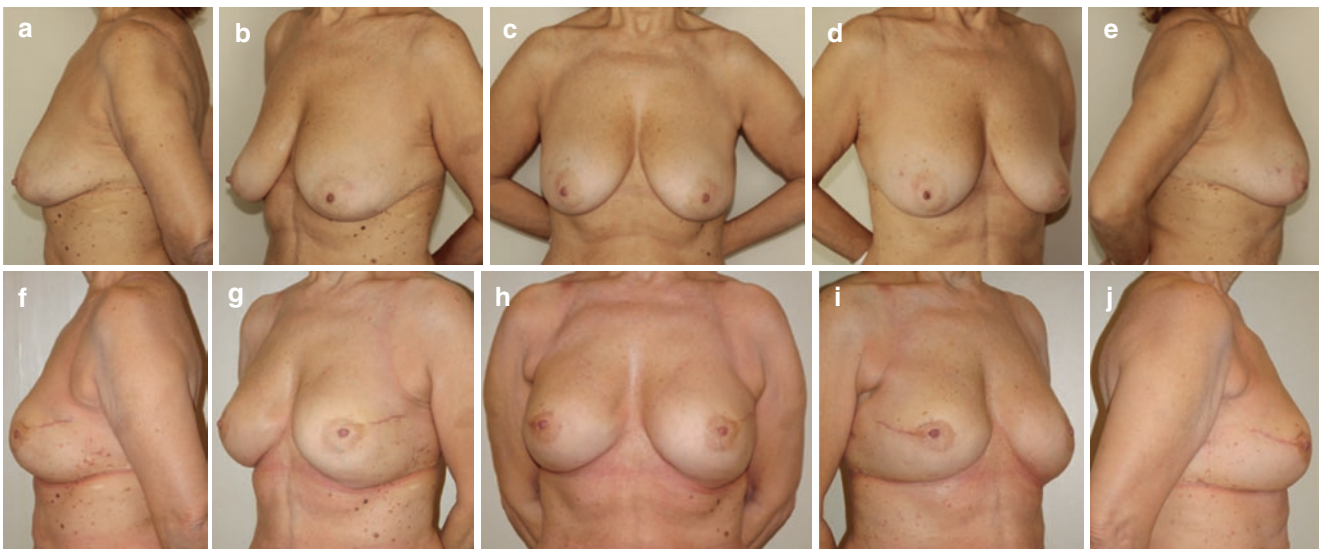

Fig. 5.8 (**a**–**e**): Preoperative lateral, oblique, and anterior view; (**f**–**j**): 6 months postoperative lateral, oblique, and anterior view

Conclusions

The introduction of ADMs in the clinical practice probably represents the greatest advance in breast reconstruction in the last decade. Although average initial costs are higher when ADMs are used, average total costs over 2 years are lower since ADMs allow to perform more DTI procedures reducing the number of surgical stages. Their protective effect against capsular contracture and other implant-related complications also reduces the number of additional surgical procedures, and their enhanced aesthetic outcomes improve patient's overall satisfaction and quality of life. However, inaccurate patient selection can lead to increased complication rates; therefore, ADMs should not be considered a panacea but rather a precious tool in the hands of an experienced plastic surgeon to afford more and, sometimes, better choices to enhance patient outcomes.

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Prepectoral Breast Reconstruction

6

Hani Sbitany

Introduction

Implant-based breast reconstruction continues to be the most utilized technique for postmastectomy reconstruction in the United States, with over 85,000 cases performed in 2015 [1, 2]. Techniques involving both two-stage (expander-implant) reconstruction and single-stage reconstruction have advanced significantly in the past decade, with excellent aesthetic outcomes consistently being achieved due to improved tools such as cohesive anatomic implants and acellular dermal matrices (ADM) [3–6].

Simultaneously, the increasing use of nipple-sparing mastectomy (NSM) techniques has also improved outcomes and patient satisfaction with postmastectomy breast reconstruction [7]. Large series have shown that NSM is oncologically safe, compared with skin sparing techniques, and this has led to greater acceptance and experience [8]. Patients now routinely benefit from the ability to maintain the entire external breast skin envelope for use in their reconstruction.

With regard to reconstructive technique, traditional methods of submuscular or partial submuscular/partial ADM (dual-plane) coverage for tissue expanders and implants are still most commonly utilized [9–11]. Both the pectoralis major muscle and serratus anterior muscle or fascia are utilized in these techniques for prosthetic coverage.

While these submuscular techniques offer excellent vascularized soft tissue coverage, they involve greater alteration and manipulation of a patient's chest wall. This is secondary to the dissection, elevation, and often disinsertion of the pectoralis major muscle during pocket creation. Additionally, the risk of animation deformity with submuscular and dual-plane techniques is significant. This contraction of the entire reconstructed breast, due to adherence of the pectoralis major muscle to the overlying skin, can be very uncomfortable for patients (Video 6.1, Fig. 6.1). Often times, additional surgery is required to correct this and convert the submuscular reconstruction into a prepectoral one [12].

Given these potential limitations of submuscular reconstruction, the use of primary prepectoral breast reconstruction techniques is being employed to greater degrees by some surgeons. Because it eliminates the need for any manipulation of the chest wall muscles, prepectoral breast reconstruction carries many potential advantages for patients. With the use of ADM for complete soft tissue coverage of expander and implants, current techniques have improved significantly over the original descriptions of subcutaneous breast reconstruction [13–15]. Because these techniques do

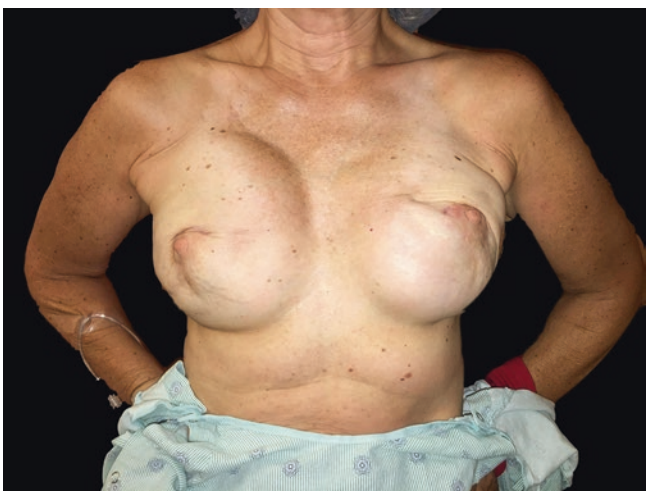

Fig. 6.1 A 48-year-old female with a 9-year history of bilateral submuscular prosthetic breast reconstruction, shown with symptomatic (painful) animation deformity on pectoralis major muscle contraction; the typical distortion of the overlying breast skin is seen on animation

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not place implants directly underneath the mastectomy skin flaps, they may reduce the risk of many of the routine sequelae seen with immediate subcutaneous reconstruction, such as higher infection rates, higher wound dehiscence and exposure rates, and higher capsular contracture rates.

As with all reconstructive techniques, the performance and outcome measures of prepectoral reconstruction must also be assessed in the setting of postmastectomy radiation (PMRT). This adjuvant treatment is a routine in the oncologic treatment of patients, delivered at rates of up to 40% of patients in some series. Radiation has been shown to increase the rates of all complication outcome measures in prosthetic reconstruction, due to the microvascular damage and fibrosis induced on the breast soft tissue envelope [16].

The use of ADM has been demonstrated to be effective in the setting of whole breast irradiation and in some series has provided a protective effect in lowering implant extrusion and encapsulation rates, relative to complete submuscular reconstruction [17–19]. However, in the setting of prepectoral breast reconstruction, where ADM provides the entire soft tissue envelope immediately covering the implant, the outcomes in the setting have been seen to be different, and data now exists to show that prepectoral reconstruction patients can safely receive radiation [20].

Clinically, there are also aesthetic advantages to prepectoral breast reconstruction in the setting of radiation. When the submuscular cases receive radiation, the pectoralis major muscle overlying the tissue expander or implant tightens and fibroses/contracts during radiation, thus often displacing the device with it (Fig. 6.2). This makes subsequent aesthetic correction very challenging. In prepectoral patients, without the muscle wrapping around the implant and displacing it during radiation, the device does not move, and thus aesthetic outcomes are improved in prepectoral reconstruction patients undergoing radiation (Fig. 6.3).

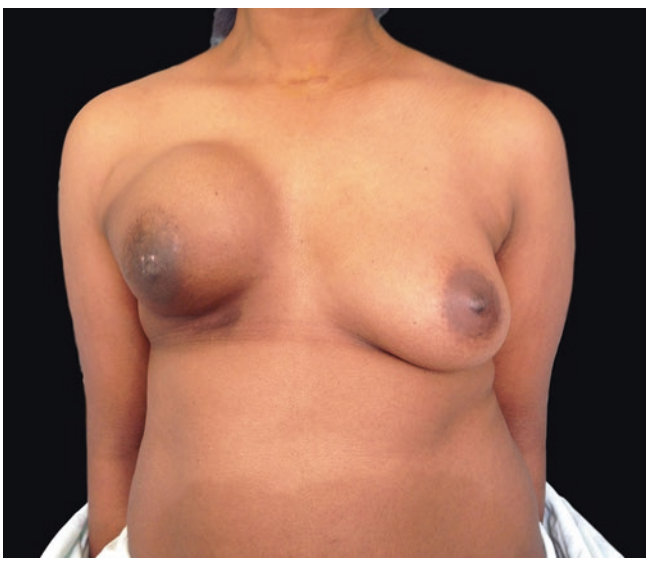

Fig. 6.2 Typical migration of submuscular tissue expander seen on the right breast, following completion of PMRT, as pectoralis major muscle tightens and contracts and pulls underlying prosthesis with it

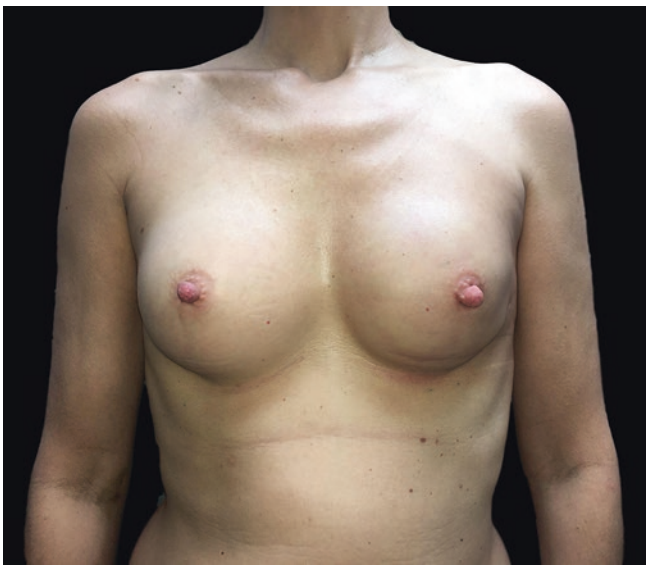

Fig. 6.3 Two-year postoperative photos of a 41-year-old female after completion of left breast NSM and two-stage prepectoral breast reconstruction, with left postmastectomy radiation therapy; the right native breast underwent augmentation for symmetry

Anatomy

Pertinent anatomy to assess prior to performing prepectoral breast reconstruction is the muscular anatomy of the chest wall in each mastectomy defect. The surgeon should mark out the location and borders of the pectoralis major muscle, as well as the serratus anterior muscle and fascia, as these will define the structures to which the ADM is sutured to. Furthermore, the location of lateral intercostal nerves and intercostobrachial nerves should be identified, as sutures will need to avoid these structures, to prevent exacerbation of postmastectomy pain syndrome.

Patient Selection

Currently, in the author's practice, any patient undergoing immediate or delayed prosthetic breast reconstruction is eligible for prepectoral breast reconstruction. During the initial patient consultation, both subpectoral and prepectoral techniques are discussed with the patient. The final decision to proceed with either option is made intraoperatively, based on assessment of the following factors, and so the patient must be made aware of both options.

The initial selection criteria made for prepectoral breast reconstruction intraoperatively are confirmation of

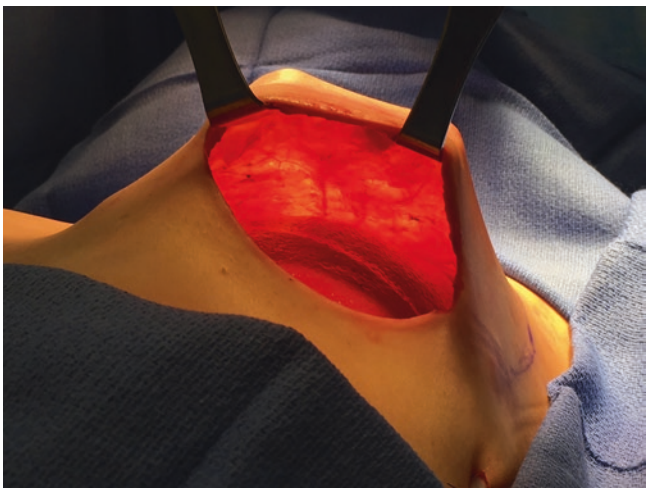

Fig. 6.4 Intraoperative view of thin but well perfused and viable skin flaps; thus, patient underwent safe placement of a prepectoral tissue expander, since flaps are perfused and can support revascularization

viable and perfused mastectomy skin flaps. This can be done with visual assessment, confirming no visible dermis on the underside of the mastectomy skin flap. Additionally, this assessment can be supported with ICG angiography, to objectively analyze blood flow in the mastectomy skin flap.

Early in the prepectoral breast reconstruction experience, it was thought that thin flaps would not tolerate prepectoral breast reconstruction, and only thick flaps could undergo this operation. However, it has now been understood that viability and perfusion are the key distinction, and even thin flaps can undergo this operation, as long as they are perfused (Fig. 6.4).

Other patient contraindications include poorly controlled diabetics, obese patients (BMI > 35), and active smokers. Such patients are better candidates for delayed reconstruction.

From the oncologic standpoint, there are also certain criteria that must be considered. Any patient with a tumor that comes within 0.5 cm of the pectoralis major muscle preoperatively, or one that directly invades the chest wall, is not an ideal patient for prepectoral breast reconstruction. Given the higher risk of a chest wall recurrence in the future, these patients are better served having their pectoralis major muscle elevated over the implant, and directly under the skin, to allow for easier self-examination for future surveillance.

Similarly, any patient with inflammatory breast cancer or palpable axillary adenopathy should not undergo prepectoral breast reconstruction, given the likely need for aggressive adjuvant oncologic therapy. These patients are also better served by delaying breast reconstruction. Apart from these criteria, all patients are candidates for prepectoral breast reconstruction.

Surgical Technique

For cases of prepectoral tissue expander/implant placement, no muscle manipulation is performed. Following completion of mastectomy, the planned footprint of the reconstructed breast is marked on the chest wall. The location of the inframammary suture line is marked approximately 0.5 cm below that of the planned IMF location on the reconstructed breast. A cm sheet of acellular dermal matrix is then placed in the breast pocket, and a suture line is first placed horizontally between ADM and the underlying pectoralis muscle fibers, approximately 3 cm above the planned IMF. The ADM is then pulled down and folded at the IMF where it will come up and over the lower pole of the tissue expander, off the chest wall. At this location, a second suture line is placed through the folded, double layer of ADM to the underlying chest wall. This "cuff" of ADM at the IMF provides improved soft tissue support to the lower pole of the implant, where the ADM is then folded up and over the anterior surface of the prosthesis.

At this point, a tissue expander or implant is placed in the breast, and the remainder of ADM is pulled up and over the entire anterior surface of the prosthesis. The medial, superior, and lateral borders of the ADM are sutured to the chest wall, at the borders of the expander. This provides full ADM coverage of the device (Fig. 6.5a–c and Video 6.2). The lower pole "gutter" of ADM, created by the enveloping of the lower portion of the implant, both anterior and posterior, allows for reduction of the risk of future implant descent.

Next, one or two drains are then placed in each breast, and the ADM is fenestrated if necessary. With increased experience, the author now routinely fenestrates the ADM, as this will allow for more rapid integration with the vascularized tissue as well as improve fluid drainage. Intraoperative expansion then proceeds cautiously, with care taken not to stretch the mastectomy skin flaps too aggressively. Tissue expansion begins between 2 and 3 weeks postoperatively. For the prepectoral patients, drains are left in place for a minimum of 3 weeks. After these time periods, drainage below 20 cc per day, for 3 straight days, will allow for drain removal.

For two-stage patients, the second-stage exchange operation is routinely performed through the same incisional approach as the mastectomy, if the patient is nonradiated. The incision is carried down straight through the underlying tissue, until the tissue expander is reached. In the prepectoral patients, this involves dividing the ADM in the same line as the skin incision. Following completion of the second-stage operation, the ADM is sutured back to itself primarily, as the first of a multilayer closure. In patients undergoing postmastectomy radiation therapy, the exchange operation is performed through a new incision, and not the original mastectomy incision, to reduce the risk of incisional dehiscence.

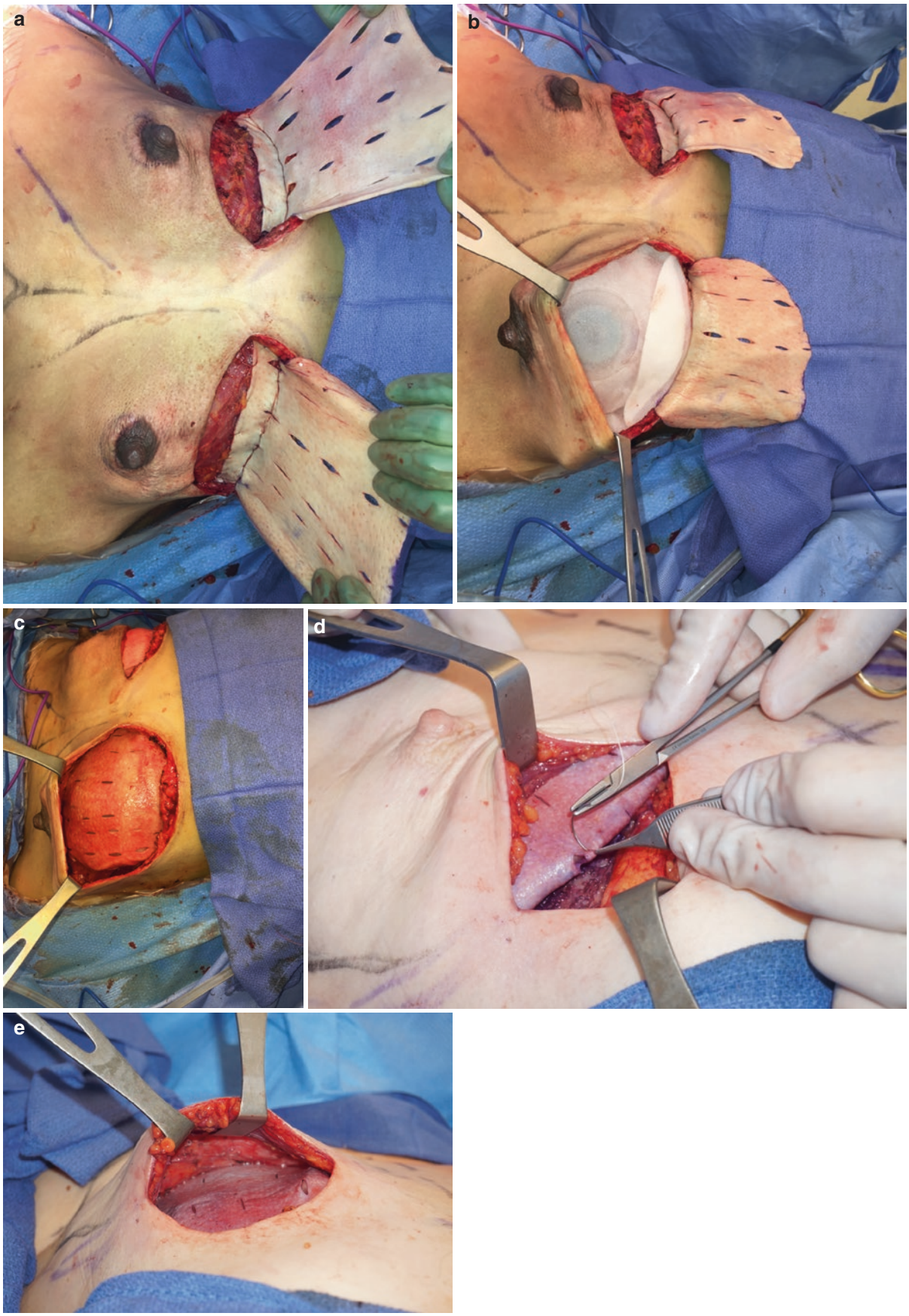

Fig. 6.5 Intraoperative view (**a**–**c**) of a prepectoral tissue expander placed at time of nipple-sparing mastectomies; full soft tissue support with acellular dermal matrix allows for full preservation of the pectoralis major muscle, making this procedure less invasive and more form preserving. This includes a lower pole cuff for soft tissue support (**d**) and complete anterior implant support and coverage (**e**)

Technical Variations

One group of patients that deserve special notice are those undergoing delayed conversion from a completed submuscular reconstruction to prepectoral reconstruction. This is usually done years after reconstruction completion, to relieve symptoms of pain and animation deformity. Such animation deformity occurs because the elevated pectoralis major muscle, as it sits around the prosthesis, adheres directly to the overlying mastectomy skin flaps (Fig. 6.6a–d, Video 6.3a, 6.3b). Thus, when the muscle contracts, it displaces the entire skin envelope above with it, as well as the underlying implant. For correction of existing animation deformity, the surgical technique proceeds as follows:

The patient's prior submuscular reconstruction incision is typically used as the skin incision for this procedure. In nipple-sparing patients, this is typically a superior periareolar or inframammary-fold incision. In patients without nipple preservation, the transverse breast scar is used.

The inferior border of the pectoralis muscle is identified and incised, to gain access to the preexisting implant and capsule, both of which are removed. It is our practice to perform a full capsulectomy with implant removal. The plane between the pectoralis major and the overlying subcutaneous tissue is then developed, using low electrocautery and sharp dissection. This is carried superiorly, medially, and laterally within the borders of the desired new reconstructive footprint, to free the pectoralis muscle from the overlying tissue and create a neo-prepectoral pocket (Fig. 6.7). When free and mobilized, the pectoralis major muscle is sutured to the chest wall soft tissue in its original anatomic location. The breast pocket is irrigated and checked for hemostasis followed by irrigation with a Betadine-containing solution.

An implant sizer is placed in the breast pocket to estimate new implant size. Cohesive gel implants are preferable, to reduce rippling potential. The new soft tissue envelope around the implant is supported with biologic mesh. The implant is placed into the pocket using no-touch technique.

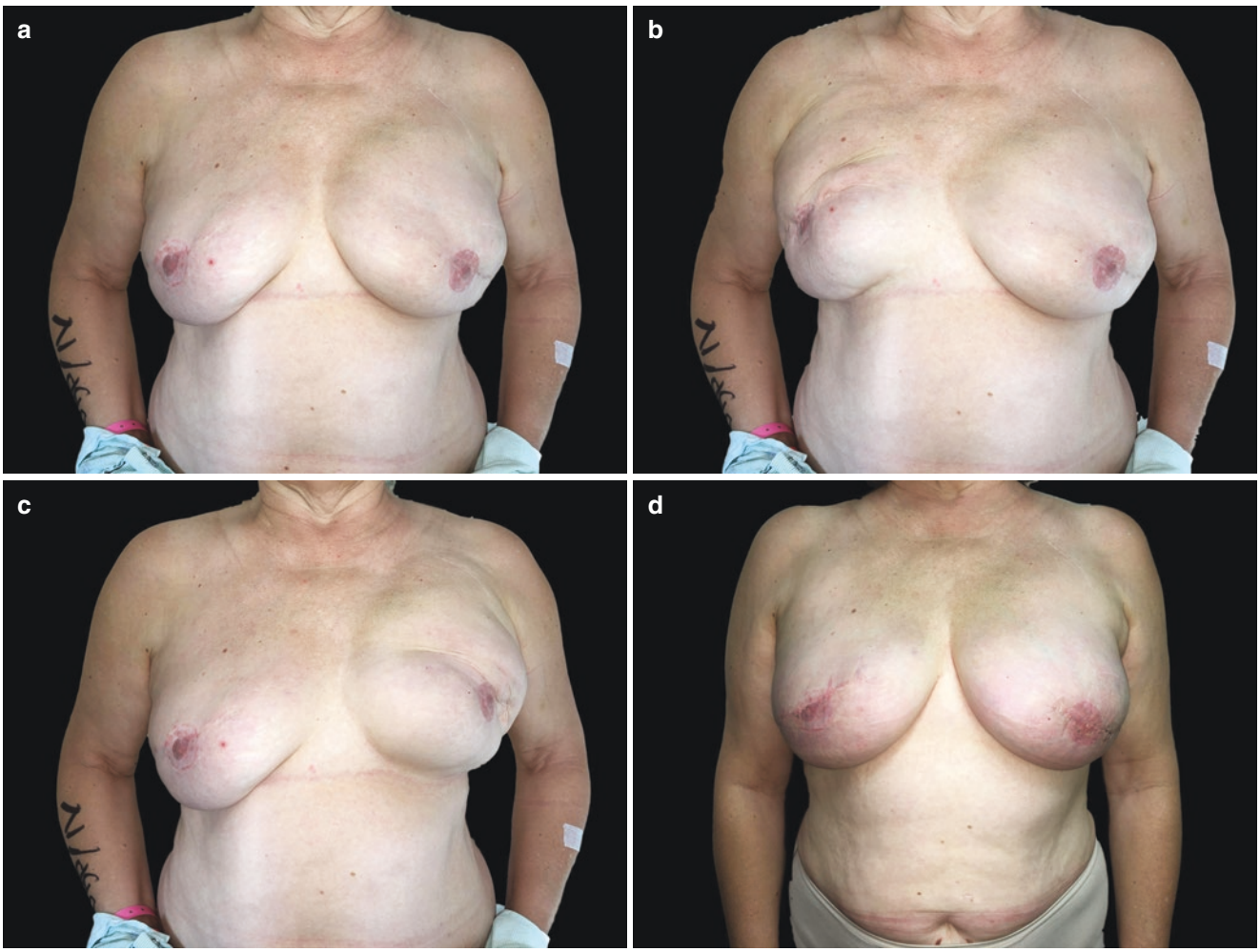

Fig. 6.6 A 58-year-old female with a 15-year history of bilateral submuscular prosthetic breast reconstruction, shown at rest (**a**) and with the ability to individually animate the right breast (**b**) and left breast (**c**) with voluntary pectoralis major muscle contraction. Patient is then seen (**d**) 1 year following conversion to a neo-prepectoral pocket and elimination of animation deformity

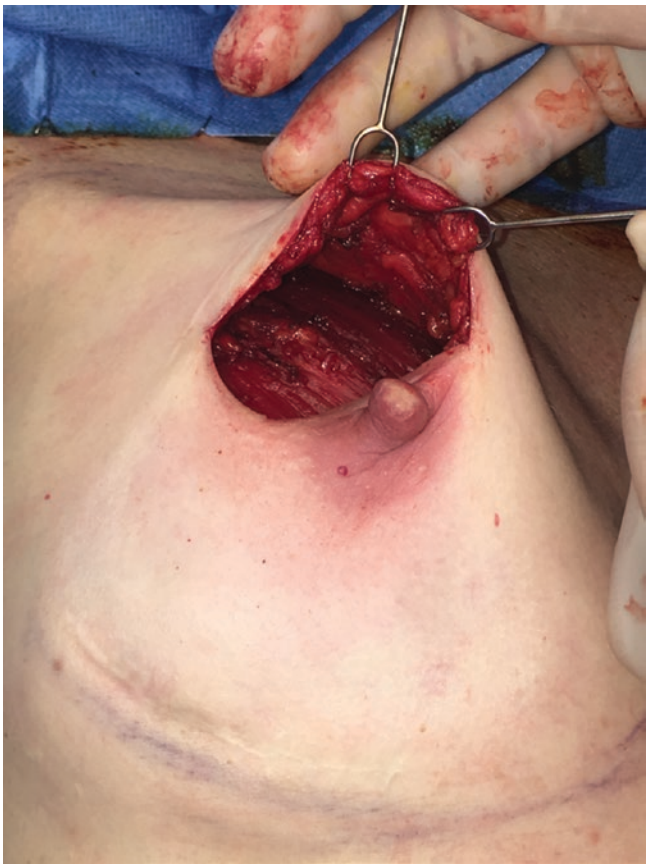

Fig. 6.7 Surgical creation of a neo-prepectoral pocket, by separating mastectomy skin from underlying pectoralis major muscle, prior to removal of submuscular implant

One drain is typically placed into the breast pocket, and the skin is closed in multiple layers.

The author has found in this patient population that utilizing an ADM for implant coverage is critically important and was associated with a decreased risk of capsular contracture (1.5% vs. 26.7%). It was also associated with less need for secondary cosmetic revisionary procedures, likely due to providing better contour, more precise implant and pocket placement, and masking of rippling or prominence of implant edges.

Similar positive benefits were seen in patients who had undergone preemptive fat grafting, approximately 1–2 months prior to their conversion operation. More recently, in this series, the senior author began offering preemptive fat grafting to any patient with thinner or attenuated soft tissue and skin envelopes. These patients are brought to the operating room, and an average of 75–150 cc is injected per breast, in the subdermal plane of the superior pole skin flaps. This serves to thicken the skin flap, making it safer to subsequently separate skin from pectoralis muscle when the conversion is performed. Furthermore, this has reduced the risk of clinical rippling and need for revisionary procedures following conversion operation, as a direct result of the enhanced soft tissue quality over the new prepectoral implant. Finally, the protective benefit of autologous fat has been illustrated by the clinically reduced rates of infections experienced following conversion operations, when patients have been previously injected with fat.

Postoperative Care

In all cases, patients are routinely given oral antibiotics covering gram-positive organisms for 7 days postoperatively. Drains are kept in until the output reaches less than 20–30 cc/day of output per drain, on average 2 weeks after surgery.

Clinical Cases

Case 1

A 37-year-old female presented to the author with right breast DCIS and elected to undergo bilateral nipple-sparing mastectomies. Given that she desired a larger breast size with reconstruction, the decision was made to proceed with bilateral two-stage expander-based reconstruction. Although her skin flaps were thin following mastectomy, they were viable, and thus prepectoral expanders were placed surgically. Following completion of reconstruction, she underwent exchange for silicone implants and tolerated this procedure well (Fig. 6.8a–c).

Case 2

A 48-year-old female presented with a prior history of a right breast mastectomy and no immediate reconstruction. Because the skin flaps were delayed and healthy, the decision was made to proceed with right breast, two-stage prepectoral reconstruction. Following placement of a right breast prepectoral tissue expander, the right breast skin envelope was expanded and then exchanged for a silicone implant at the second surgical procedure. Also at this second procedure, a left breast augmentation with silicone implant was performed, for symmetry (Fig. 6.9a,b).

Case 3

A 42-year-old female presented with right breast cancer and a desire for bilateral nipple-sparing mastectomies. She desired a very large size postoperatively and thus underwent bilateral prepectoral tissue expander placement. After complete expansion (over expansion) of the viable skin flaps, she was exchanged for silicone gel implants and also underwent upper pole fat grafting on each side. The fat

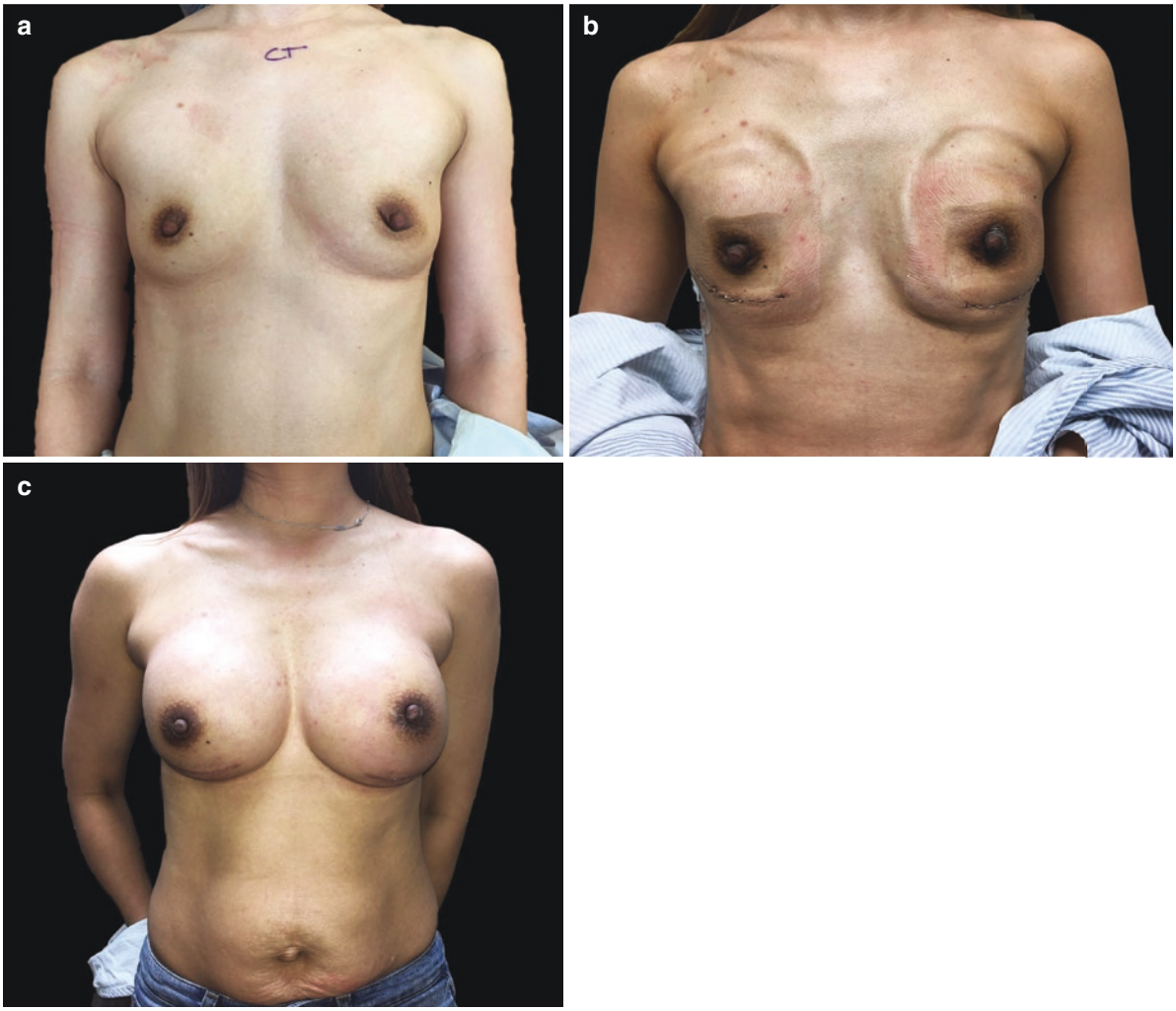

Fig. 6.8 (**a**) Preoperative view of a 37-year-old female undergoing bilateral NSM and bilateral prepectoral tissue expander placement. (**b**) Three-week postmastectomy photo, showing thin mastectomy skin flaps over tissue expanders. (**c**) Postoperative view, 18 months after completion of prepectoral breast reconstruction

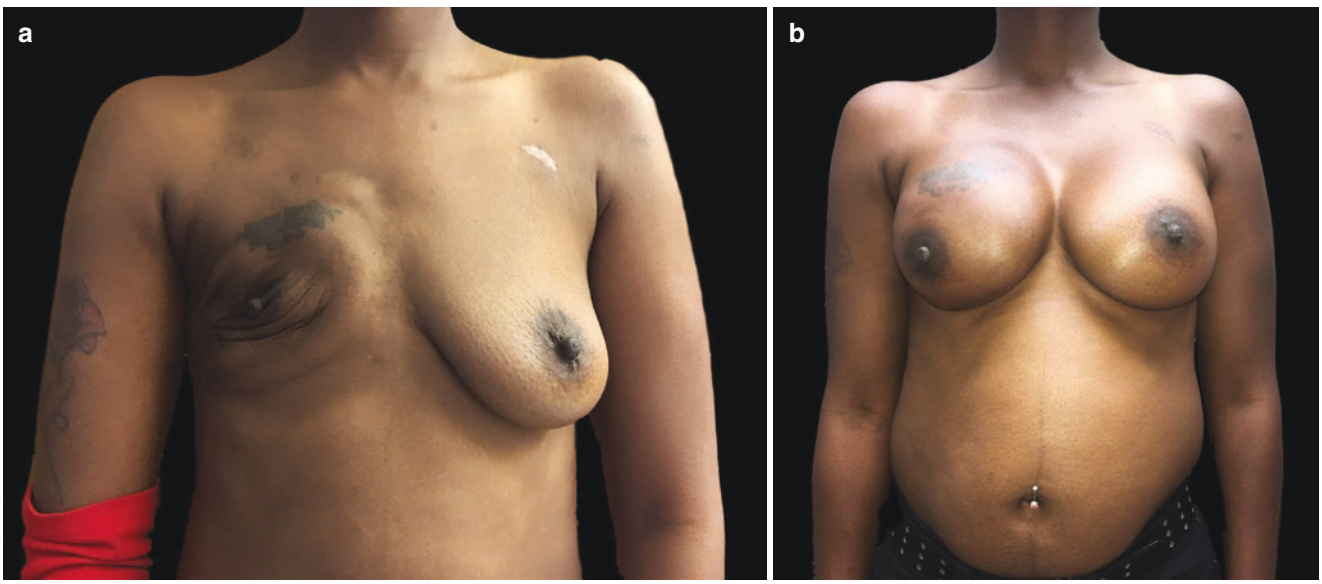

Fig. 6.9 (**a**) Preoperative and (**b**) 2-year postoperative photographs of a 48-year-old female after undergoing delayed right breast two-stage prepectoral breast reconstruction; patient also underwent left breast augmentation for symmetry

grafting was performed to restore a natural-appearing slope to the upper pole of each breast and avoid a shelf-like appearance on profile. At 2 years postoperatively, she maintains a stable, soft breast reconstruction on each side (Fig. 6.10a–e).

Case 4

A 32-year-old female presented with BRCA mutation. She expressed an interest in both complete nipple/areola preservation, as well as prepectoral breast reconstruction to prevent

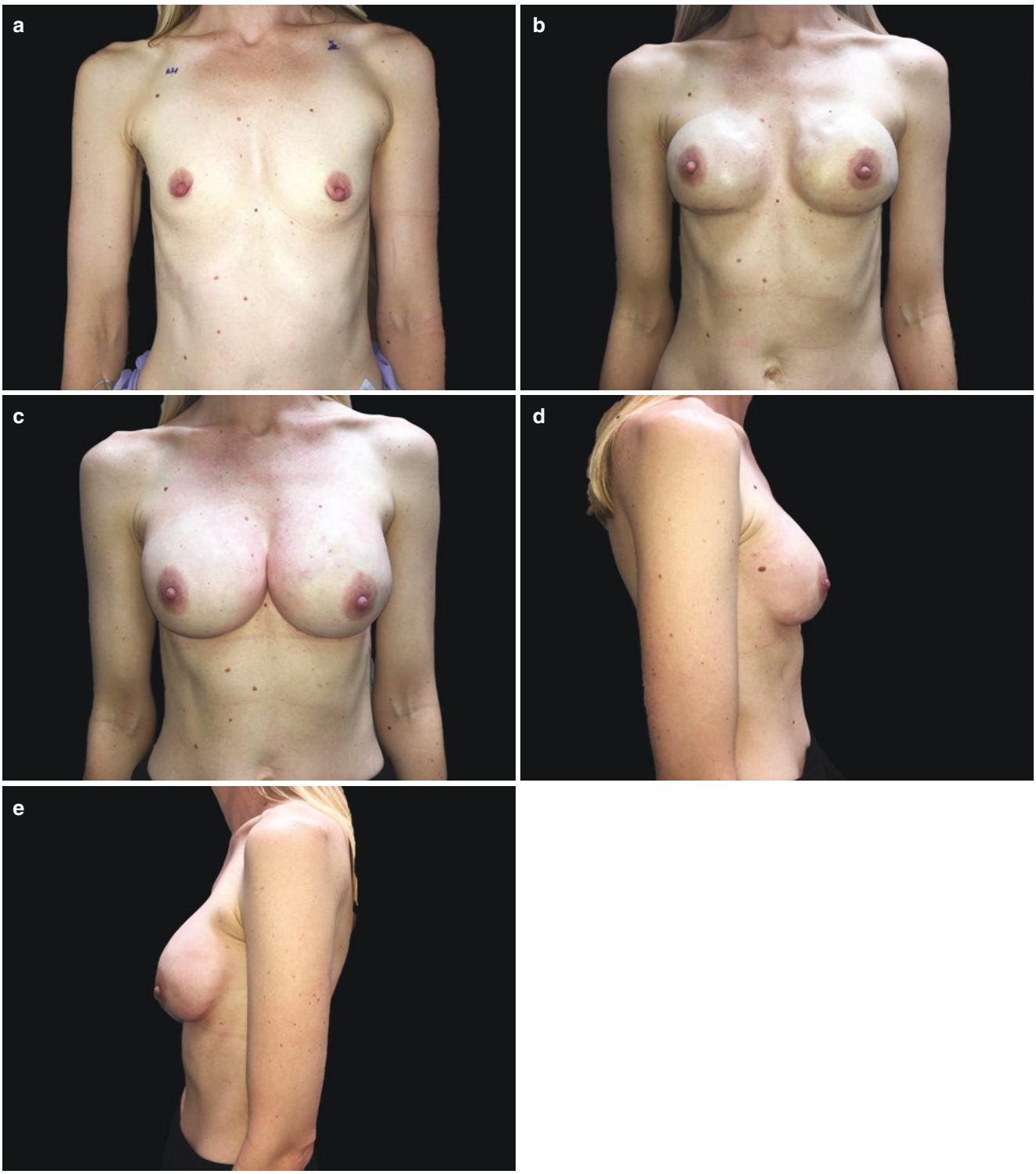

Fig. 6.10 (**a**) Preoperative view of a 42-year-old female undergoing bilateral NSM and bilateral prepectoral tissue expander placement. (**b**) Following completion of tissue expansion, patient has thin upper pole skin, indicating a need for fat grafting at time of exchange, to prevent rippling and contour deformity of upper pole. (**c–e**) Postoperative view, 2 years after completion of prepectoral breast reconstruction, showing no clinical rippling, and a natural upper pole slope, due in part to autologous fat grafting

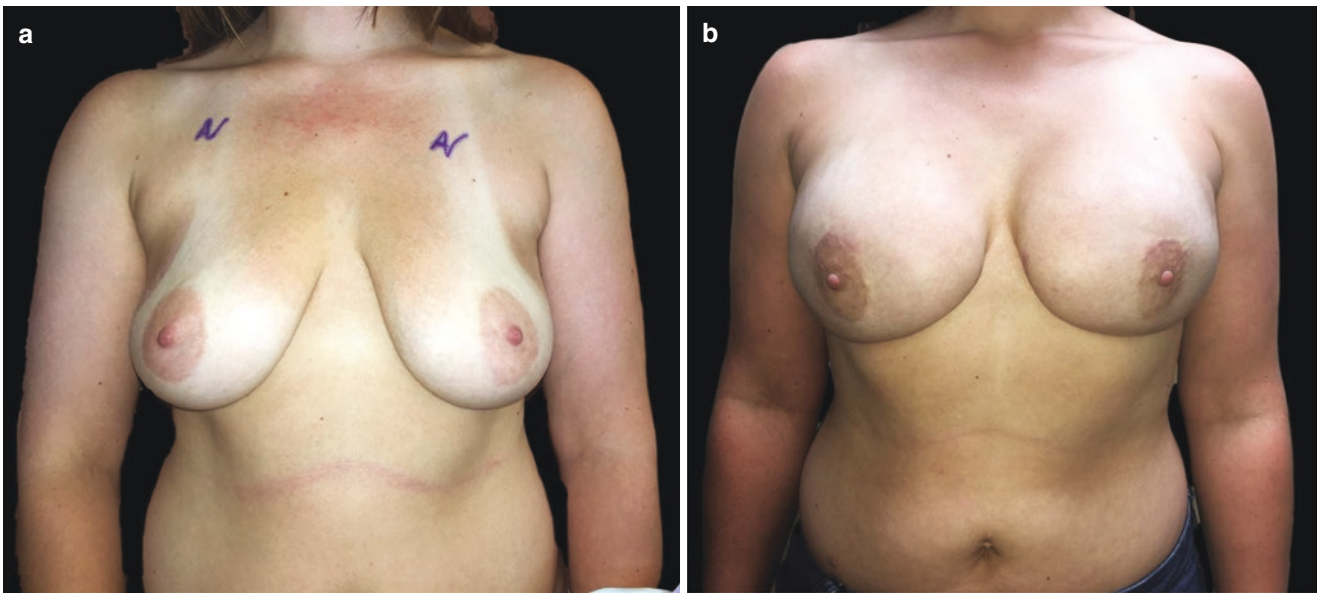

Fig. 6.11 (**a**) Preoperative view of a 32-year-old female undergoing bilateral NSM and bilateral prepectoral single-stage, direct-to-implant reconstruction. This was done through an inframammary-fold incisional approach. (**b**) Postoperative view, 2 years after completion of prepectoral breast reconstruction

loss of any muscle function. Given her preoperative pseudoptosis, an inframammary-fold incision was used for mastectomy, with a lower pole skin resection in crescent shape. This reduced her nipple inframammary-fold distance from 12 cm to 5 cm, with the mastectomy. She also underwent an immediate, direct-to-implant reconstruction with placement of silicone gel implants in the prepectoral position on each side. At 1 year postoperatively, she maintains a stable reconstruction on each side (Fig. 6.11a,b).

Case 5

A 48-year-old female presented with left breast cancer underwent a two-stage expander-based prepectoral breast reconstruction on the left breast and a right breast augmentation for symmetry. After completion of reconstruction, the patient had notable rippling and upper pole implant visibility on the left reconstruction breast. She underwent a third-stage procedure, where fat grafting alone was performed to the left breast reconstruction in the upper pole skin flaps (90 cc). Another 9 months following this revision with left breast fat grafting, there is complete correction of the left breast rippling. This highlights the importance of autologous fat grafting in prepectoral patients, which is routinely done by the author at the second-stage expander to implant exchange operation (Fig. 6.12a–d).

Case 6

A 49-year-old female presented with a 5-year history of completed submuscular breast reconstruction. She continuously experienced pain and animation deformity with her completed submuscular reconstruction over this time period. She first underwent autologous fat grafting to her thin skin flaps, around the submuscular reconstruction. Approximately 2 months later, she underwent delayed conversion of this submuscular reconstruction to a prepectoral reconstruction with silicone gel implants. Following this procedure, she experienced complete resolution of her pain and animation deformity (Fig. 6.13a–d; Video 6.4a, 6.4b).

Conclusions

While prepectoral breast reconstruction remains an evolving technique, it certainly carries a number of potential benefits for patients, relative to submuscular reconstruction techniques. The technique is justified by the significant benefits to patients. The elimination of pectoralis major muscle alteration and stretching is significant on its own. Furthermore, the ability to eliminate the occurrence of animation deformity, and the future operation necessary to correct it, will undoubtedly improve patient satisfaction with their breast reconstruction outcomes. With the ability to perform both nipple-sparing mastectomy and prepectoral breast reconstruction together, we are able to offer patients the least invasive breast reconstruction possible, with maximal preservation of both form and function (Fig. 6.14).

Furthermore, the ability to perform prepectoral reconstruction even when postmastectomy radiation is required significantly enhances this operation and extends the benefits to almost all patients. This is critically important in radiation, as the pectoralis muscle severely distorts submuscular implants as it receives radiation and undergoes fibrosis.

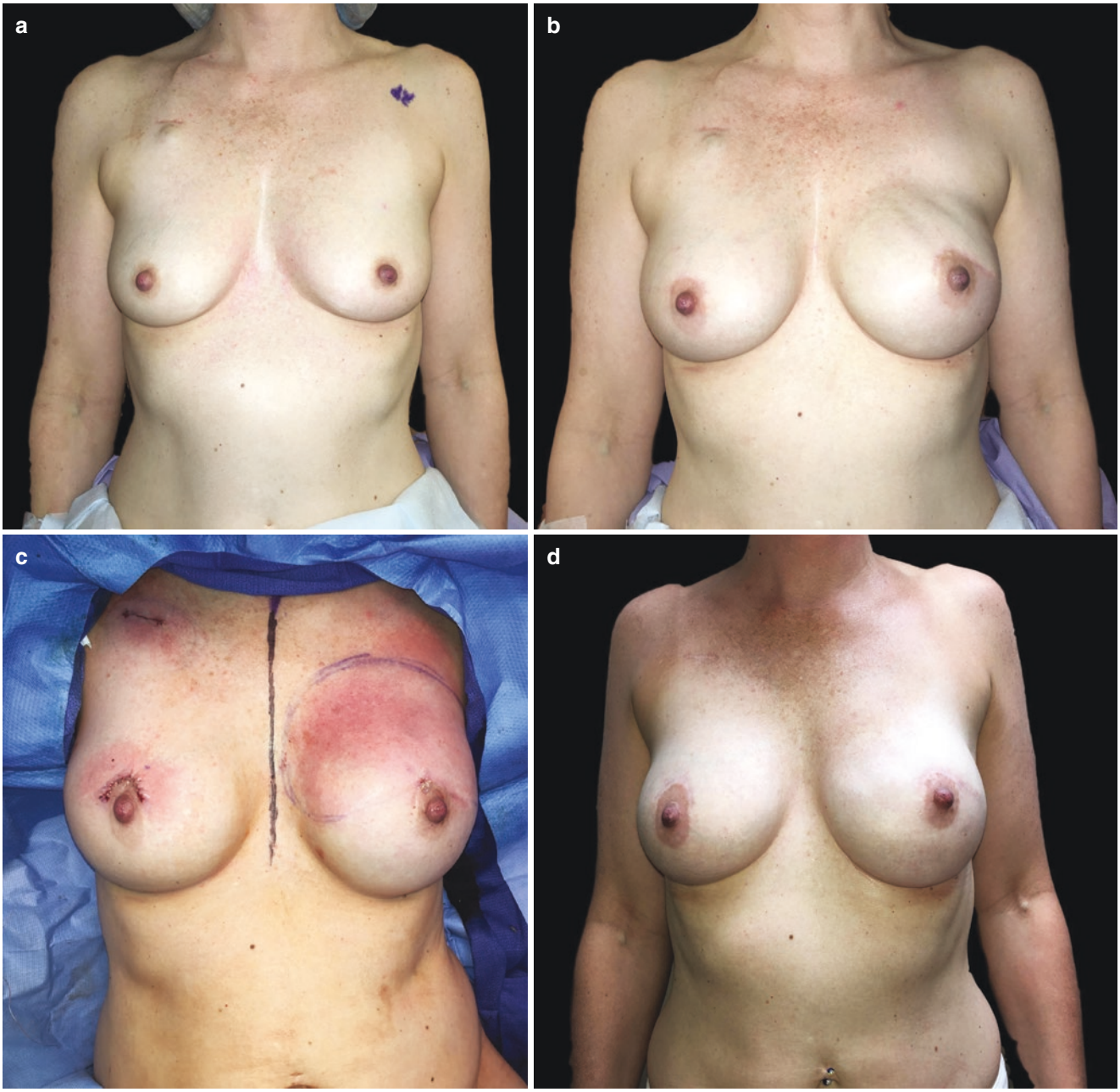

Fig. 6.12 Preoperative (**a**) view of a patient with left breast cancer, prior to surgical treatment. Post-reconstruction view (B) of the patient following left nipple-sparing mastectomy and prepectoral breast reconstruction without fat grafting and right augmentation for symmetry. Patient (**b**) exhibits left breast upper and medial pole rippling and volume hollowing, due to lack of fat grafting. This is treated (**c**) with left breast fat grafting over the existing prepectoral implant. Postoperative view (**d**) at 6 months shows aesthetic correction of the left breast volume deficiency and rippling

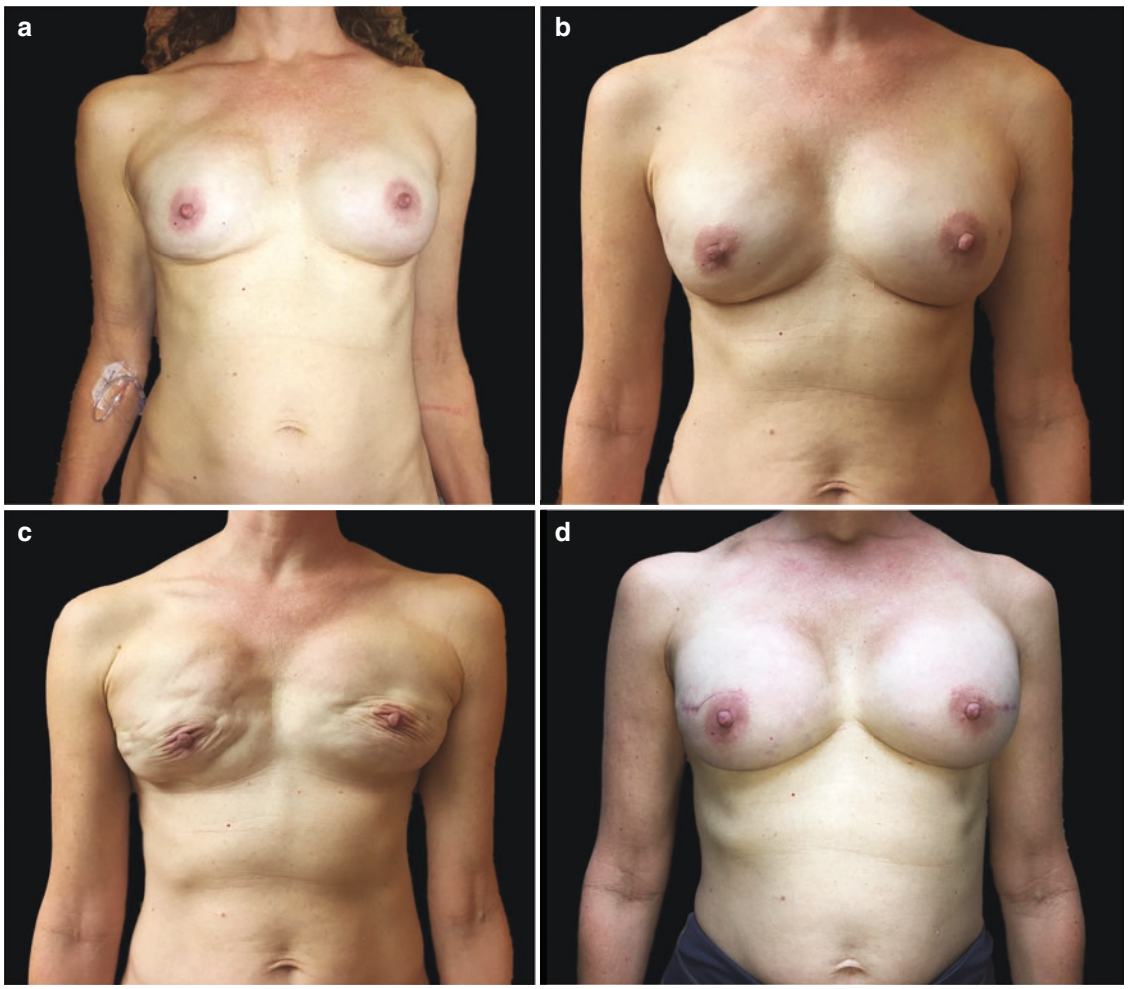

Fig. 6.13 A 49-year-old female with a 5-year history of bilateral submuscular prosthetic breast reconstruction, shown at rest prior to preemptive fat grafting (**a**) with a thin soft tissue envelope; 2 months later, following fat grafting with improved breast skin flap thickness at rest (**b**) and with symptomatic (painful) animation (**c**) of her bilateral submuscular reconstructed breasts. Patient is then seen (**d**) 1 year following conversion to a neo-prepectoral pocket and elimination of animation deformity

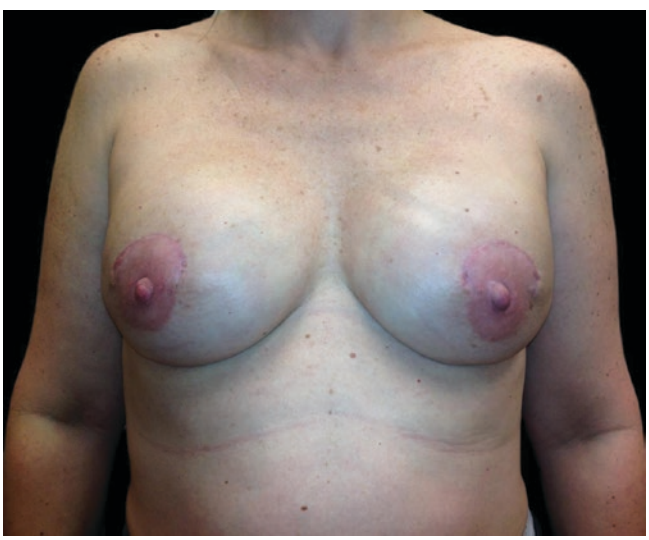

Fig. 6.14 Postoperative photograph of a 52-year-old female, 5.5 years following bilateral nipple-sparing mastectomies and bilateral two-stage prosthetic breast reconstruction

Finally, the conversion of a previous subpectoral breast reconstruction to a prepectoral plane for correction of chronic animation deformity and pain is a powerful operation that is safe and reproducible. There are techniques that can reduce complications and the need for future revisionary procedures, such as use of ADM, preconversion fat grafting of the mastectomy skin envelope, and routine administration of prophylactic antibiotics. When performed in such a manner, aesthetic outcomes have been excellent, and correction of animation deformity has been complete.

Given all these benefits, prepectoral breast reconstruction is the method of choice moving forward. The muscle sparing technique is minimally invasive and carries significant patient satisfaction.

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Breast Reconstruction with Fat Grafting Alone

7

José Maria Serra-Renom and José Maria Serra-Mestre

Introduction

Breast reconstruction with fat grafting is very useful for correcting and modifying size and symmetry [1], but reconstructing a breast with fat alone is difficult because the shape obtained is flat rather than rounded. In this chapter, we describe our technique for breast reconstruction using fat grafting alone in patients with flaccid, elastic skin, via multiple injections of fat tissue [2].

The technique involves three stages: puckering stitches, to remodel the mass each time fat grafting is performed; cone formation, the creation and lifting of a cone with the tissue from the area; and neoformation of the inframammary fold, in which the cone is anchored in the pectoralis major and the fold at the level of the sixth rib. Using fat grafting and these three maneuvers, the results obtained are satisfactory.

Patient Selection

We use this technique in cases of delayed breast reconstruction in which autologous reconstruction or implants have been ruled out. We explain carefully to the patient that multiple sessions will be required in order to obtain the desired volume and shape. It is important that the patient's skin is elastic and has not been made excessively fibrous by radiotherapy.

Preoperative Planning

To reconstruct a mastectomized breast with fat alone, two approaches are available. In both, at least three sessions of fat injection of approximately 150 cc are required in order to guarantee the viability of the graft and to ensure that it "takes" properly and is not reabsorbed.

Some authors have reported positive results with preexpansion of the area followed by serial injection of fat [3–7]. This preexpansion can be done either by the conventional method already described above or by an external preexpansion method known as BRAVA TM [5–7]. In BRAVA TM, a negative pressure device is placed on the mastectomized area for between 6 and 8 h a day during the 3 months before the reconstruction. After the injection, the patient must wear the device for 2–4 weeks. Although the results are satisfactory, the disadvantage of this system is evident – the inconvenience of having an aspiration pump connected to the chest wall for so many hours a day and for a prolonged period of time.

Another procedure is our technique of breast reconstruction with fat grafting only in those patients with redundant and elastic skin, through fat injections and puckering stitches to remodel the resulting mass [2]. Once the desired volume is obtained, we remodel the reconstructed breast, forming the new inframammary fold, creating a cone from the adjacent tissue and its pexia, and anchoring this cone in the pectoralis major muscle and in the fold at the level of the sixth rib.

Surgical Technique

In the first surgical stage, 150 cc of fat is injected on each side. The site of the new inframammary fold is chosen, and the puckering stitches are made at this point, with an incision of 4 cm that penetrates the epidermis and two-thirds of the dermis. At the ends of the incision, we make two further 3 mm incisions, thus reaching the fat tissue. With a permanent and braided suture thread of 0 thickness and with a 22 mm needle, we tie the ends of this incision as deep as possible within the fatty tissue to obtain the greatest amount of tissue possible, but without anchoring it to any deep structure. The closing of this stitch creates a puckering effect. We tie the stitch at one of the ends and bury it inside the incision.

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Three months later, we perform the second stage. Again, we inject fat throughout the surface, which is still not conical; it is becoming flattened, but is acquiring volume. In this second stage, we repeat the puckering stitches at the level of the new inframammary fold, creating a round shape in the lower quadrants. By injecting 150 cc of fat, we remodel the future lower quadrants and the slope of the upper quadrants. We try to inject more volume of fat in the area that will become the lower outer quadrant.

In the third stage, we design the mastopexy to give the definitive conical shape to all the injected fat, which has acquired a flattened shape, but providing more volume in the areas that will be the lower inner and outer quadrants. To do so, we design the inframammary fold, which we place in the scars of the puckering sutures. At the center of this mass, the midpoint, where we want to place the nipple areola complex, we draw an isosceles triangle facing downwards toward the planned site of the inframammary fold, wide enough to create the desired cone shape when the two sides are joined, with an inverted "T" scar and the definitive mammary fold. We remove the epithelium from this central triangle. Then, in the area where the scars of the puckering sutures are located, we draw a curved line that corresponds to the new inframammary fold, sectioning the skin and fat tissue completely until we reach the muscle plane. We dissect this accumulation of fatty tissue from below and above the pectoralis major muscle and suture the two pillars of skin to the sides of the de-epithelialized area, obtaining a cone shape which will be that of the new breast. After this, the tissue is anchored upward so that the inframammary fold coincides with the level of the sixth rib. Next we reconstruct the nipple areola complex, using the appropriate technique in each case.

Then, we remodel this new breast, again by fat injection (approximately 100–150 cc fat), to produce the different quadrants of the breast and the cleavage.

At the height of the fold, we close the wound with a small lifting of the abdominal skin.

Postoperative Care

Fat injection in breast surgery is a widely used method with very low complication rates, precisely because fat is an autologous material, completely biocompatible, non-migratory, non-carcinogenic, and non-teratogenic. In this procedure, lost tissue is substituted with similar tissue, applying the principle "replace like with like" [8].

Despite the low complication rate, the surgeon's experience and familiarity with the technique of obtaining, processing, and injecting fat are vital to the success of the procedure.

It must be borne in mind that the fat is handled prior to its implantation and that the fat tissue lacks vascularization between the moment of extraction and its incorporation in the recipient tissue, and so there is a risk of infection. This is why maintaining conditions of maximum sterility during the procedure, correct asepsis of the area, and close postsurgical monitoring is essential. We also recommend antibiotic prophylaxis immediately prior to surgery.

Another possible complication is damage to neighboring structures such as vessels or nerves. To avoid this, we use blunt tipped cannulas, and we always perform a slight aspiration before injecting the fat so as to not to inject it into the vessels and to avoid the potential risk of fat embolization.

As the surgeon gains experience with the techniques, irregularities or problems of hypo- and hypercorrection of the defects are reduced. In any case, hypocorrection is preferred to hypercorrection, as it can be resolved with subsequent injections.

As in any surgical procedure, inflammation or small bruises will appear during the days after the intervention. In these cases, the use of anti-inflammatory medication, cold therapy, and even homeopathic treatment may all be helpful.

In the medium to long term, calcifications may appear, but they are easy to recognize and to distinguish from those produced by the growth of a tumor. There may also be oil droplets or fat cysts. If the fat is not injected correctly, large accumulations may appear, and areas of steatonecrosis or hardening may be observed due to the encapsulation of this ischemic fat. This may be alarming for patients, because they may associate it with the tumor.

It is very important to avoid irregularities in the donor area. For this reason, the fat must be obtained by varying the direction of the tunnels and performing drainage and massage during the postoperative period, as in the case of liposuction.

Clinical Case

A 65-year-old patient presented with bilateral mastectomy and redundant tissue. Breast reconstruction with fat grafting alone was planned. During the first stage, puckering stiches to recreate the inframammary fold at the level of the sixth rib were carried out in order to fix the fold. After fat grafting, cone formation and pexia to reshape the reconstructed breast were performed achieving a very good result (Fig. 7.1).

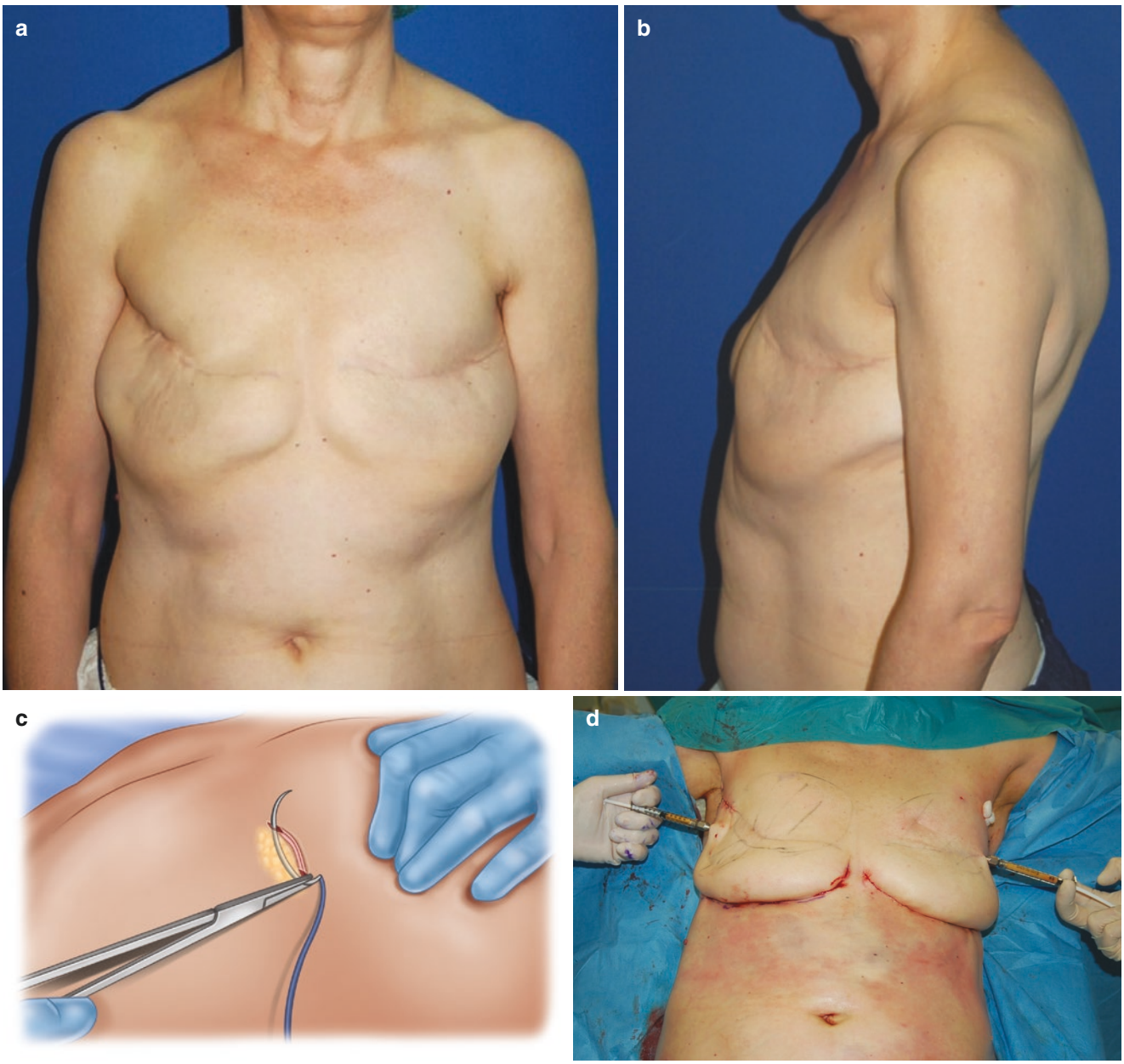

Fig. 7.1 (**a**) Preoperative frontal view of the patient. (**b**) Preoperative lateral view of the patient. (**c**) Puckering stiches to recreate the inframammary fold at the level of the sixth rib during the first stage in order to fix the fold. (**d**) Fat grafting to the entire breast in the second stage. (**e**) At the third stage, 3 months later, cone formation and pexia to reshape the reconstructed breast were performed. (**f**) Postoperative frontal view at 12 months. (**g**) Postoperative oblique view at 12 months

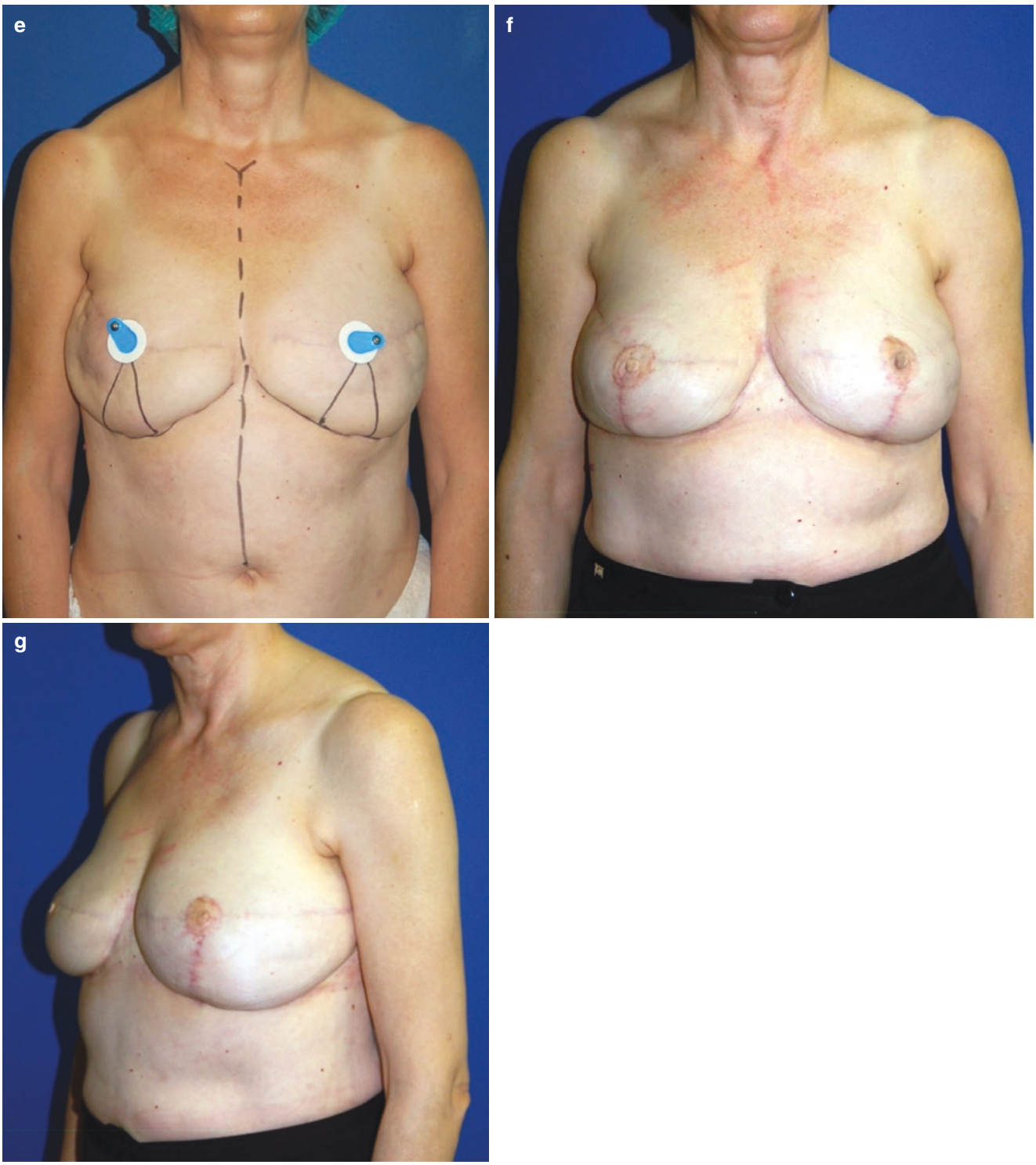

Fig. 7.1 (continued)

Conclusions

This technique allows us to perform reconstruction exclusively with fat from the patient herself without the need to perform microsurgical techniques or implants. However, although it is clearly indicated in patients who do not want to undergo microsurgery or receive implants, it requires multiple sessions in order to achieve the desired volume and to shape the new reconstructed breast.

Cone formation and pexia are essential in order to give the desired shape to the reconstructed new breast, but it must be performed in the final session once the required volume has been achieved.

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Hybrid Breast Reconstruction

8

José Maria Serra-Mestre and José Maria Serra-Renom

Introduction

Fat injection has established itself as a useful technique for the management of defects and asymmetries after breast reconstruction [1, 2]. Today, however, fat is considered not just as an autologous "filler" that can correct volumetric defects in various areas of the breast but also as a regenerator of the injected tissues, thanks in part to stromal vascular fraction cells [3, 4]. This regeneration is an important issue in breast surgery due to the damage caused to the tissue by radiotherapy.

In this context, Rigotti demonstrated the improvement in radiated tissues after serial fat injection, reporting a fall in LENT-SOMA score from 3–4 to 0–1 [3]. Along the same lines, our research group demonstrated the formation of a new subcutaneous plane in the mastectomized breast after radiotherapy, reducing the formation of the periprosthetic capsule and presenting improved quality and elasticity of the breast tissue [4]. Numerous studies have examined the subject in depth and have designed a variety of injection protocols in order to improve the skin quality while creating greater coverage for implants, known as LIPOBED, in cases of breast reconstruction post-radiotherapy [1, 5, 6].

This great expansion in the field of breast reconstruction, however, has raised two major doubts: first, the oncological safety of fat injection in patients with breast cancer; second, the modification of the radiological image and its possible interference in the follow-up of these patients. Since the 1980s, the issue of the use of fat grafts has aroused considerable controversy. The main problem is the possible modification of the radiological image in both mammography and magnetic resonance imaging (MRI), which may hinder radiological control after the intervention and thus interfere in the early detection of breast cancer. The radiological findings after fat injection are not specific to tumor growth; they are images which radiologists must learn to recognize and interpret, just as they have to familiarize themselves with the changes that appear in other conventional breast surgeries (reduction, augmentation, mastopexy, and so on) which are commonly accepted. It is true that multimodal imaging techniques may be necessary to resolve cases of diagnostic difficulty in the follow-up of these patients, but the use of fat grafting as a complement to breast reconstruction techniques is not currently contraindicated in any situation [7].

As regards oncological safety, fat grafting has not been associated with an increase in local recurrence of breast cancer or an increase in the risk of new cancers. In fact, the increase in aromatase after breast augmentation surgery is 20 times greater than that caused by fat grafting [8].

The use of tissue expansion and prosthesis in post-cancer breast reconstruction is controversial because of the evolution of the implants after radiotherapy. For this reason, other techniques involving autologous tissue surgery have been proposed, such as the use of a DIEP flap from the abdominal region or a latissimus dorsi flap from the back. Recently, however, the incidence of breast cancer in young, thin women has increased. In these patients the abdominal flap is not indicated, and the latissimus dorsi flap causes a functional limitation and an unsightly scar. In this chapter we present our experience in hybrid breast reconstruction with fat grafting and implants.

Patient Selection

This technique is used at our service in both immediate and delayed breast reconstruction in patients in whom autologous reconstruction has been ruled out.

We use this combination of fat grafting and implants regardless of whether the patient has received radiotherapy.

Preoperative Planning

In immediate reconstructions, before beginning the surgery, we design and mark the reference lines with the patient in the standing position. First, the oncological surgeon designs the incision of the mastectomy to be performed. In cases of large

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breasts, our technique of choice is a Wise pattern breast reduction [9], while in patients with normal-size or small breasts, the choice will depend on the need to remove the areola and on the amount of skin that must be preserved. Next, we design the pocket that we will create for the insertion expander. To do this, we mark the midline from the sternum to the navel and we define the width of the pocket, marking the anterior axillary line and a line 1.5 cm from the midline. We mark the current inframammary fold and the site further down where the new inframammary fold will be placed. This site will be placed parallel to the current fold, and at a distance corresponding to half the patient's pinch test result (i.e., the thickness of the skin and subcutaneous fat layer). In most cases, this is around 1–2 cm below the current fold. We stress that these measures are only indicative and that the site of the definitive new fold will be chosen using the already reformed contralateral healthy side as a reference.

In delayed reconstructions, on the mastectomized side, we mark the midline running from the sternum to the navel. We define the width of the pocket, marking the anterior axillary line and a line 1.5 cm from the midline. The new inframammary fold is marked at the level of the sixth rib plus half the thickness of the pinch test result (1 or 2 cm, depending on the patient).

Subsequently, if correction on the contralateral healthy side is required to maximize symmetry, a reduction mammoplasty, mastopexy, or breast augmentation will be performed.

Surgical Technique

One of the main aims of reconstruction is to ensure that the shape and volume of the two breasts are as symmetrical as possible. In most patients, this requires some remodeling in the healthy breast. We favor carrying out any necessary remodeling in the first stage, since better results are obtained if we can perform the symmetrization with the expander and the fat grafting using the already reformed healthy side as our reference point. This approach also allows us to make any necessary adjustments in the second stage. If the healthy breast is small, we perform an augmentation mammoplasty [10]; if a mastopexy or reduction is indicated, our technique of choice is the vertical scar [11].

First Stage

At the same time as the remodeling of the healthy breast, and once the mastectomy is finished, we partially detach the pectoralis major muscle at the level of the fourth, fifth, and sixth ribs.

The new inframammary fold is placed 1 or 2 cm below the level of the sixth rib. We suture the lower free edge of the pectoral muscle to the lower skin flap of the mastectomy, 2 cm from its free edge.

We then insert the expander and fill it with saline solution (approximately 100 cc) to avoid the formation of folds in the expander, but without creating tension at the level of the skin so as to avoid excessive strain if the flaps are very thin. Finally, we insert a suction drain and suture the skin.

With our technique [12] the upper quadrants form an inclined plane, as they are below the pectoral muscle. The expansion of the lower quadrants is highly satisfactory, since the muscle is detached, obtaining a clear curved shape especially in the lower outer quadrant. The reconstruction thus achieved acquires a very natural form.

Two weeks later, the expander is filled at a rate of 50 cc per week until the breast reaches the same size as the contralateral breast. Once this is achieved, we perform a slight overexpansion prior to the second stage.

In delayed reconstructions, we insert the expander with endoscopic assistance through a 4 cm incision in the lateral third of the mastectomy scar, at the level of the anterior axillary line, and with the help of our endoscopic retractor [4, 13], we create the pocket below the muscle in the upper quadrants and below the subcutaneous plane in the lower quadrants. The new fold is created at the same height as the contralateral side which has already been reformed.

We then insert the expander (we favor the use of expanders with a built-in filling valve) and increase the volume without damaging the skin. In up to 90% of cases, symmetrical volumes can be achieved in the two breasts in this first stage.

Simultaneously, a member of the team harvests and prepares the fat. Fat grafting is performed exclusively in the upper quadrants, injecting the fat into the subcutaneous plane and pectoral muscle [4].

Second Stage

Some 3 months after the first surgery, the expander is replaced with the definitive prosthesis through a 4 cm incision in the lateral third of the mastectomy scar and outside the free edge of the pectoral muscle. In delayed reconstructions, the expander is replaced through the incision that we made in the first stage.

We use sizers to calculate the dimensions of the prosthesis required. At our practice we use anatomic cohesive silicone prostheses. Once the prosthesis is inserted and the skin sutured, we perform fat grafting all over the breast. In the upper quadrants, we inject fat in the subcutaneous plane between the muscle and the skin, and also into the muscle, and in the lower quadrants between the capsule and the skin in order to achieve a good reconstruction.

This technique [4] improves tissue quality and reshapes the breast to obtain as symmetrical a result as possible with regard to the contralateral breast. In the contralateral breast, if necessary, we also perform fat grafting.

To perform the fat grafting, we use the method defined by Coleman [14] with some slight modifications. Firstly, using a multiperforated tumescent cannula with a Luer Lock

connection of 1.6 mm × 9–15 cm in length, we create the tumescence of the periumbilical region by injecting saline with adrenaline at a rate of 100 c.c. of serum and 1 mg of adrenaline and 10 cc of 2% lidocaine.

After obtaining the fat by performing low-pressure liposuction, the fat is washed and filtered with the aim of eliminating the remains of local anesthetic and blood detritus with devices such as the Puregraft or with a surgical filter.

To avoid irregularities in the abdomen, we change the site and direction of the aspirations. Once the extraction is complete, we rectify the donor area using a flat liposuction cannula without aspiration.

To inject the fat in both upper and lower quadrants and in the tail of the breast, we use a blunt microinfiltration cannula. In areas where there may be fibrosis, for example, in the mastectomy scars, we also use a V-shaped dissection cannula for microinfiltration [V7], either straight or convex, with a blunt tip and a side aperture of 2 mm.

When injecting in the form of microtunnels, very small amounts of fat must be deposited in each tunnel. It is advisable to deposit the fat as the cannula is being withdrawn rather than when it is being introduced and to use crisscross injection planes from the depth to the surface to avoid accumulations of fat.

The injection of fat not only provides greater symmetry but also helps to prevent the formation of a hardened capsule and, after radiotherapy, improves the vascularization and skin quality and the neoformation of subcutaneous tissue [4–6]. In this way we obtain a much more natural look and feel in the reconstructed breast. In this second stage, we also apply any necessary retouches to the healthy side to optimize the aesthetic results, and we reconstruct the areola-nipple complex.

In breast reconstruction (especially unilateral reconstruction), the intermammary distance is often excessive, and clear asymmetries may also appear. These problems cannot be corrected with current surgical techniques, because the space between the two breasts is determined by anatomical factors such as the attachment points of the breast tissue to the periosteal tissue covering the sternum, and also to some extent by the medial attachments of the pectoralis major muscle and the thickness of this muscle when a retropectoral dissection plane is used. We have recently described a technique [15] in which we use fat grafting as a complement to the different breast surgery procedures, not only in cases of reconstruction but in cosmetic surgery as well. Using limited amounts of fat, this approach allows the redefinition of the cleavage, correcting asymmetries as well as reducing the distance between the two breasts. Fat grafting is always performed once the surgery is finished, and the cannula is inserted via previously made incisions. In cases of breast reconstruction with expanders and implants, we perform this technique in the second stage when the expander is replaced with the final prosthesis, since we have a capsule formed in the lower quadrants that will prevent any contact between the fat with the implant. The microfat graft is injected using a 0.7 mm blunt cannula into the subcutaneous layer in the shape of a half-moon and spreads from the inframammary fold toward the upper quadrants. It is important to extend this half-moon shape toward the upper quadrants, creating an inverted "L" shape to obtain a satisfactory medial cleavage and avoid possible irregularities in the upper inner quadrant.

Postoperative Care

Each patient requires a specific treatment and follow-up depending on the techniques that have been performed in both the reconstructed and the contralateral breasts. The purpose of this chapter is not to describe the postoperative control and care of breast reduction, mastopexy, or the reconstruction of the nipple areola complex, but we should nonetheless stress that fat grafts need to be immobilized in order for them to "take" correctly. The patient must sleep in the supine position for 2 or 3 weeks, and prompt inspection of wounds is important.

As these patients have a personal history of cancer, they should continue their radiological control just as they would if they had not undergone fat grafting.

At the donor site, in the postoperative period, we recommend the application of chelating creams to alleviate bruising and also lymph drainage and massage to help restore the whole area. If a large surface has been aspirated, a month of acupressure is highly recommended.

In cases of immediate reconstruction, expansion begins when the mastectomy healing is consolidated, usually after 3 weeks. The fact that the cutaneous scar is protected by the pectoral muscle beneath it avoids extrusion of the intradermal stitches in many cases.

In cases of delayed reconstruction, in the immediate postoperative period, it is important to check the skin for signs of ischemia due to intraoperative expansion. If these signs are found, the expander must be partially emptied.

Clinical Cases

Case 1

A 62-year-old patient who had a previous mastectomy in her left breast underwent contralateral mastectomy with immediate breast reconstruction with an expander and lipobed. At the second stage, after 3 months, the expander was replaced by an anatomical implant, and fat grafting was performed in the entire breast – in the two upper quadrants between the skin and the pectoral muscle and also inside the muscle, and in the two lower quadrants between the skin and the newly formed capsule. The nipple areola complex was also reconstructed using a local flap and an inguinal skin graft for the areola (Fig. 8.1).

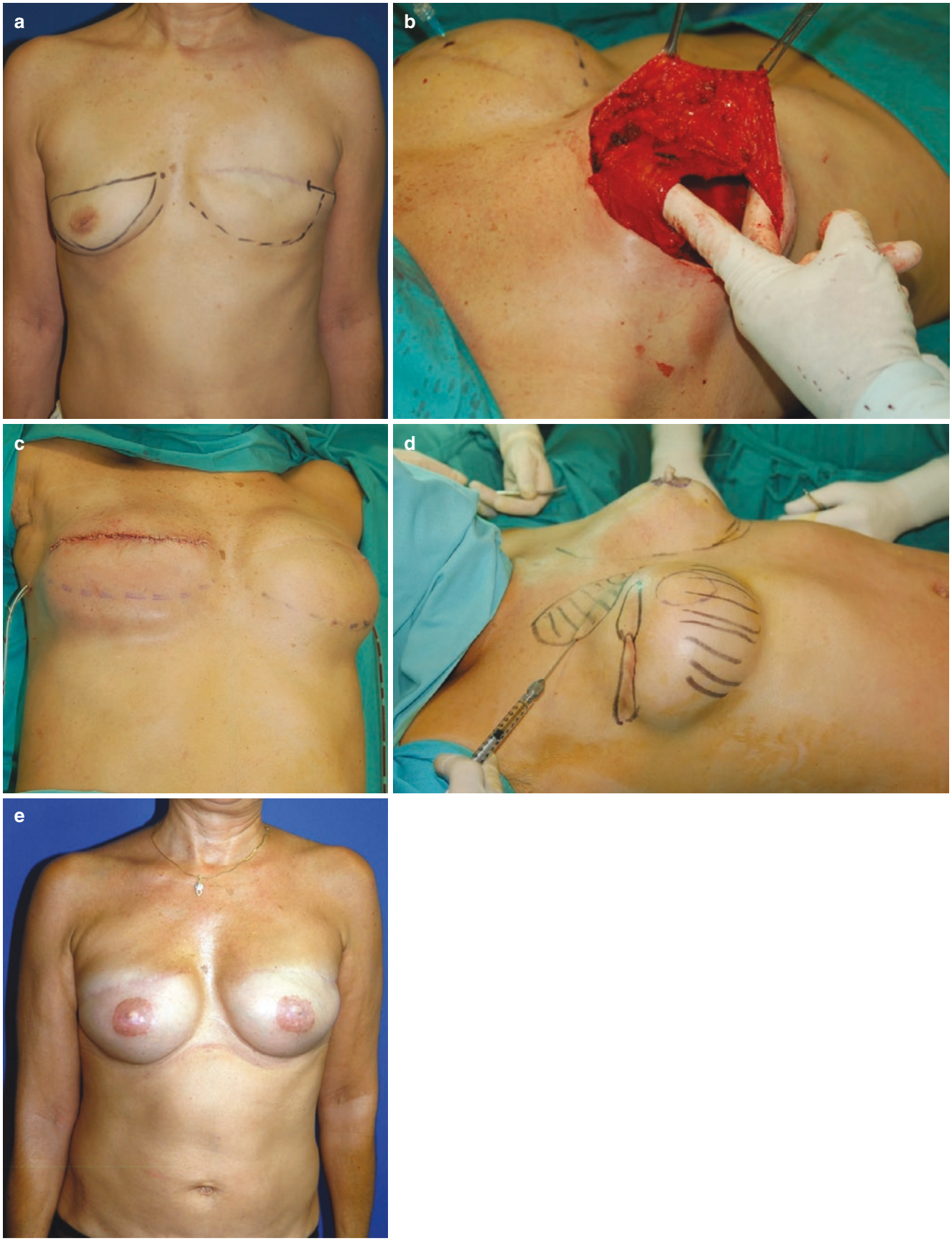

Fig. 8.1 (**a**) Preoperative frontal view. (**b**) At the first stage, the pectoralis major muscle was detached from the sixth and fifth ribs, and the free edge of the muscle was sutured to the lower flap of the mastectomy. (**c**) A minimum filling of the expander is also performed during this stage. (**d**) At the second stage, the expander was replaced by an anatomical prosthesis, and fat grafting was performed in the entire breast. (**e**) Postoperative frontal view at 12 months

Case 2

A 45-year-old patient who had a previous mastectomy due to an infiltrating ductal carcinoma of the left breast underwent delayed endoscopic breast reconstruction with expanders and lipobed with fat grafting. At the first stage, an expander was inserted via endoscopy through an incision in the axilla. During the second stage, after 3 months, the expander was removed, an endoscopic capsulotomy was performed, and the anatomical implant was inserted via the lateral incision previously used. Fat grafting of the two lower quadrants, between the skin and the newly formed capsule, was also performed during this stage (Fig. 8.2).

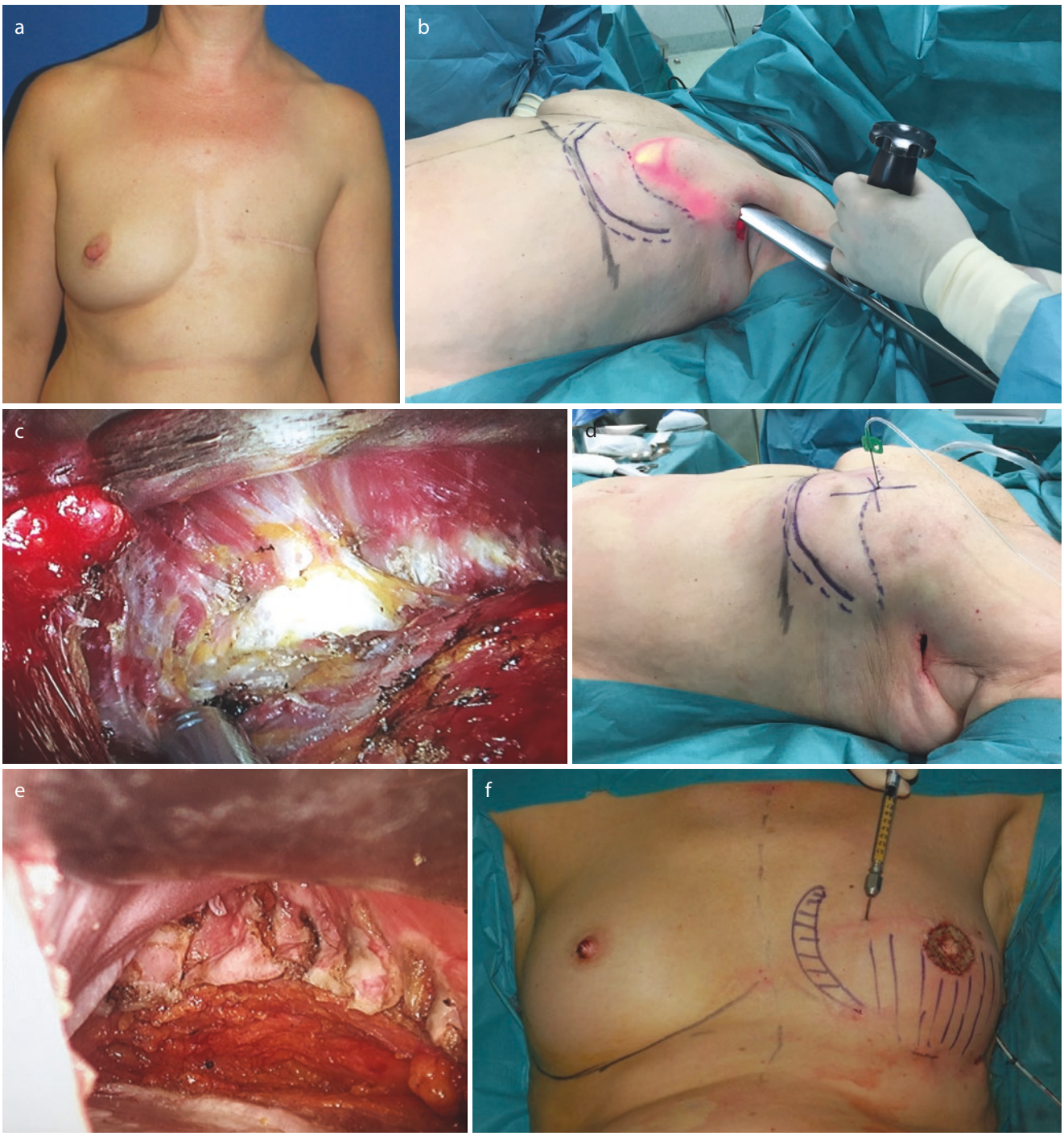

Fig. 8.2 (**a**) Preoperative view. (**b**) An expander was inserted via endoscopy through an incision in the axilla. (**c**) Detachment of the pectoralis major muscle was performed. (**d**) Intraoperative filling of the expander. (**e**) At the second stage, the expander was removed and an endoscopic capsulotomy was performed. (**f**) Fat grafting of the two lower quadrants between the skin and the newly formed capsule is performed in this second stage. (**g**) Postoperative frontal view at 12 months

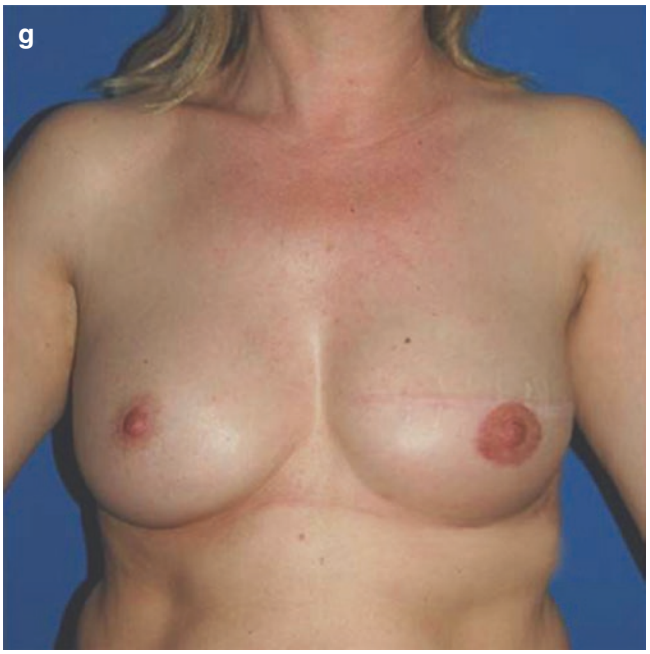

Fig. 8.2 (continued)

Conclusions

Careful selection of the technique for each particular case and the surgeon's experience with the surgical approach are the key factors for successful reconstruction. There is no gold standard that is valid for all situations and that can guarantee the absence of complications.

Breast reconstruction with expanders and prostheses is currently the most widely used option. Its popularity is due in part to its apparent simplicity; however, to obtain successful results and to avoid high rates of long-term complications, several important considerations need to be borne in mind.

The detachment of the pectoral muscle allows correct expansion of the lower quadrants and at the same time obtains a very natural inclination in the higher planes. The fat grafting improves tissue quality, thickens the subcutaneous cellular tissue, and improves the symmetry of the two sides. It also allows us to define the neckline in the medial upper quadrants and the tail of the breast in the lateral quadrants. However, the key factor in achieving good results in unilateral cases is the correct choice of the aesthetic treatment applied to the healthy contralateral breast.

Another aspect widely criticized is the evolution of the implant in certain cases (i.e., extrusion and capsule formation). Fortunately, extrusion and complete loss of the implant is very rare. To avoid it, we always make the incision in the lateral third of the mastectomy scar, in the anterior axillary line, so that the weakest area (the incision) is not the area where the prosthesis exerts the maximum pressure. In addition, muscle coverage and suture 2 cm from the free edge of the lower flap of the mastectomy minimize this complication.

While chemotherapy does not seem to alter the results, radiotherapy is a predisposing factor for periprosthetic capsule formation. However, the use of textured implants, and above all the performance of fat grafting, can significantly reduce these complications even in radiated patients.

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Breast Reconstruction with Intratissular Expansion and Fat Grafting

9

Filip B. J. L. Stillaert

Introduction

Breast reconstruction modalities are based on allogeneic materials, autologous tissue transfer, or a combination of both with each of them having their own unique advantages and disadvantages. The choice for a certain technique is based on a personalized approach of the patient and the surgeon's expertise as well as the patient's wishes, motivation, associated risk factors, clinical presentation, and available infrastructure. Still, the common objective is an oncological safe and aesthetically pleasing, long-lasting result.

Alloplastic breast reconstructions involve fewer scars, no donor site morbidity, and less operating time, but the drawback is the implant's impact on surrounding tissues. Even with submuscular or dual-plane approaches, implant-based reconstructions are infamous for inducing tissue atrophy, implant migration, lateralization, capsular contraction, higher risk of infection, breast animation deformity, poor aesthetic outcomes with upper pole fullness, and poor lower pool expansion. The lack of sufficient tissue support, compromised tissue vascularity, and poor tissue coverage in post-mastectomy patients increase the risk of those complications significantly.

Autologous, microsurgical tissue transfer is superior due to its tissue plasticity and based on the "replace like with like" principle, but it implies the sacrifice of unaffected anatomical regions. Often, it is not an option due to insufficient or compromised donor tissue.

Fat grafting bypasses the disadvantages related to the abovementioned techniques and relocates fat without major incisions or discomfort. However, lipofilling uses lipoaspirate material or liquefied fat that consists of countless small particles of fat. The superiority of lipoaspirate material is that it can be injected in a targeted manner. It is the most natural filler and in breast reconstruction it is mainly used to correct irregularities or contour deformities after alloplastic or autologous breast reconstructions.

Fat grafting for total breast reconstruction involves a major challenge: building up a three-dimensional, geometrically shaped, prepectoral tissue surrogate using a liquescent material. Moreover, the limiting factor in fat grafting is the unpredictable resorption rate. This is an annoying hitch when predictable and reliable results are expected.

Large-volume, single-stage reconstructions with lipofilling are not feasible yet except when numerous sessions of fat grafting are successfully applied [1–4]. To improve resorption rates, external volume expansion devices based on tissue engineering principles have been introduced in the clinic [1–4]. The technique requires a strict, daily compliance to the expansion treatment protocol, which can be inconvenient for some patients or brings some morbidity along for others [3].

Grafted fat survives the immediate post-transplant period through a biological process called plasmatic imbibition just like a skin graft [5–7]. This process precedes the graft's revascularization which is initiated mainly because of the graft's hypoxic condition [6, 7]. To optimize the homeostatic environment of grafted fat, the technique of structural fat grafting was introduced, a layered, multidirectional injection technique to benefit uttermost from the plasmatic imbibition phase [8, 9].

We know from our previous research that four basic principles need to be respected in adipogenesis: [1] space for the tissue to survive, [2] a supportive environment, [3] angiogenesis, and [4] a potent, viable cell source [10].

To include those four principles in autologous breast reconstruction, an ideal environment needs to be created within the mastectomy pocket that prevents dispersion of injected fat into the pocket, supports its survival, and allows volume expansion. All multicellular processes involved in survival and tissue morphogenesis should be supported within this environment.

The (post-)mastectomy recipient site consists essentially of two tissue units: the pectoral muscle posteriorly and the skin envelope anteriorly. The focus of the reconstructive

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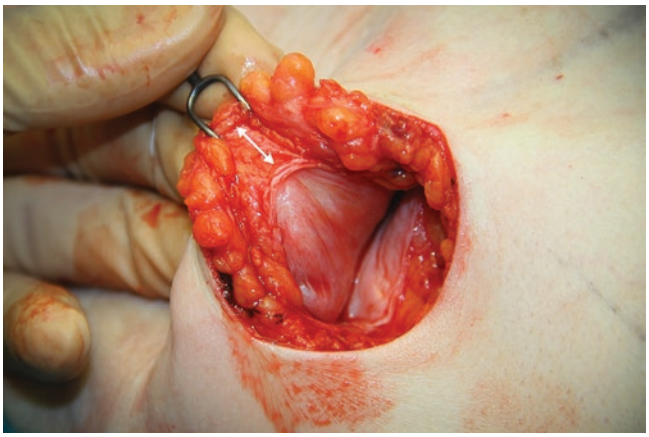

Fig. 9.1 Intraoperative view on the capsule. The capsule is a compliant, stretchy but resilient structure and borders a space between the skin and the capsule itself. In between the capsule and the skin, fat grafting can be performed to build up the subcutaneous tissue layers (white arrow)

approach is in between those two compartments: "replace the breast glandular tissue with like-tissue." Volume restoration requires an expandable, compliant recipient site.

A native extracellular matrix is a "biological glue" that holds cells together and coordinates their survival and behavior. We need to incorporate some sort of "anchoring" matrix or environment that prevents migration or diffusion of the injected fat. It needs to be an expandable matrix allowing gradual, staged volume increase.

Tissue expansion induces the formation of a vascularized capsule which is an autologous, compliant structure [11, 12]. This capsule plays a pivotal role in our breast reconstructive protocol. It defines the boundaries of a newly created recipient site or space between the capsule itself and the skin to that extent that it prevents oozing or dispersion of subcutaneously injected fat into the mastectomy pocket. Secondly, the capsule is highly vascularized at 8 weeks [11, 12]. This large-scale vascular plexus in the outer layer of the capsule is an appreciative angiogenic source for injected fat. Thirdly, this young capsule is a compliant, stretchy but resilient structure and defines an expandable space (Figs. 9.1 and 9.2).

With this design one can augment the niche between the skin and capsule with fat grafting and decrease the volume beneath the capsule (expander deflation): the breast can be built up in a layered, centripetal manner.

Anatomy

The breast is a subcutaneous, three-dimensional structure: glandular tissue lies over the pectoral muscle and is covered anteriorly by a layer of subcutaneous fat tissue and skin. A mastectomy basically leaves two tissue units intact: the pectoral muscle and the skin envelope.

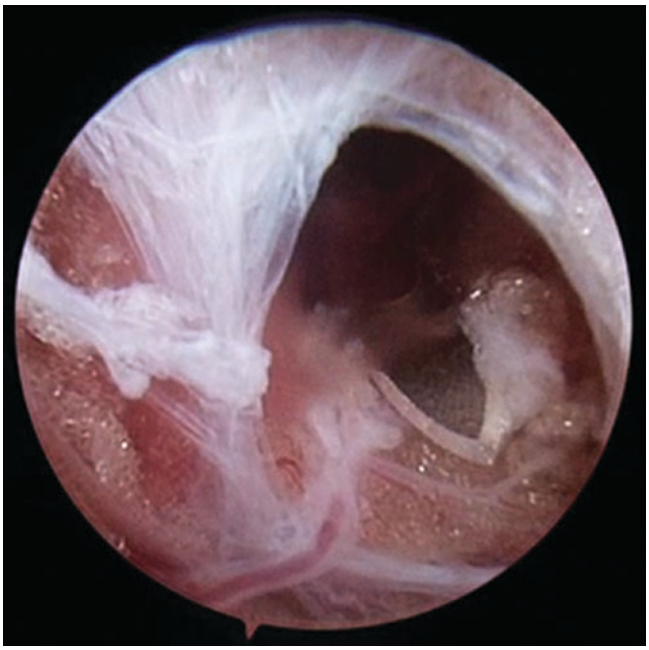

Fig. 9.2 Video endoscopic view after expansion. An 18G needle has been introduced subcutaneously within the space between the skin and the capsule. A well-defined environment is observed and functions as the recipient site for fat grafts. Notice a young vessel on top of the capsule

The footprint is the base of the breast onto the chest wall [13]. A well-performed mastectomy leaves the footprint intact as well as the inframammary fold which is a clearly defined anatomical structure. The focus of the reconstruction is the space between the pectoral muscle and the skin.

Patient Selection

Breast reconstruction with fat grafting is indicated for specific cases and based on a rational, personalized approach of the patient with realistic expectations. Lipofilling is indicated to reconstruct small-volume breasts (200–300 cc), and its feasibility depends mainly on the available bulk of donor tissue. A thorough clinical assessment of potential donor site regions is necessary in order to assess the amount of available donor tissue (Fig. 9.3). Patients should be motivated and be instructed that several fat grafting sessions are necessary and that several procedural steps are involved.

Primary reconstructions with fat grafting are initiated when no adjuvant treatment is involved. When adjuvant chemotherapy or radiation therapy is planned, it is advisable to postpone the reconstruction (and expander insertion) at least 6 months after completion of the adjuvant treatment protocol.

In secondary reconstructions expander insertion is safe when the abovementioned 6-month delay has been respected. Obviously, smoking is a relative contraindication to perform

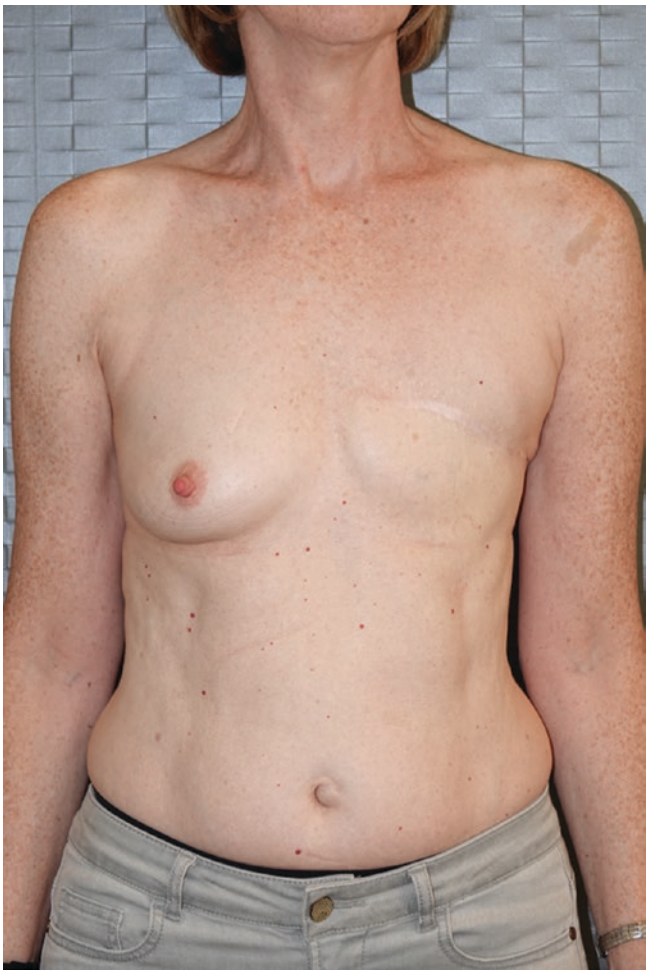

Fig. 9.3 The ideal candidate for a breast reconstruction with fat grafting. Small-volume breast on the right side and good-quality tissue at the mastectomy recipient site. She presents with a sufficient amount of available donor tissue to perform the lipofilling procedure

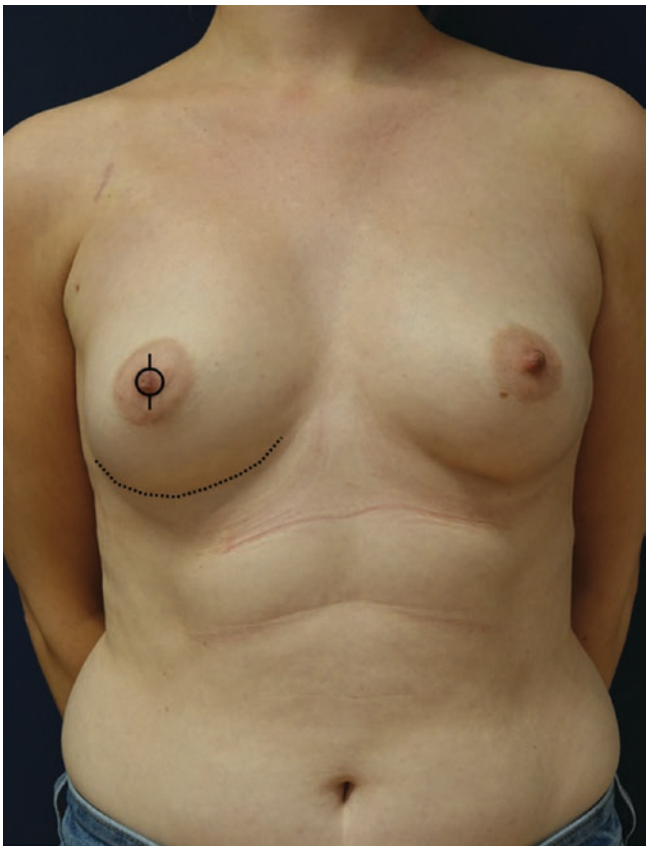

Fig. 9.4 Incision markings to remove the breast glandular tissue and the nipple. Inframammary fold incision with a separate incision to remove the nipple

the procedure as it has a deleterious impact on fat graft survival. Patients are advised to quit smoking at least 6 weeks before surgery.

Preoperative Planning

All different reconstructive options should be discussed with the patient. Motivation to undergo several lipofilling sessions and realistic expectations are key factors to achieve a successful outcome. In case of larger volume breasts, the option of a hybrid (fat with implant) breast reconstruction should be discussed.

Preoperative planning consists of a clinical examination of the breast or mastectomy area with assessment of skin quality and location of previous scars.

The amount of available donor site tissue is discussed with the patient as well as the wanted final breast volume. Frequently used donor sites are inner thigh region, love handle region, abdomen, buttock region, and lateral thighs.

In general, based on our magnetic resonance imaging (MRI) study, we assume that injection of 100 cc of fat will result in a volume augmentation of 50 to 60 cc although many other variables are involved in the survival of grafted fat [14].

Primary reconstructions are feasible in oncological or prophylactic (genetic predisposition) cases. In oncological reconstructions incision location is determined in consultation with the breast surgeon. Whenever practicable the breast is removed through an inframammary fold (IMF) incision. This approach is definitely indicated in prophylactic cases. A separate, straight areolar incision including the nipple is performed to remove the nipple if indicated (Fig. 9.4). The IMF incision disguises the incision in this natural fold and improves the aesthetic outcome.

Attention points in secondary reconstructions are the tissue quality (previous radiation therapy) and the position and quality (atrophic) of the mastectomy scar. Markings are performed in an upright position and include the IMF and upper breast pole (footprint). In secondary reconstructions it is advisable not to open the existing mastectomy scar to insert

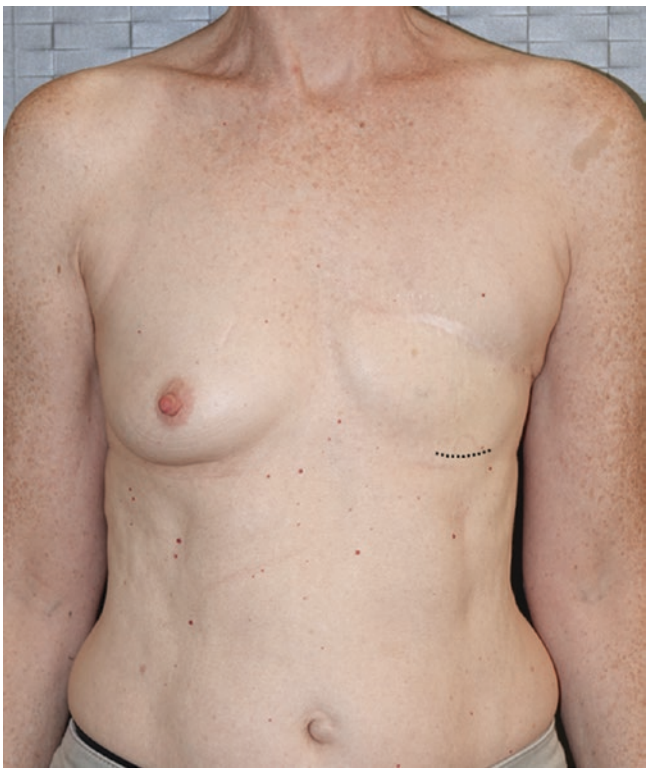

Fig. 9.5 Incision marking in secondary reconstructions to preserve the residual skin envelope. The incision is marked in the (imaginary) inframammary fold along which the expander will be inserted

the expander. Re-opening this scar would delay the procedure as the scar would need to heal again before any lipofilling can be performed. One needs to consider the existing (post-mastectomy) skin as a complete, intact recipient site. The incision (5 cm in length) is marked in the IMF in the upright position (Fig. 9.5).

Surgical Technique

Essentially, the technique consists of expander insertion, fat grafting, and expander deflation and eventually expander removal (Fig. 9.6). All procedures are done under general anesthesia. In secondary reconstructions, the expander can be inserted under local anesthesia. Most of the post-mastectomy patients have a diminished sensibility at the recipient site.

The patient is marked preoperatively in the upright position. Markings included the limits of planned dissection (primary cases), the existing inframammary folds, and the proposed new inframammary fold (IMF) in secondary reconstructions (Fig. 9.7). Expanders (CPX4 Contour Profile Tissue Expander, Mentor®, Leiden, The Netherlands) with suture tabs are used to prevent expander migration.

In primary reconstructions, the breast is removed preferentially through an IMF incision (Figs. 9.8 and 9.9). This approach leaves the scar well-hidden in the IMF.

The prepectoral plane is our first choice, but in primary cases with thin mastectomy flaps (less than 1 cm), the expander is positioned in a submuscular plane (Fig. 9.10). In secondary reconstructions insertion is done through an inframammary incision (4 cm in length). Previous scars on the skin envelope are not re-opened to maintain the integrity of the skin envelope.

The expander is fixated with the suture tabs to the underlying pectoral muscle with resorbable polyglactin 2/0 sutures (3, 6, and 9 o'clock) to prevent migration or lateralization in submuscular approaches (Fig. 9.4).

We used to pre-fill the expander with 50 cc of NaCl 0.9% enriched with 5 cc methylene blue, but recently we started to inject air which has a more homogenous distribution and is more comfortable for the patient. After insertion the expander is expanded to check for symmetry and positioning (Fig. 9.11).

Expanders are always left in a deflated condition (just 50 cc in volume) to offload the pressure on surrounding tissues and incisions. Expansion at the inset of the expander could compromise wound healing and creates a voluminous pocket susceptible to seroma formation (Fig. 9.11).

A closed suction drain is placed in the pocket. Incision is closed in a multi-layer approach with everted wound edges with resorbable sutures. The drain is removed postoperatively until drainage output is <30 cc over 24 h.

Oral antibiotics were prescribed for 5 days (amoxicillin 500 mg/clavulanic acid 125 mg). The drain is removed postoperatively until drainage output is <30 cc over 24 h.

In secondary cases it is important to insert the expander at the level of the imaginary new IMF. The expansion process itself creates the new IMF (Fig. 9.12).

Expansion is started at 2 weeks postoperatively in the event of uneventful wound healing (Fig. 9.12). It is continued for 8 weeks until the desired volume (symmetry with the contralateral side) is achieved, and slight overexpansion is performed in secondary reconstructions to allow for sufficient lower pole expansion and to obtain ptosis in the final result. Expansion is performed with air injection on an ambulatory basis at the outpatient clinic.

The structural lipofilling approach, introduced by Sydney Coleman, with layered fat injections ensures maximal survival of the grafted fat, but it also obligates the surgeon to include several sessions in the breast reconstructive protocol.

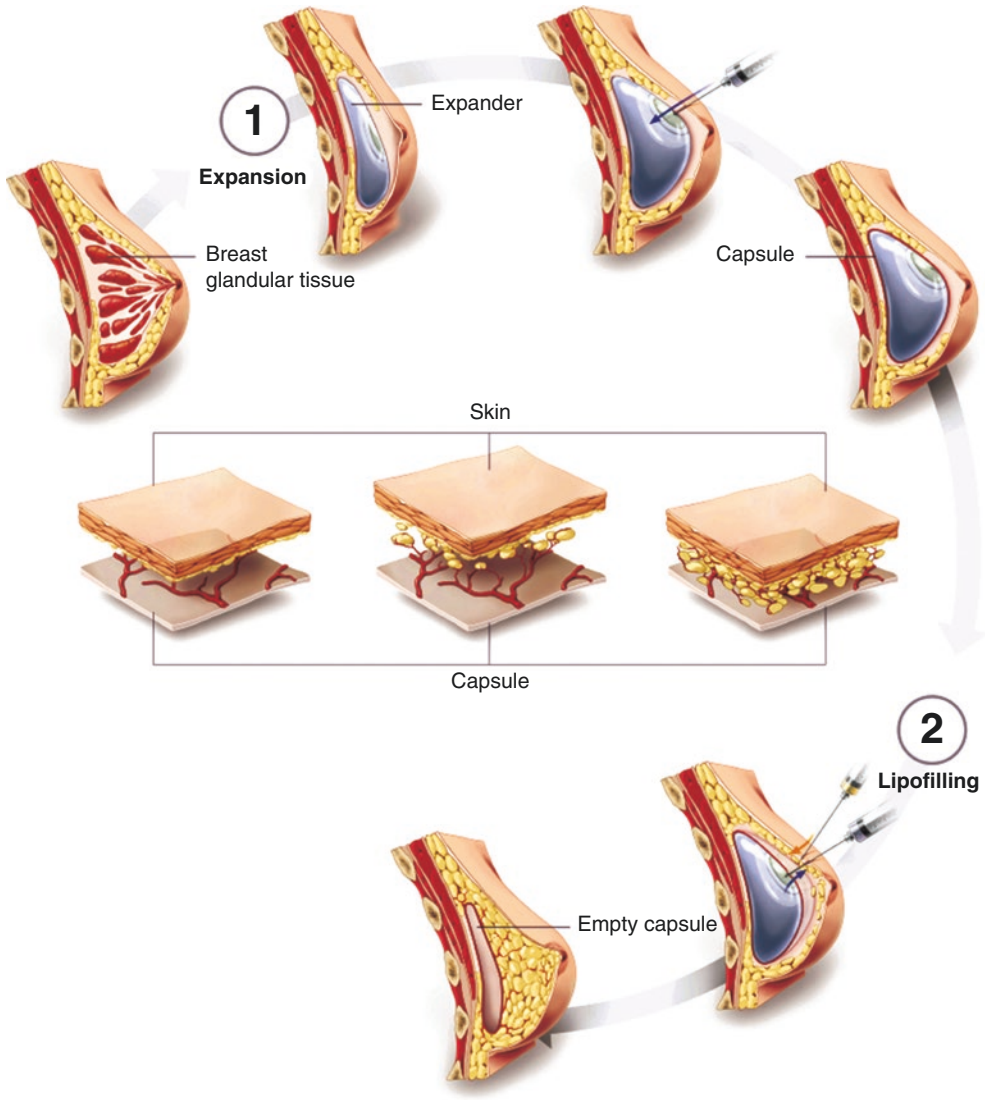

Fig. 9.6 An expander is inserted preferentially in the subcutaneous plane. The submuscular plane is chosen in case of thin mastectomy flaps. Expansion is started at 8 weeks postoperatively. By that time a compliant but resilient capsule has formed with a rich vascular plexus in its outer layer. At 8 weeks the first lipofilling session is performed and the expander partially deflated (about 1/3 of the volume). With an interval of 3 months, several lipofilling sessions are performed to build up the breast with structural fat grafting. At the end of the procedures, the expander is removed and the capsule left in place

Over-injection will result in cell necrosis, induration, and oil cyst formation.

Coleman's structural fat grafting was performed at 8 weeks post-implant. In summary, donor sites (thigh, buttock area, and abdomen) were infiltrated with a liposuction solution (1 L NaCl 0.9%, 20 mL Xylocaine 1%, 1 mL epinephrine 1.0 mg/1 mL). After a delay period of 20 min, fat was liposuctioned manually with a 50-cc syringe connected to a three-hole Mercedes tip, 3-mm cannula. Lipoaspirate (LA) was transferred into 10-cc Luer lock syringes and centrifuged at 12 g for 3 min (Centrifuge LC 24, 230 V, Sarstedt®, Nümbrecht, Germany). The expander is partially deflated, and a small stab incision with an 18G needle is made as an entry point for the lipofilling cannula (Fig. 9.13). Potential entry points are within the transition zones between the areola and skin and at the medial or lateral side of the breast within the IMF.

Concentrated LA was injected subcutaneously with a single-hole cannula (Concave Infiltration Cannula, Style I, 12 g, Coleman®, Byron, Mentor Corp., Santa Barbara, CA) in a layered, multidirectional fashion (Fig. 9.14). Care was taken not to compromise the skin turgor to avoid obstruction of the capillary perfusion.

The interval between two consecutive fat grafting sessions was set at 3 months. This arbitrary time period was chosen to allow the fat grafts to settle and angiogenesis to occur and to limit the total duration of the treatment.

Although resorption has been described as an ongoing phenomenon for at least 1 year, this time frame seemed to be ideal to achieve acceptable and durable results [6, 7].

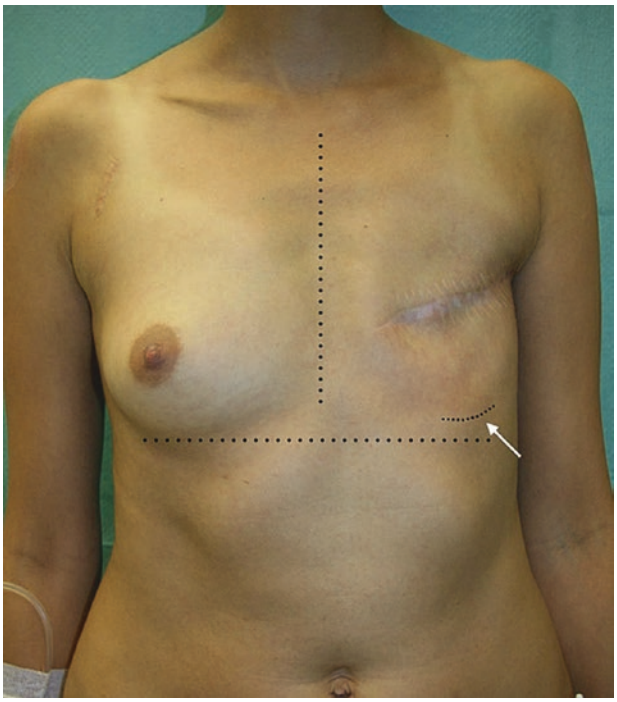

Fig. 9.7 Markings in secondary reconstructions include the proposed IMF and the incision within the IMF. The residual skin envelope is left intact and the previous mastectomy scar is not used or re-opened to insert the expander

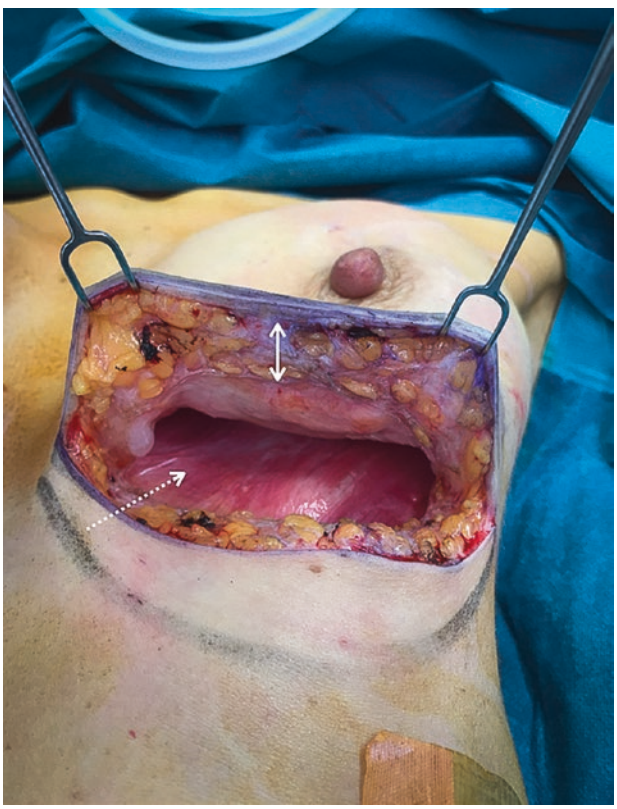

Fig. 9.8 This patient had a breast augmentation in the past. A prophylactic mastectomy is planned because of genetic predisposition. The mastectomy is performed with an IMF incision. The implant has been removed with a clear view on the pocket and the breast glandular tissue (double arrow)

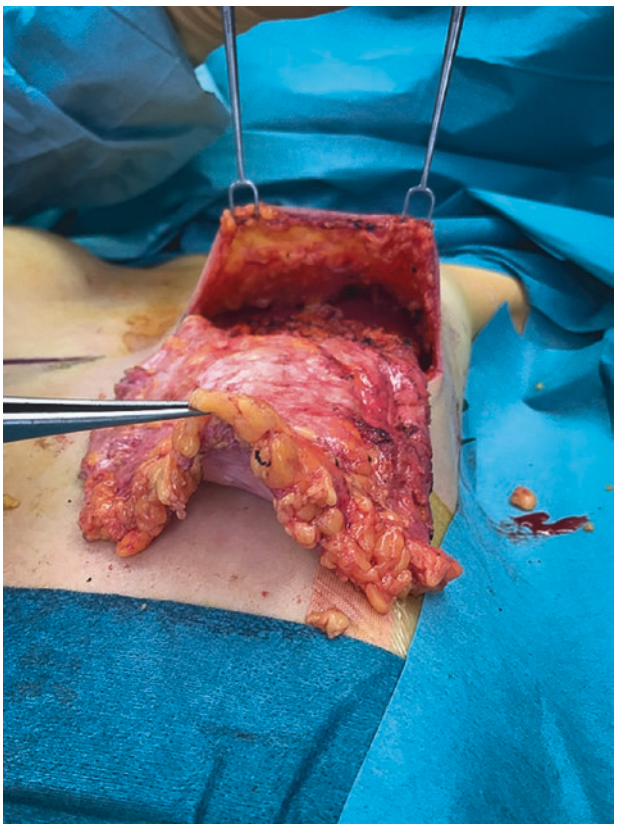

Fig. 9.9 Removal of the breast glandular tissue through an IMF incision

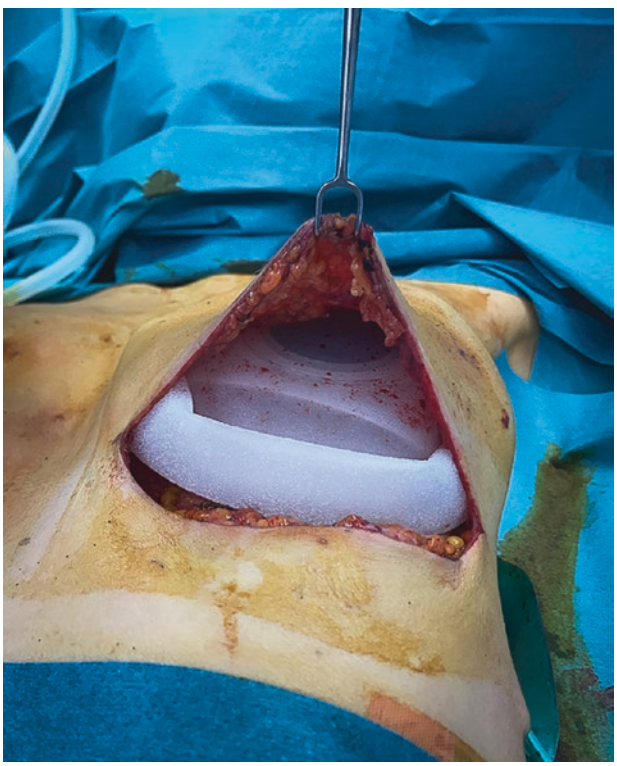

Fig. 9.10 The expander is inserted in the subcutaneous plane with fixation of the suture Tables (3, 6, and 9 o'clock) with a polyglactin 2/0 to prevent migration

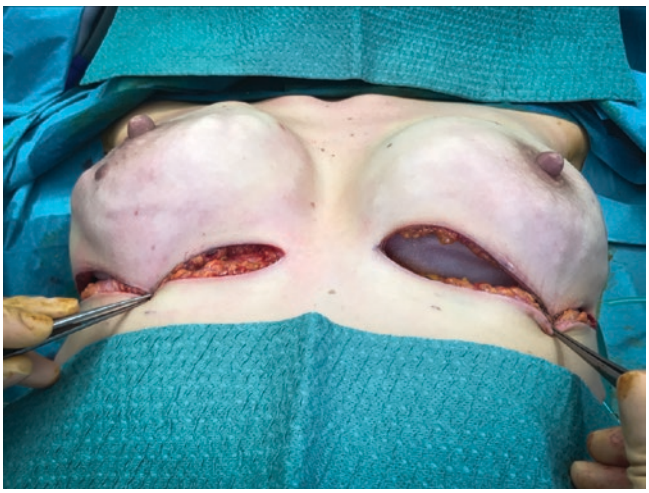

Fig. 9.11 Once the expanders are inserted and positioned, they are inflated with air to check for symmetry and definition of the footprint. The wound edges are approximated to check for tension. Incisional wounds are closed without tension to avoid wound healing complications

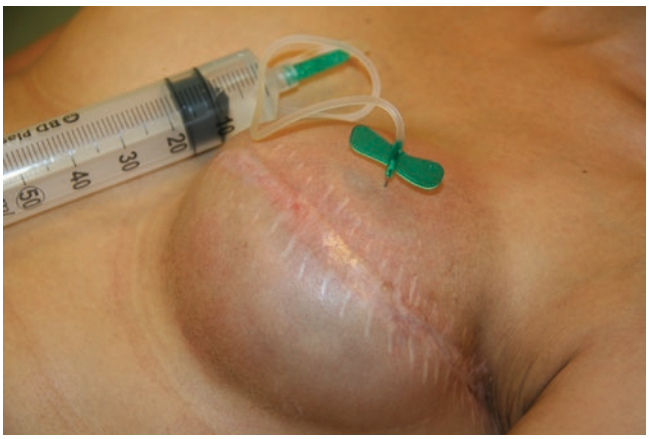

Fig. 9.12 One of the advantages of the expander is that it creates an IMF in secondary reconstructions. Careful positioning of the implant is of uttermost importance with specific attention to the lower pole

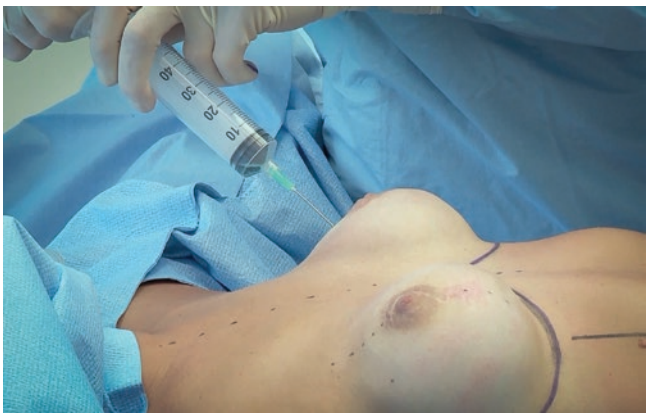

Fig. 9.13 The expander is deflated. Usually approximately 1/3 of the volume is extracted

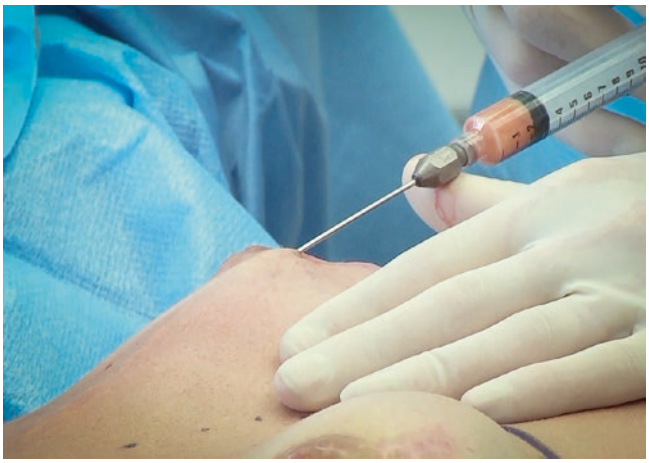

Fig. 9.14 A small stab incision is made with an 18G needle and allows insertion of the lipofilling cannula. Multiple passages with fat grafting are performed until an acceptable tissue turgor is achieved. This is clinically assessed

Initial fat grafting seemed to be more susceptible to resorption compared to following sessions. Interestingly, based on our MRI findings, injection of 100 cc of fat results in a stable, 3D volume restoration of approximately 55 cc (range of 32.5–80 cc). In our personal series of breast reconstruction with fat, the overall grafted volume was 160 ml per breast per session with an average of four fat grafting sessions per patient.

Once the wanted volume is obtained, the expander is removed during the last lipofilling session through the same access incision. The capsule is left in place and not removed. It will collapse and provide additional firmness to the newly reconstructed breast. No drainage is left behind.

Technical Variations

Lipofilling is indicated to reconstruct small-volume breasts (cup size B). For larger breast volumes, an additional implant can be inserted to give central core projection and increased volume. This technique is suitable when implant-based reconstructions are planned and tissue coverage is needed. The first step is the reconstruction of a prepectoral tissue layer, and secondly an implant is inserted to add that extra volume and projection (Figs. 9.15, 9.16, and 9.17).

Postoperative Care

No specific wound care is necessary during the first postoperative week after insertion of the expander. Wound dressings are changed 1 week after the final procedure and the wounds are inspected. Drainage is removed when the drainage rate is below 30 cc over 24 h. Residual seromas are

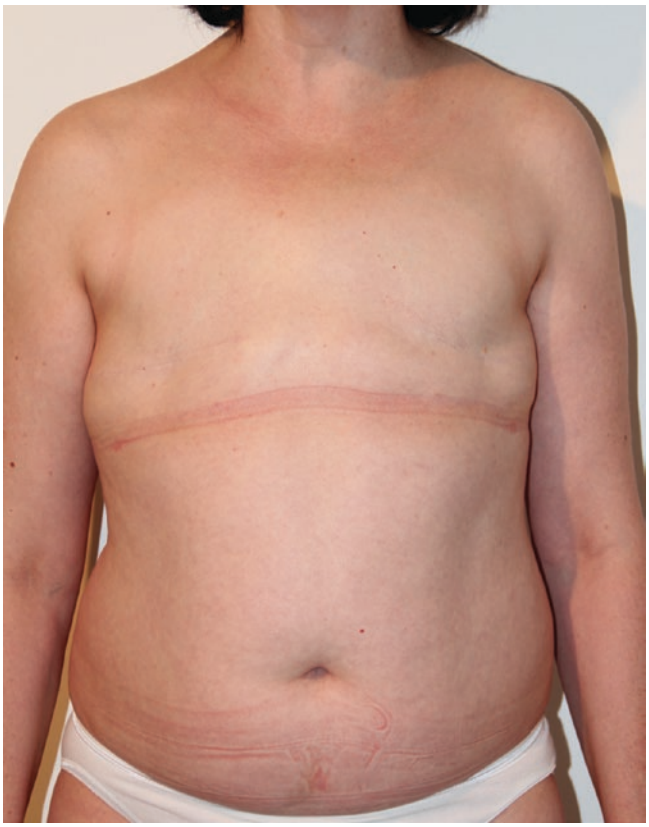

Fig. 9.15 Preoperative view of a bilateral mastectomy. Expanders will be inserted through an IMF incision

drained on an outpatient basis but avoided as much as possible to prevent infection.

The postoperative care after the lipofilling sessions consists mainly of skin care and pressure avoidance of the grafted areas. No specific wound care is otherwise indicated.

Clinical Cases

Case 1: Secondary Reconstruction

This case involves a 34-year-old patient with a 4-year history of left mastectomy and adjuvant chemotherapy and radiation therapy (Figs. 9.18, 9.19, and 9.20). The patient preferred not to have microsurgery to reconstruct her left breast. An expander was inserted in the prepectoral plane and expansion was initiated 2 weeks postoperatively (Figs. 9.21 and 9.22). She had a total of four lipofilling sessions with the injection of 630 cc of fat in total. She is seen 3 years after the last fat grafting session of the left breast (Figs. 9.23, 9.24, and 9.25). Two years later, she was diagnosed with a genetic predisposition (BRCA2), and the right breast was removed through an inframammary incision. An implant-based reconstruction (285 cc; Motiva©, SilkSurface Ergonomix, Establishment Labs, Alajuela, Costa Rica) was performed, and a small implant (125 cc; Motiva®,

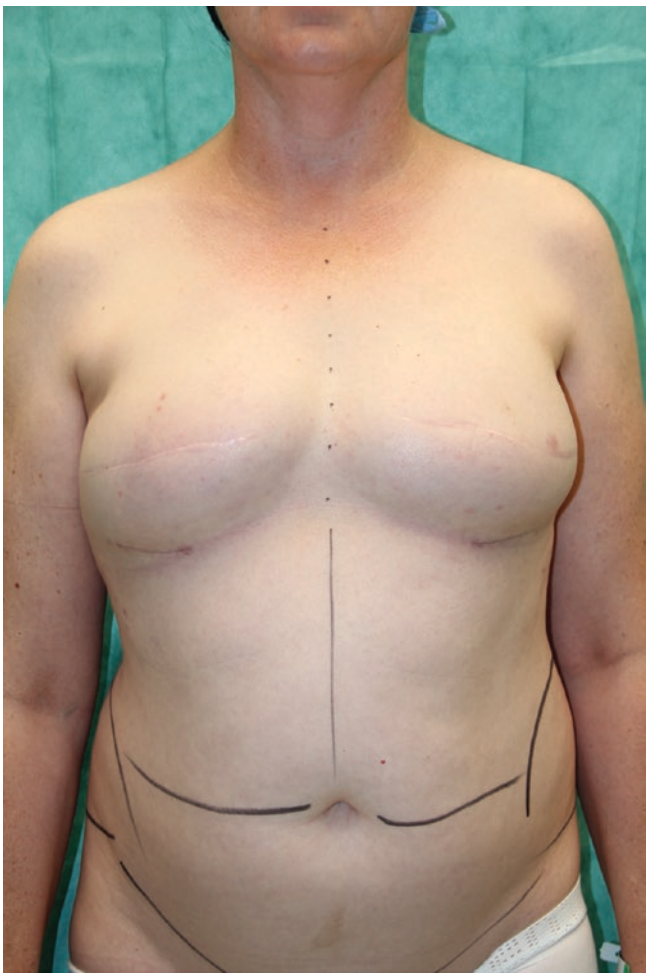

Fig. 9.16 Both expanders are completely expanded and the first lipofilling session can be performed. The goal is to reconstruct the subcutaneous tissue layers and restore a prepectoral tissue unit

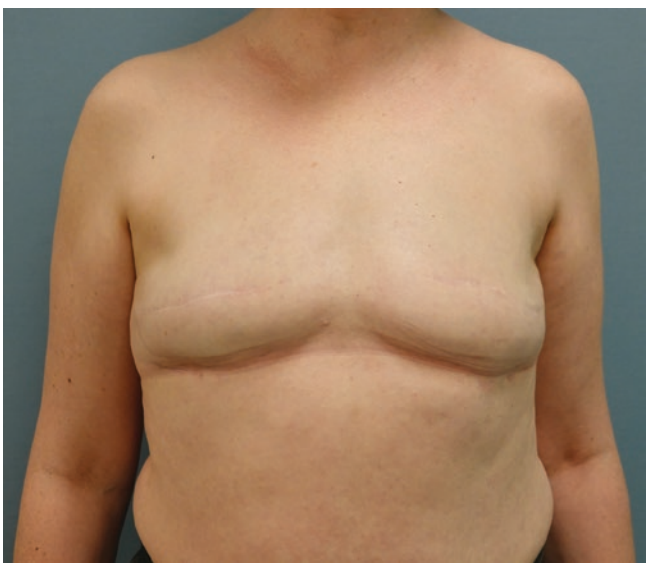

Fig. 9.17 Both expanders have been removed with restoration of an acceptable tissue volume in the prepectoral plane. The reconstructive approach has been completed and the patient is now considered a "breast augmentation" patient. Implants are considered to add additional core projection and volume

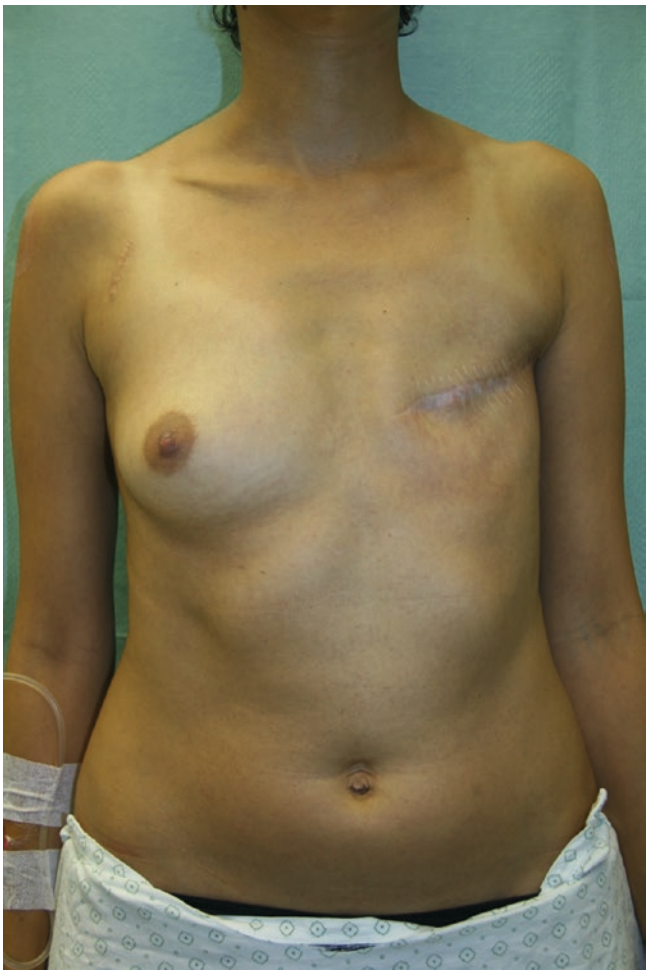

Fig. 9.18 Preoperative view. Left mastectomy with adjuvant radiation therapy and chemotherapy in 34-year-old patient. Small to moderate breast size of the right breast. Patient is planned for intratissular expansion and fat grafting to reconstruct the breast. The expander will be inserted through an IMF incision and through the existing mastectomy scar

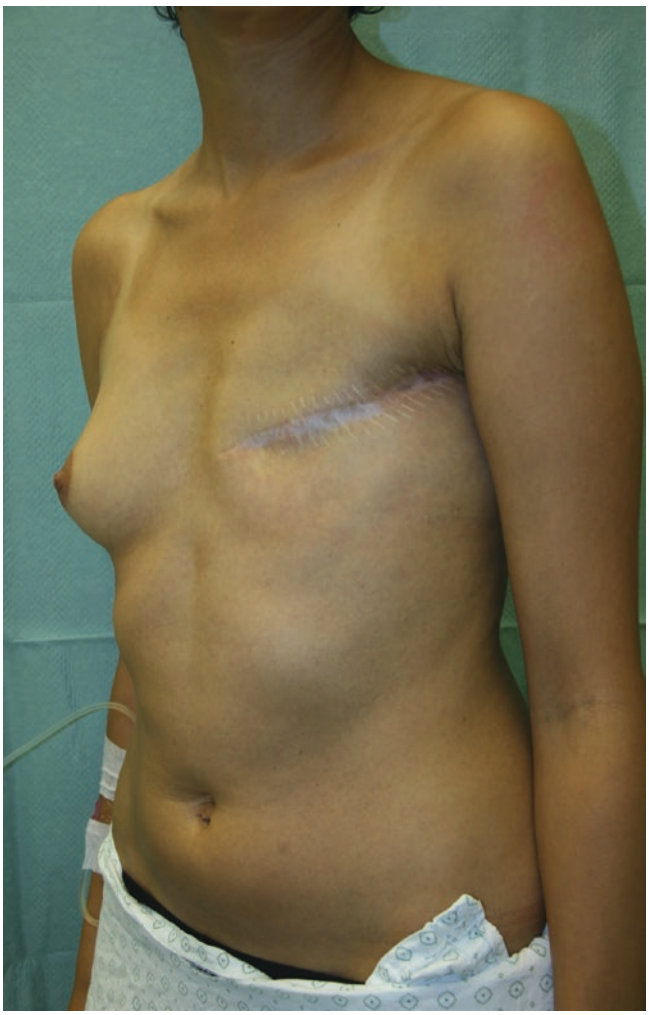

Fig. 9.19 Preoperative view. Left mastectomy with adjuvant radiation therapy and chemotherapy in 34-year-old patient. Small to moderate breast size of the right breast. Patient is planned for intratissular expansion and fat grafting to reconstruct the breast. The expander will be inserted through an IMF incision and through the existing mastectomy scar

SilkSurface Ergonomix) was inserted in the prepectoral plane on the right side to add central core projection (Figs. 9.26, 9.27, and 9.28). When additional volume is wanted, an implant can be added to augment the central core projection of the breast. The reconstructed breast has a prepectoral tissue unit with fat and is now considered as an augmented breast.

Case 2: Primary Reconstruction

This case involves a 48-year-old patient with diagnosis of ductal carcinoma in situ of the right breast (Figs. 9.29, 9.30, and 9.31). A nipple-sparing subcutaneous mastectomy was performed with a periareolar incision and vertical extension. An expander was inserted, and the fat grafting protocol started 8 weeks after expander insertion. A total of 532 cc of fat was injected and she is seen 2 years after the last fat grafting session (Figs. 9.32, 9.33, and 9.34). An additional mastopexy was performed of the right breast with a clear view intraoperatively on viable fat tissue (Fig. 9.35). MRI examination showed viable fat within the right breast with some small oil cysts (Figs. 9.36 and 9.37).

Case 3: Reconstruction After Failed DIEP Flap

Bilateral reconstruction with the DIEP flap. Tertiary reconstruction of the right breast (previous expander insertion) and prophylactic reconstruction of the left breast (genetic predisposition). Failure of the left reconstruction with DIEP flap removal. The patient did not opt for a secondary microsurgical tissue transfer, and the expansion-fat grafting protocol was chosen (Figs. 9.38, 9.39, and 9.40). A total of 549 cc of fat was injected to reconstruct the left breast (Figs. 9.41, 9.42, and 9.43). Additional mastopexy was performed with clear view on the viable injected fat tissue (Fig. 9.44).

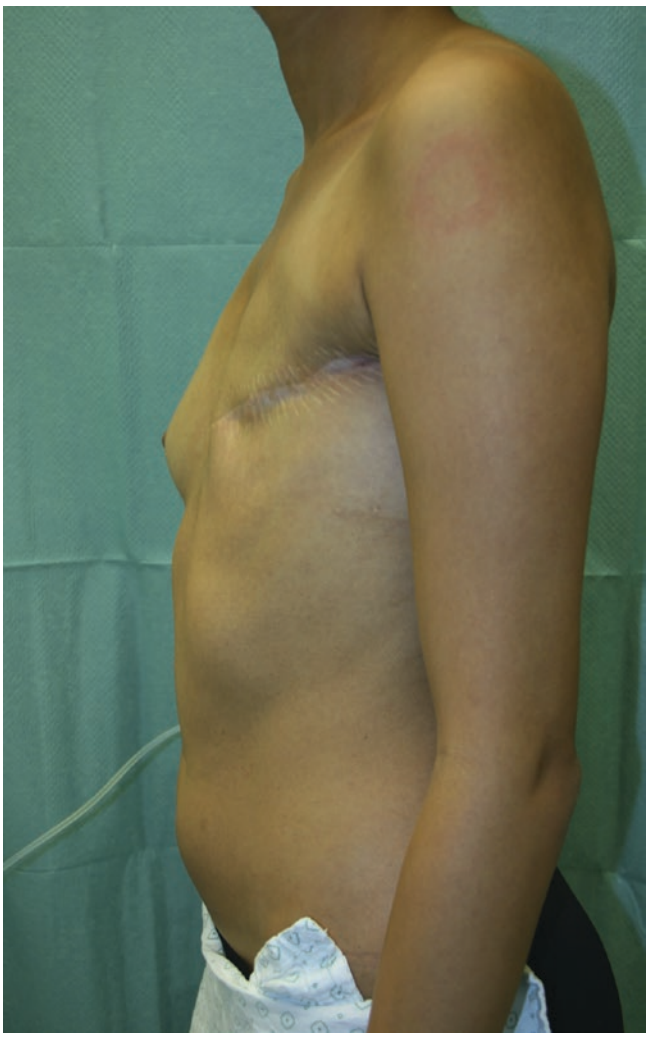

Fig. 9.20 Preoperative view. Left mastectomy with adjuvant radiation therapy and chemotherapy in 34-year-old patient. Small to moderate breast size of the right breast. Patient is planned for intratissular expansion and fat grafting to reconstruct the breast. The expander will be inserted through an IMF incision and through the existing mastectomy scar

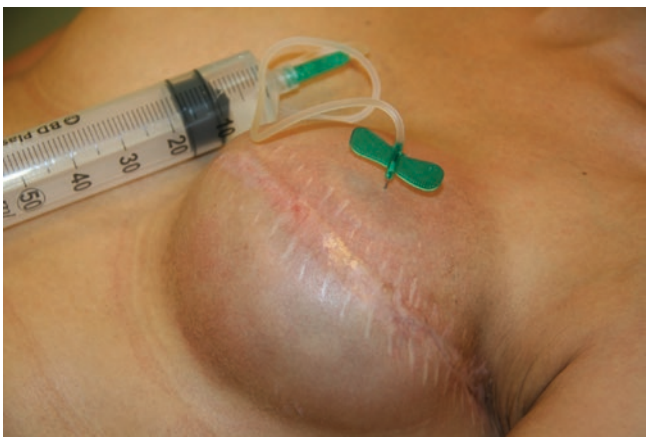

Fig. 9.21 Expansion is performed on an ambulatory basis until the desired volume is obtained. Overexpansion is performed to have additional skin laxity mainly in the lower breast pole. The expansion process itself creates an acceptable and well-defined inframammary fold

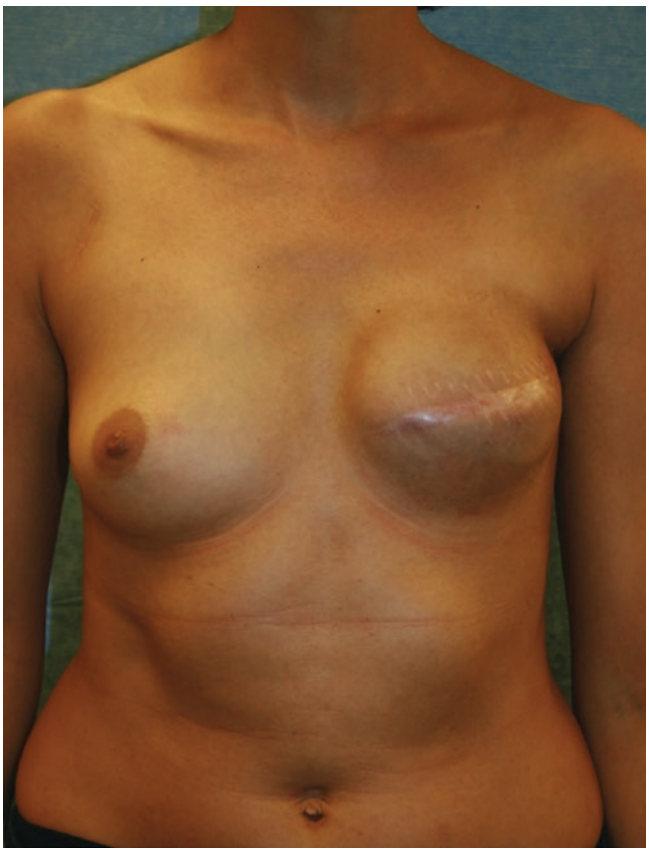

Fig. 9.22 Expansion is performed on an ambulatory basis until the desired volume is obtained. Overexpansion is performed to have additional skin laxity mainly in the lower breast pole. The expansion process itself creates an acceptable and well-defined inframammary fold

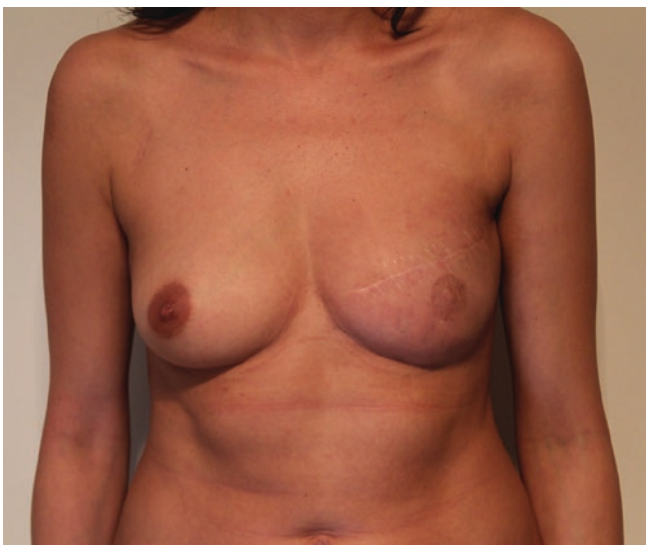

Fig. 9.23 Postoperative result at 3 years postoperatively. The newly reconstructed breast has a well-defined footprint and IMF and acceptable breast projection. Nipple tattoo was performed

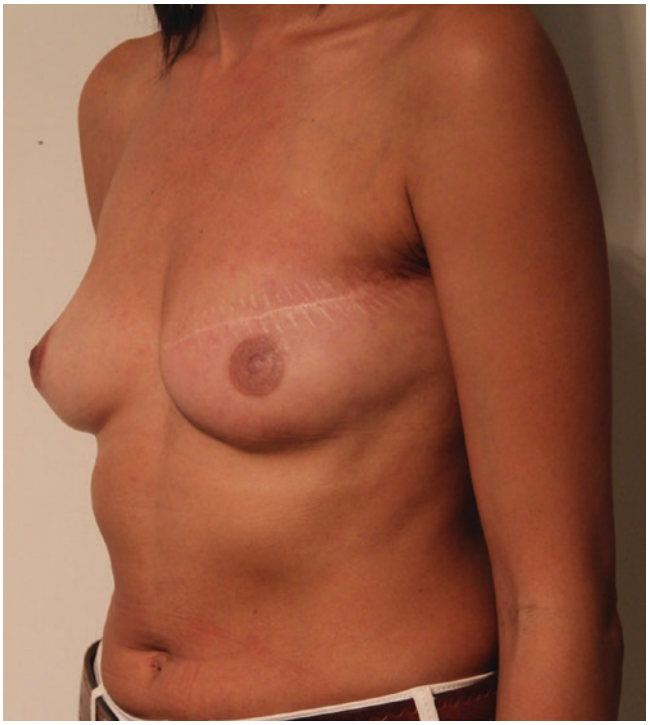

Fig. 9.24 Postoperative result at 3 years postoperatively. The newly reconstructed breast has a well-defined footprint and IMF and acceptable breast projection. Nipple tattoo was performed

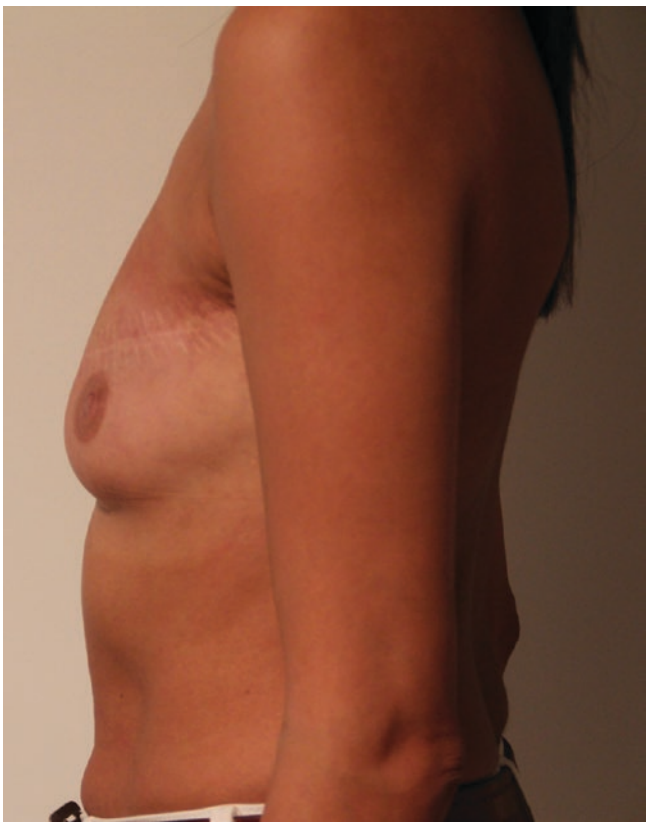

Fig. 9.25 Postoperative result at 3 years postoperatively. The newly reconstructed breast has a well-defined footprint and IMF and acceptable breast projection. Nipple tattoo was performed

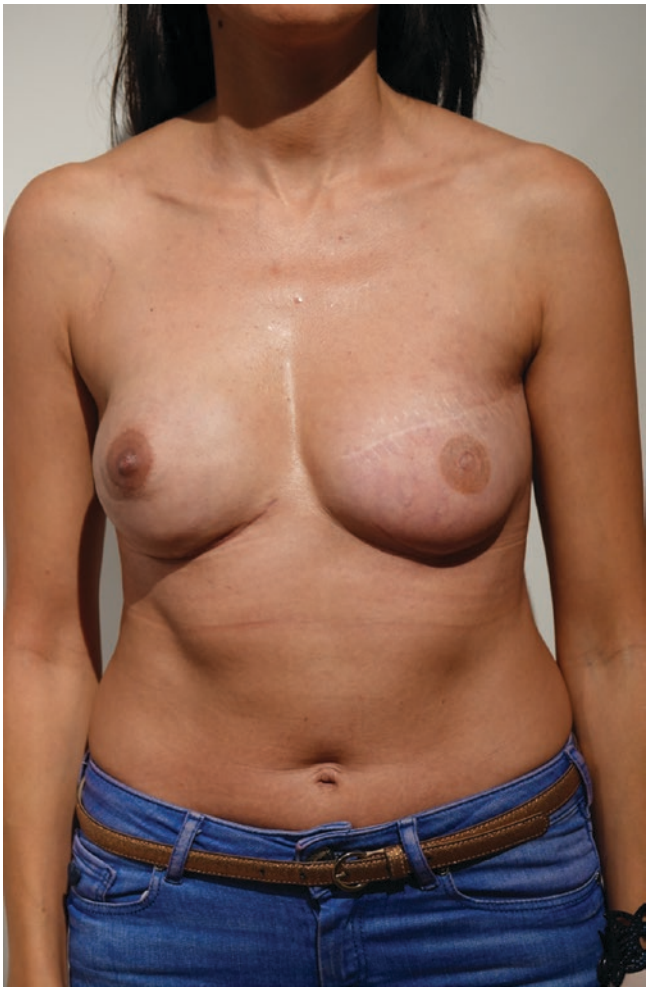

Fig. 9.26 The same patient was diagnosed 4 years after the final lipofilling session with a genetic predisposition for breast cancer, and a right prophylactic mastectomy was performed through an IMF incision with insertion of an implant. A small Motiva® SilkSurface Ergonomix implant of 125 cc was added to the left breast for additional volume and projection

Conclusions

The ultimate goal in breast reconstruction is a natural-looking breast with a well-defined footprint, natural volume distribution, and acceptable breast projection. Autologous-based reconstructions are superior to obtain this result. Implant-based reconstructions are more challenging due to lack of soft tissue support with additional risks at the long term such as implant migration and capsular contraction. The drawbacks in autologous reconstructions are the sacrifice of healthy donor sites and potential associated discomfort. Fat grafting circumvents those disadvantages. It is a minimally invasive, autologous-based technique. However, its major shortcoming is the unpredictable resorption rate. It is a very ambitious exercise to reconstruct the breast with a liquescent, lipoaspirate material. The expander plays a pivotal role in our protocol; it creates a new, expandable recipi-

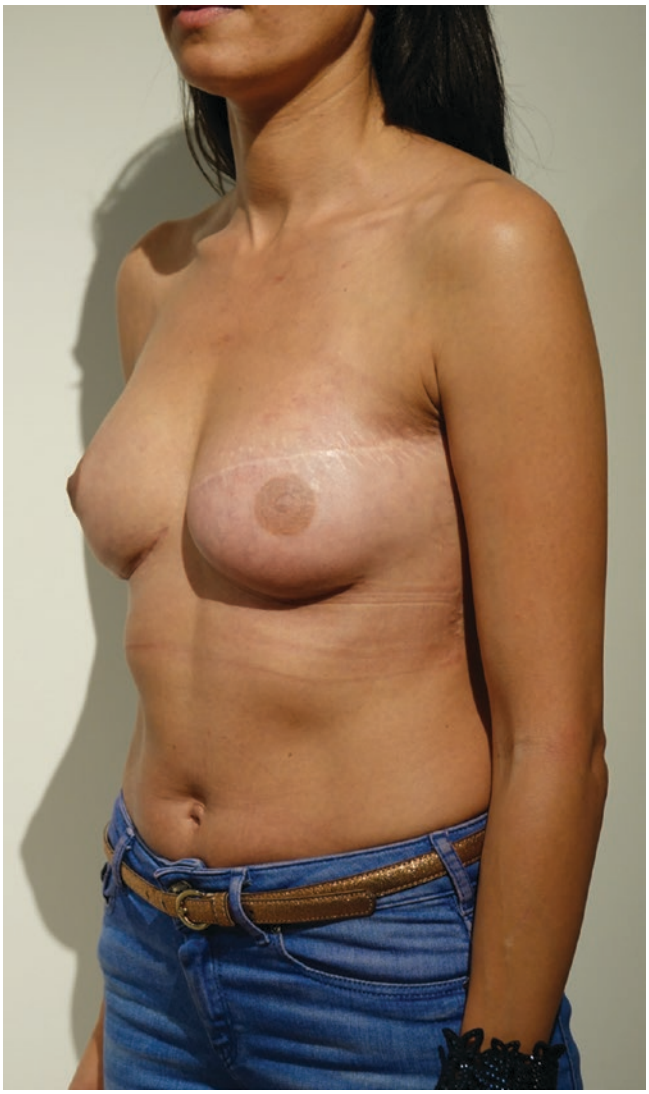

Fig. 9.27 The same patient was diagnosed 4 years after the final lipofilling session with a genetic predisposition for breast cancer, and a right prophylactic mastectomy was performed through an IMF incision with insertion of an implant. A small Motiva® SilkSurface Ergonomix implant of 125 cc was added to the left breast for additional volume and projection

Fig. 9.28 The same patient was diagnosed 4 years after the final lipofilling session with a genetic predisposition for breast cancer, and a right prophylactic mastectomy was performed through an IMF incision with insertion of an implant. A small Motiva® SilkSurface Ergonomix implant of 125 cc was added to the left breast for additional volume and projection

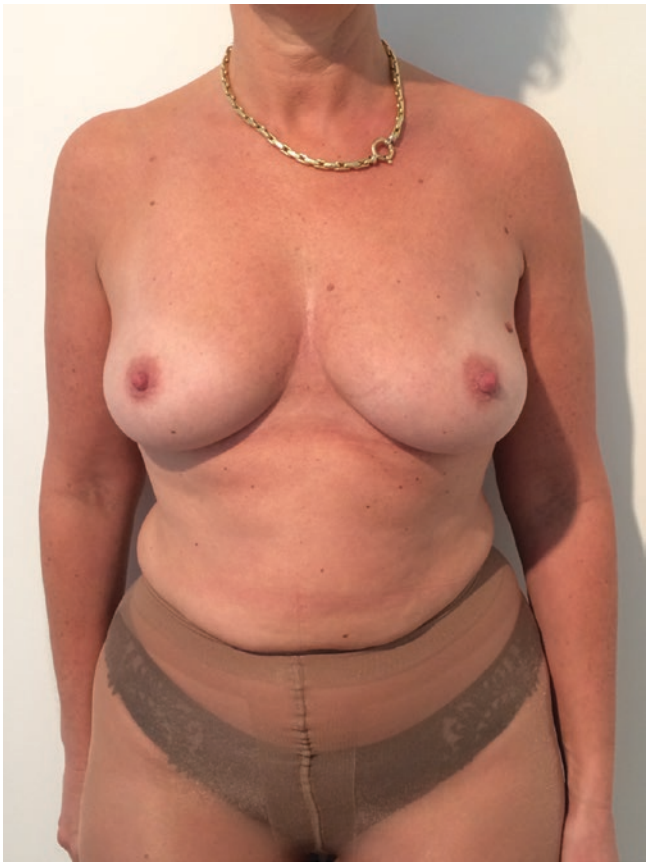

Fig. 9.29 Preoperative view. Primary reconstruction of the right breast is planned with a subcutaneous nipple-sparing mastectomy

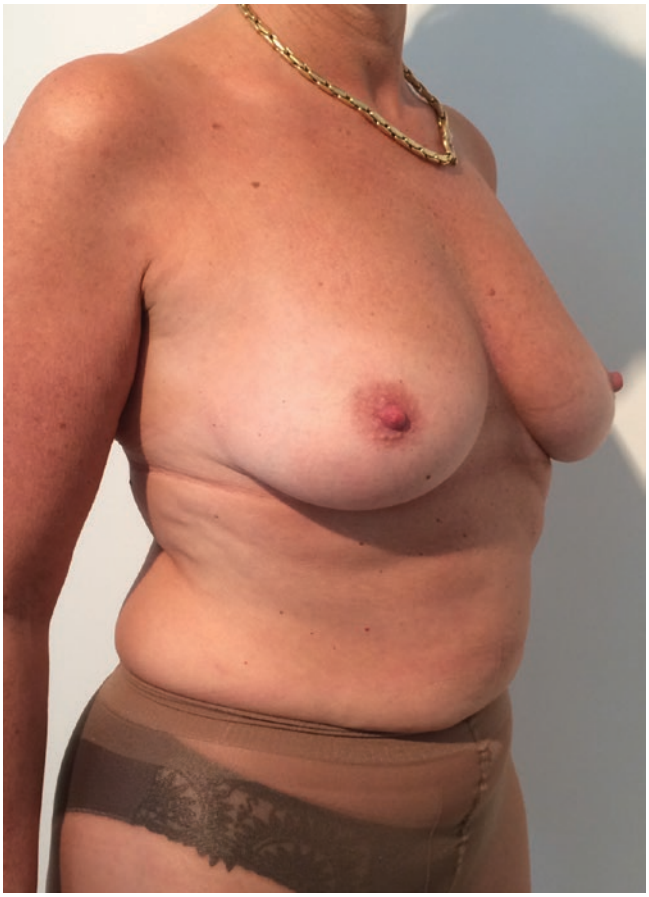

Fig. 9.30 Preoperative view. Primary reconstruction of the right breast is planned with a subcutaneous nipple-sparing mastectomy

ent site, defines the breast contours and the IMF, and is an angiogenic source.

Our technique is indicated for selective cases and patient selection is crucial to obtain acceptable and durable results.

From a practical point of view, we found that overexpansion is necessary in secondary reconstructions, and the first fat grafting sessions should focus on the lower pole. Patients that are not motivated to undergo several fat grafting sessions or patients with larger breasts could benefit from limited fat grafting and insertion of an implant, the so-called hybrid approach in breast reconstruction.

Moreover, fat grafting in breast reconstructive surgery could profit from tissue engineering knowledge using the body's own biological processes as a vector to support the long-term homeostasis of grafted adipose tissue. Further research in adipose tissue survival, the fabrication of biocompatible matrices, and the development of cryopreservation protocols could be the onset of ambulatory breast reconstruction based on this algorithm.

This reconstructive algorithm based on intratissular expansion and serial fat grafting is a reconstructive strategy based on the divide between the practical, the doable, and the ideal. It can be offered to patients as an alternative for microsurgery in specific indications or as an alternative after previous failed attempts in breast reconstruction. The annoying hitch in fat grafting, which is the unpredictable resorption rate, is addressed with the in vivo fabrication of a well-vascularized capsule with distinct boundaries. A general rule based on our clinical findings and MRI studies is that injection of 100 cc of fat will result in a volume augmentation of 50–60 cc.

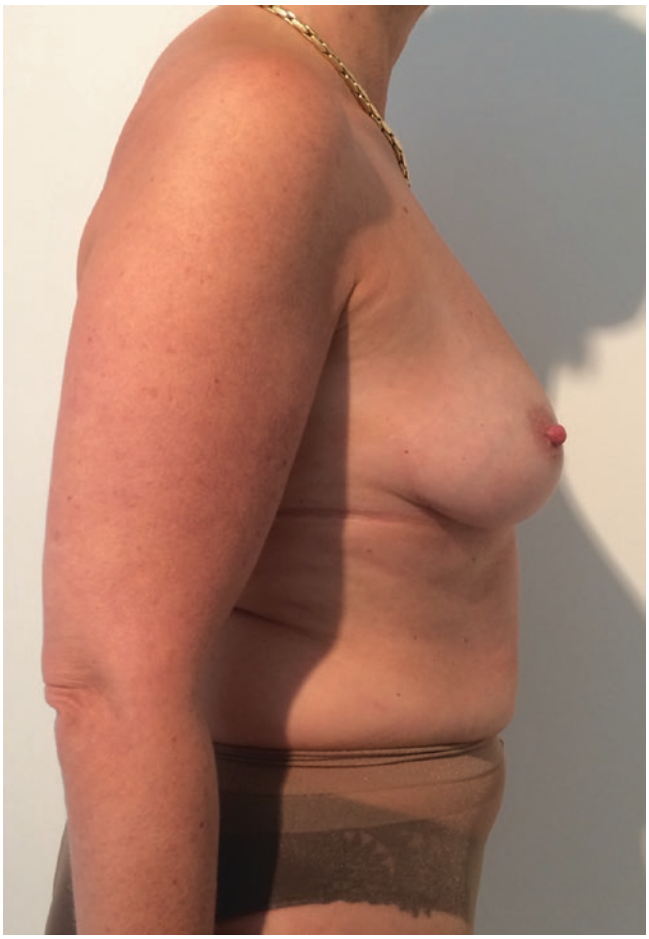

Fig. 9.31 Preoperative view. Primary reconstruction of the right breast is planned with a subcutaneous nipple-sparing mastectomy

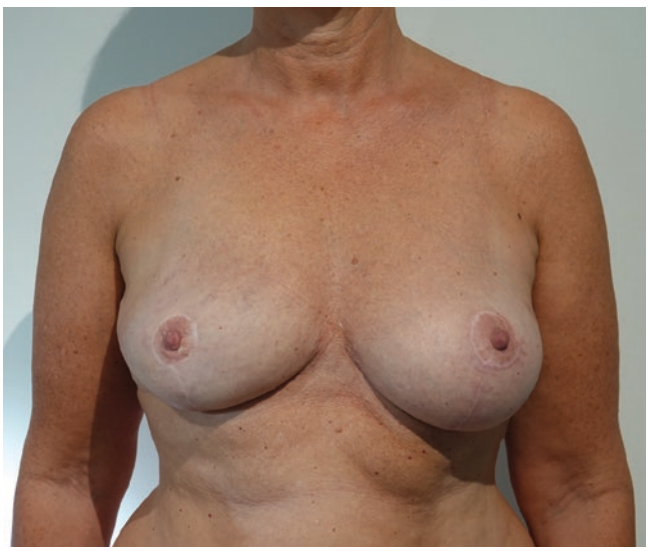

Fig. 9.32 Subcutaneous expander and serial fat grafting sessions to reconstruct the right breast. A total of 532 cc of fat was injected and she is seen 2 years after the last fat grafting session

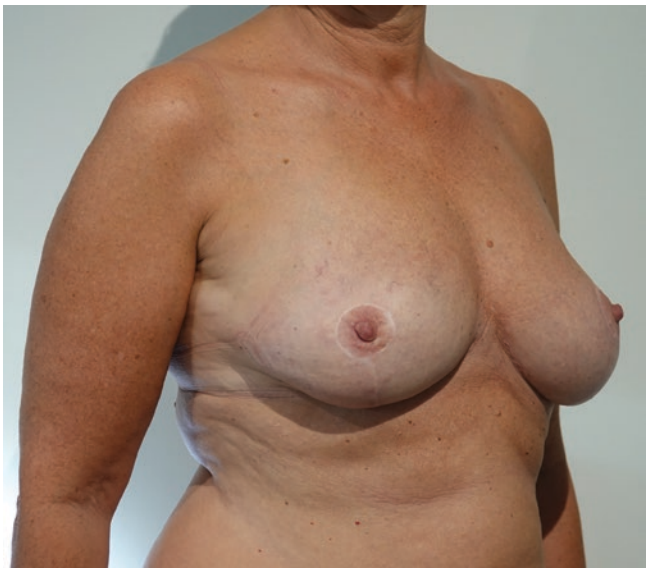

Fig. 9.33 Subcutaneous expander and serial fat grafting sessions to reconstruct the right breast. A total of 532 cc of fat was injected and she is seen 2 years after the last fat grafting session

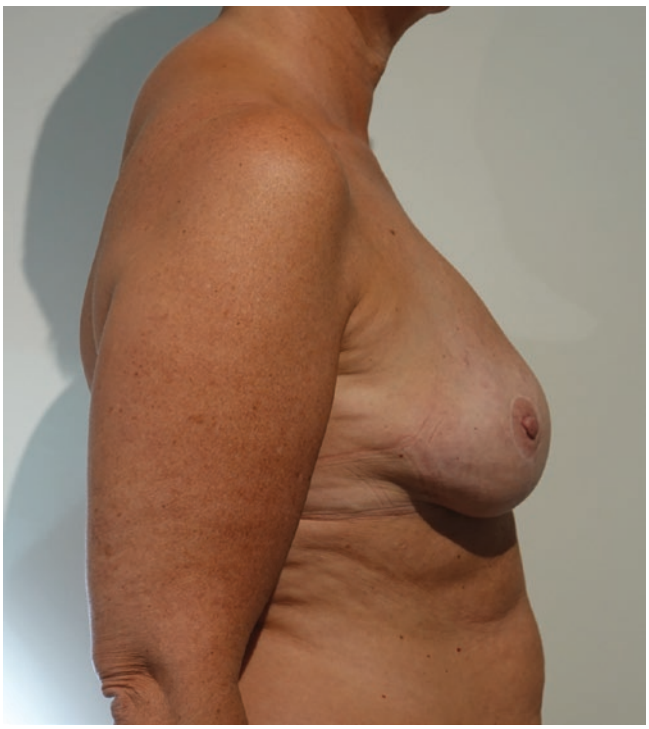

Fig. 9.34 Subcutaneous expander and serial fat grafting sessions to reconstruct the right breast. A total of 532 cc of fat was injected and she is seen 2 years after the last fat grafting session

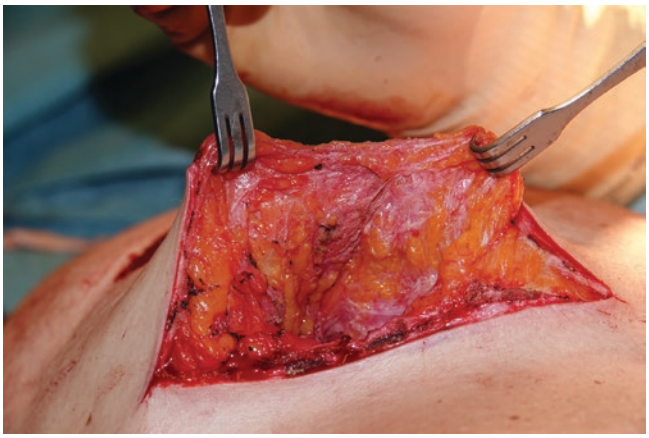

Fig. 9.35 An additional mastopexy was performed of the right breast with a clear view intraoperatively on viable fat tissue

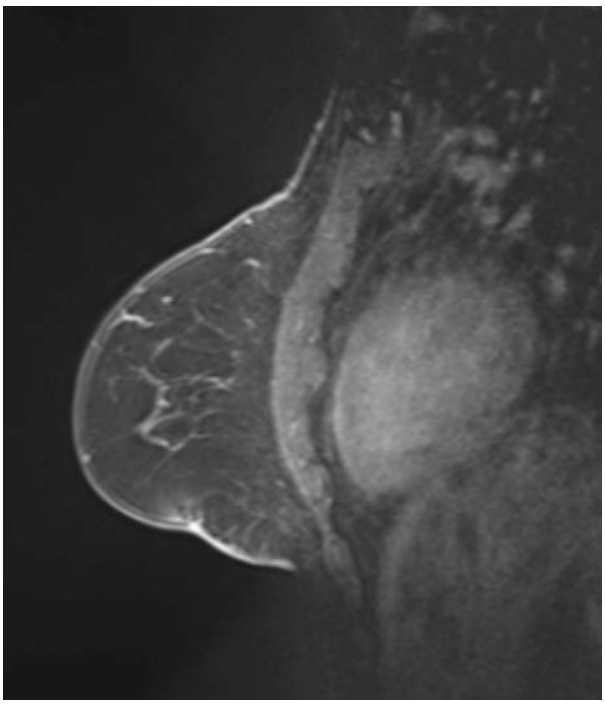

Fig. 9.37 MRI examination showed viable fat within the right breast with some small oil cysts

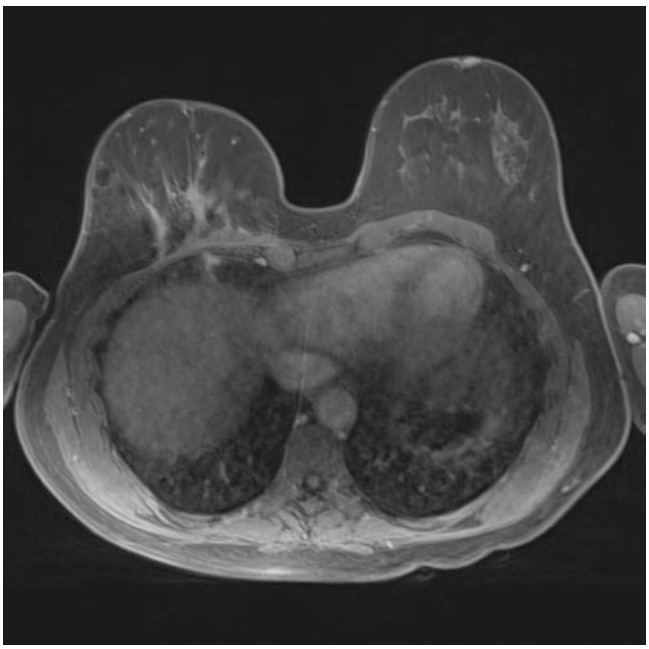

Fig. 9.36 MRI examination showed viable fat within the right breast with some small oil cysts

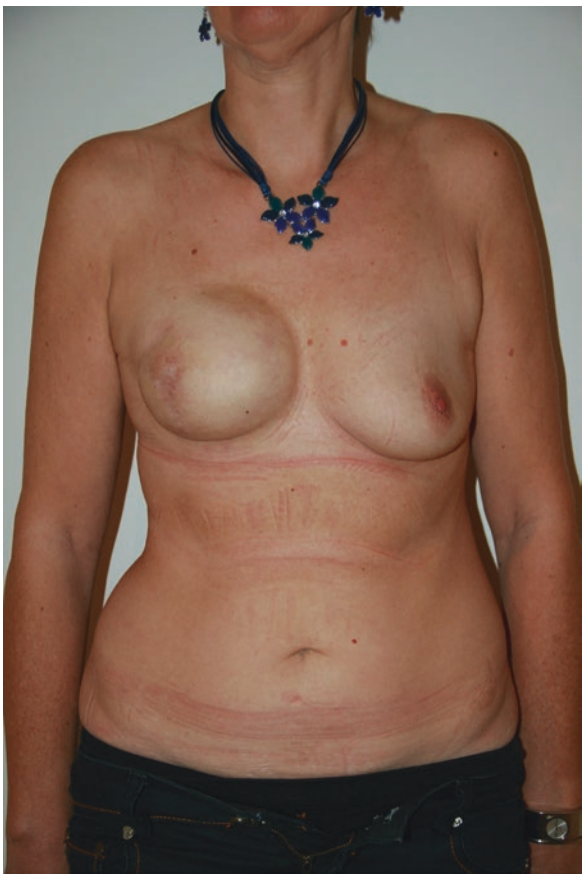

Fig. 9.38 Bilateral reconstruction with the DIEP flap. Tertiary reconstruction of the right breast (previous expander insertion) and prophylactic reconstruction of the left breast (genetic predisposition). Failure of the left reconstruction with DIEP flap removal

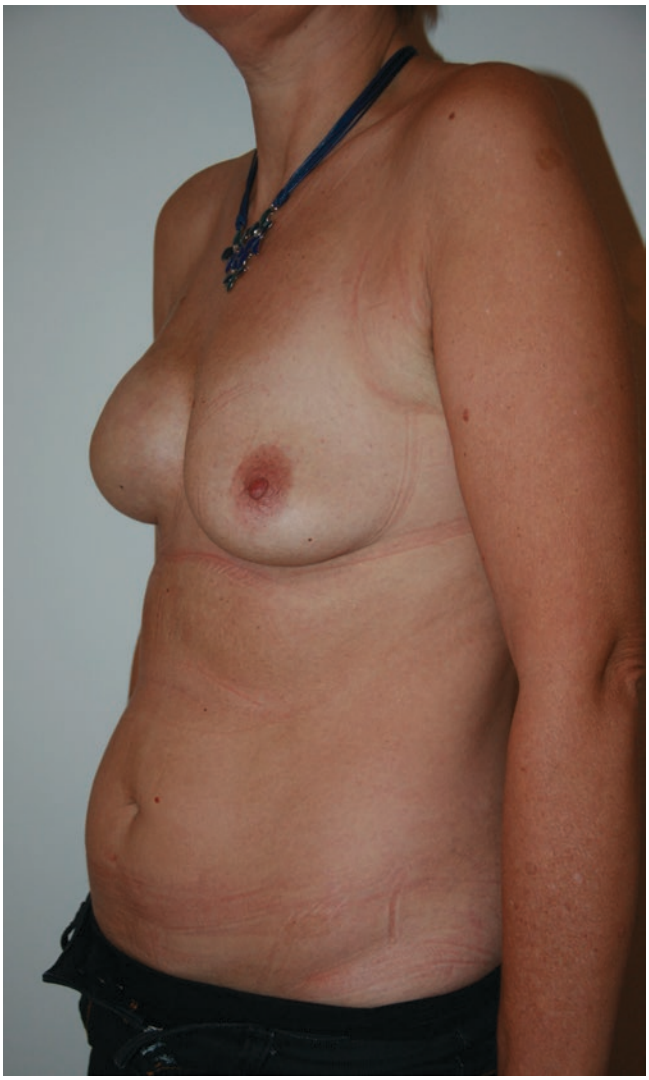

Fig. 9.39 Bilateral reconstruction with the DIEP flap. Tertiary reconstruction of the right breast (previous expander insertion) and prophylactic reconstruction of the left breast (genetic predisposition). Failure of the left reconstruction with DIEP flap removal

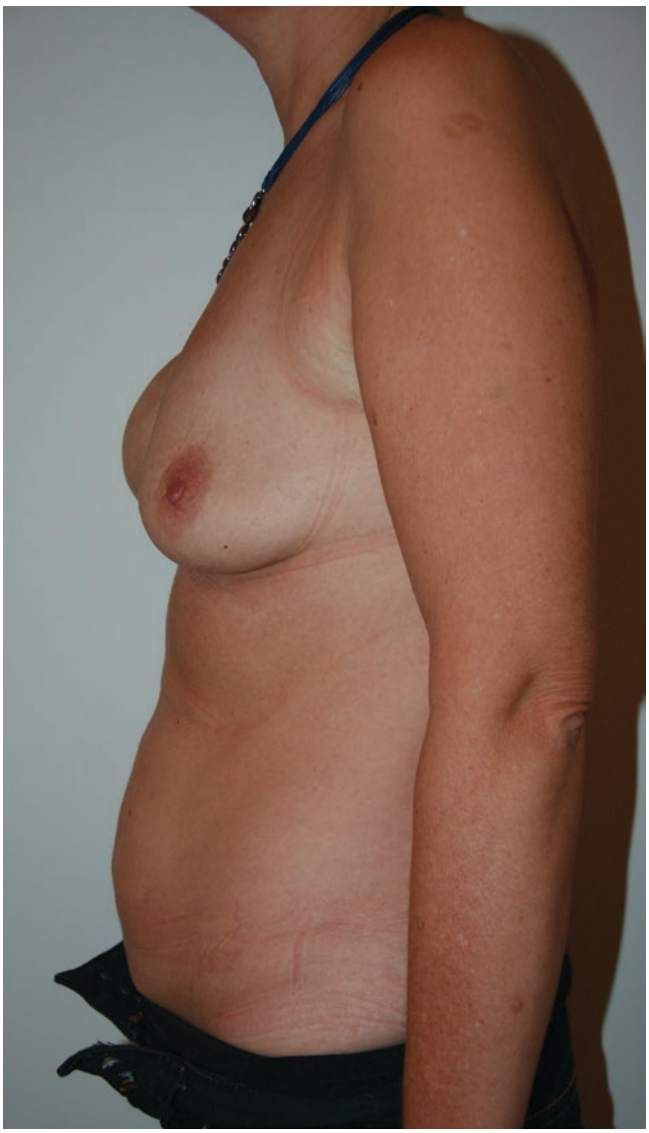

Fig. 9.40 Bilateral reconstruction with the DIEP flap. Tertiary reconstruction of the right breast (previous expander insertion) and prophylactic reconstruction of the left breast (genetic predisposition). Failure of the left reconstruction with DIEP flap removal

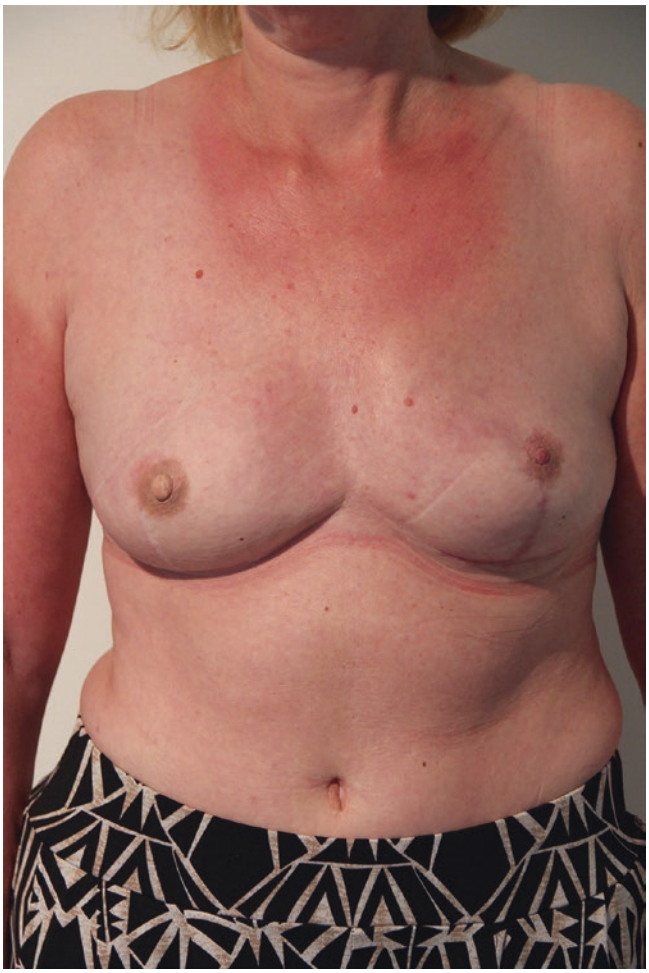

Fig. 9.41 The patient opted for an expansion-fat grafting protocol to reconstruct the left breast. A total of 549 cc of fat was injected to reconstruct the left breast

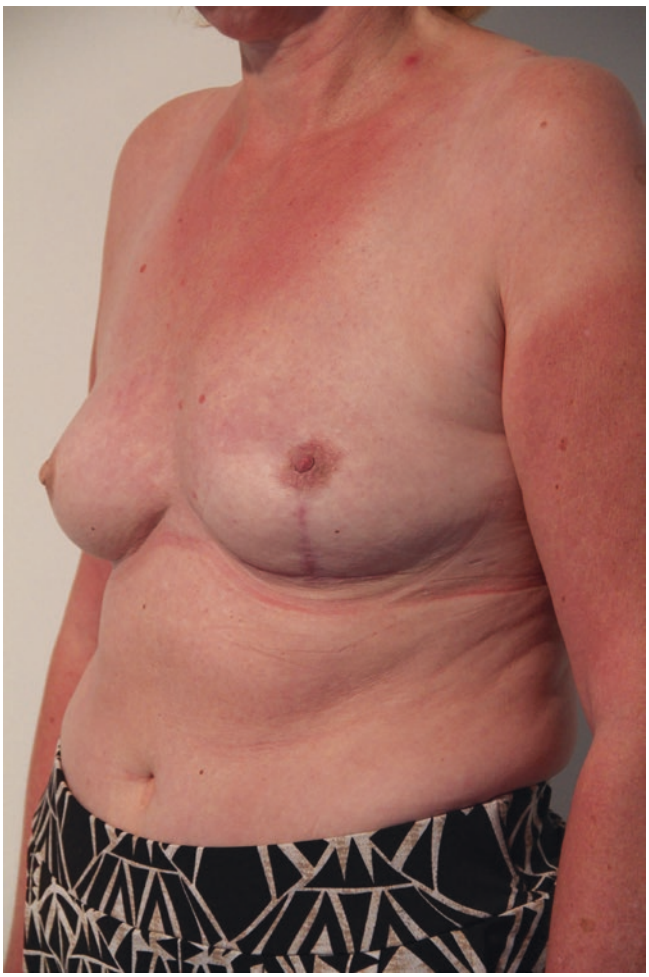

Fig. 9.42 The patient opted for an expansion-fat grafting protocol to reconstruct the left breast. A total of 549 cc of fat was injected to reconstruct the left breast

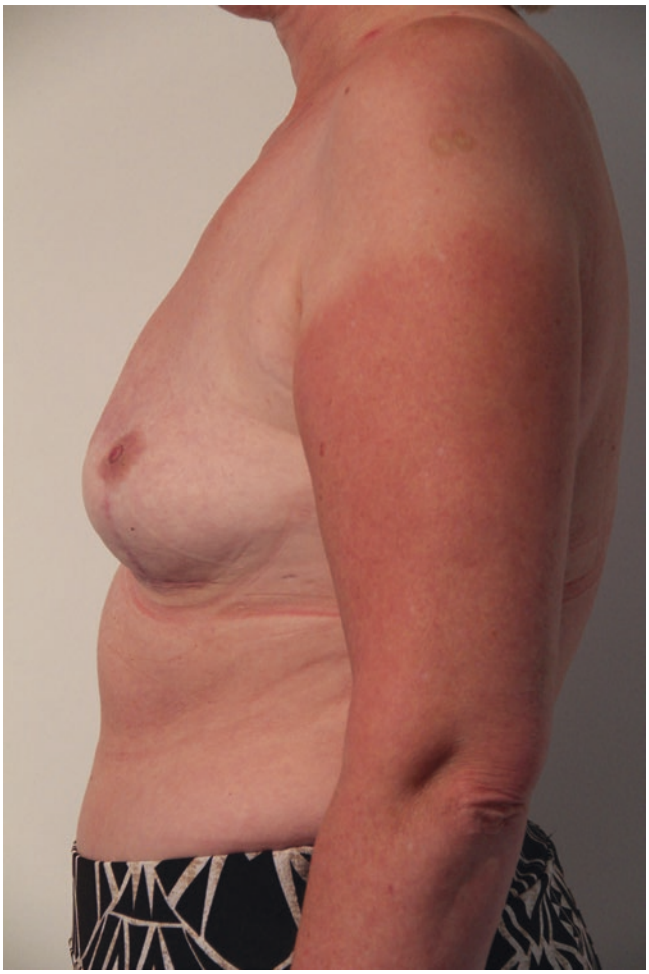

Fig. 9.43 The patient opted for an expansion-fat grafting protocol to reconstruct the left breast. A total of 549 cc of fat was injected to reconstruct the left breast

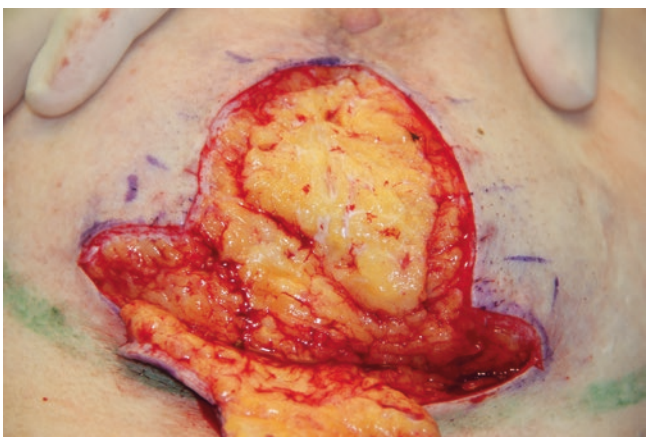

Fig. 9.44 Additional mastopexy was performed with clear view on the viable injected fat tissue

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Breast Reconstruction with External Expansion and Fat Grafting

10

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Introduction

The use of autologous fat grafting (AFG) is widely used in plastic surgery for both reconstructive and aesthetic indications, in particular for breast and buttock augmentation and facial rejuvenation [1–5]. AFG is a simple and effective procedure presenting several advantages. Among them is the possibility of combining liposuction of areas with unpleasant accumulation with volumetric enhancement and reshaping of anatomical regions where augmentation is sought. Moreover, regeneration capacity is recognized to the graft, as a copious literature has investigated the role of adipose-derived stem cells contained in its stromal vascular fraction. Importantly, this potential has encouraged its clinical application for the therapy of scars, scar-related conditions, and burns [6, 7].

However, volume retention rates of AFG vary largely in a range between 30% and 80% [3]. Several factors contribute to the success of the procedure, and a vast research has been performed to optimize three steps of the procedure: modalities of harvesting, processing, and reinjection [1–5]. Instead, less attention has generally been attributed to the preparation of the recipient site prior to AFG. Nevertheless, there is evidence that this last point appears to be extremely relevant to ensure improvement of outcomes and reduction of complication [1, 2].

The characteristic of the recipient site which impact AFG can be summarized as follows: age of the patient, trauma, burns, scars, structural defects, face compartments, and mobility [5]. Our group has recently comprehensively analyzed all preclinical and clinical evidence supporting the use of techniques to prepare the recipient site, with a focus in breast surgery [1, 2]. Several procedures were studied preclinically, including external volume expansion (EVE), microneedling, implantation of alloplastic materials, administration of cell-proliferating factors, and ischemia. Although all procedure unequally showed positive outcomes in terms of fat graft survival, vascularity, cell proliferation, skin thickness, quality of tissue, and inflammation, only EVE has been extensively applied clinically. Moreover, the preclinical research conducted on EVE offers the most robust evidence. At the clinical level, 14 studies have investigated the use of EVE in breast surgery. The majority of these studies used the Brava system (Brava LLC, Miami, Fla.), a bra-like device which applies low negative pressure to the breast during the weeks before AFG [4, 8–19]. Another option was published by our group, with the use of a device named VAC-6000 M with a Palm Pump (Clinical Innovations, South Murray, Utah), to treat localized breast contouring defects and contracted scars with a strong negative pressure [20].

Pre-expansion was investigated preclinically observing increased cell proliferation, angiogenesis, adipogenesis, hair follicles number, and skin thickness with enhanced fat graft survival [21–26]. The mechanism of action was explained with an inflammatory reaction caused by cell strain, ischemia, and edema generated by the controlled noninvasive suction. In the clinical context, the first use of Brava as EVE of the breast was presented by Khouri et al. in 2000 to perform nonsurgical breast augmentation, based on the principle of tissue growth caused by controlled distractive mechanical forces [27]. It was afterward combined with AFG as a preparation technique due to its capacity of generating an ideal environment for fat graft survival. Kiwi VAC-6000M with a Palm Pump is the sole alternative to the use of Brava as pre-expansion device, used for the different indication of preparing localized recipient sites with the application of strong negative pressure for short times. With the use of Kiwi were observed satisfactory clinical outcomes with high patient acceptance and compliance and minimal morbidity.

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Patient Selection

Several surgical indications for EVE prior to AFG to the breast were described [2, 4, 8–20]. In particular the use of Brava is indicated in case of breast reconstruction after treatment for cancer, breast augmentation for aesthetic purposes, correction of congenital or iatrogenic deformities, and replacement of previous implants. In general, it is indicated for those patients whom the totality of the breast required to be treated. In these patients also mega-volume AFG (>300 ml) becomes possible [15]. Instead, the use of Kiwi VAC-6000M with a Palm Pump is indicated for patients presenting with localized contracted scars or breast contouring deformities, also as a result of radiation therapy, requiring only small volume enhancement (up to 80 ml) [20].

The use of Brava has been supported by Del Vecchio and Bucky for all those cases requiring the creation of a larger parenchymal space, the reduction of interstitial pressure in the breast for a given volume of transplanted graft, correction of contour irregularities through breast reshaping prior to AFG, and increased vascularization as a result of micromechanical forces applied on the recipient site [15].

Particular attention must be posed for patients with less compliant recipient sites due to mechanical reasons: constricted breasts, dense nulliparous breasts, and pre-irradiated breasts [15]. In these situations, additional sessions of AFG or procedures such as release of constriction bands may be needed. Moreover, the use of EVE in pre-irradiated tissues remains an area of debate. In particular, Uda et al. [17] discouraged the use of Brava in this case, due to the higher rate of complications, in particular ulceration, while Kosowski et al. [19] supported its use postulating that the regeneration potential of AFG would be able of reversing radiation damage and improve outcomes. However, they also recommended to avoid over-grafting due to the less compliance of the recipient site and to prefer a series of multiple AFG sessions.

Finally, an accurate selection of the patients must also include the evaluation of their compliance, in particular with reference to the Brava system, as the device required to be worn for weeks may generate an impact on patient social life [2]. Instead, the use of Kiwi was reported to be easily tolerated and only requires certain ability of the patient to follow the postoperative recommendations [20].

Patient Preparation

The patients are requested to prepare their breast with Brava for 10–24 h/day for a period starting up to 4 weeks before the operation [2, 4, 8–19]. The preparation of the recipient site with the Brava system has been performed with a wide range of different pressure values. In the initial description of the devise by Khouri et al., a negative pressure of −15 to −25 mm Hg is applied to the breast [27]. The following studies reported pressures cycling between −60 and 0 mmHg preoperatively and pressures cycling between −80 and −60 mmHg [12, 19].

Del Vecchio and Bucky highlighted the importance of a careful analysis of the psychological compliance of the patient and her lifestyle in order to adapt the use of the device to each patient individual needs [15]. This individualized approach is conducted to the application of a negative pressure ranging between −1 and −3 in. of mercury (−25.4 to −76.2 mmHg) [13].

Surgical Technique

The use of Kiwi VAC-6000M with a Palm Pump is the sole technique with intraoperative application (Fig. 10.1) [20]. The device, which was originally described and commonly used as complete vacuum delivery system, is applied on localized contracted scars and breast contouring defects and scarred recipient sites generating intense cycling negative pressures equal to −550 mmHg, for a series of 10 times of 30 s each, before AFG. Kiwi determines a gross expansion of tissue, with macroscopic swelling inflammation and ischemia to generate an ideal environment for cell proliferation and angiogenesis and thus improved AFG outcomes (Fig. 10.2).

The infiltration of the donor site is performed with a modified Klein solution (lidocaine hydrochloride, 0.91 mg/ml; epinephrine, 1.8 μg/ml) as previously described by our group [28]. The fat is harvested 15 min after completion of infiltration through hand-assisted liposuction using a blunt three opening cannula (cannula diameter, 4 mm; cross sectional area, 12.6 mm^2; oval opening, 2 × 4 mm; area, 6.3 mm^2; Lenoir System AG, Roggwil, Switzerland) [28]. The lipoaspirates are then processed through centrifugation at 920 g for 3 min and transferred to 10-cc syringes (opening diameter, 2 mm; area, 3.1 mm^2; Becton Dickinson AG, Basel, Switzerland) con-

Fig. 10.1 The Kiwi VAC-6000M with a Palm Pump (Clinical Innovations). (Reproduced with permission from Oranges et al. [20])

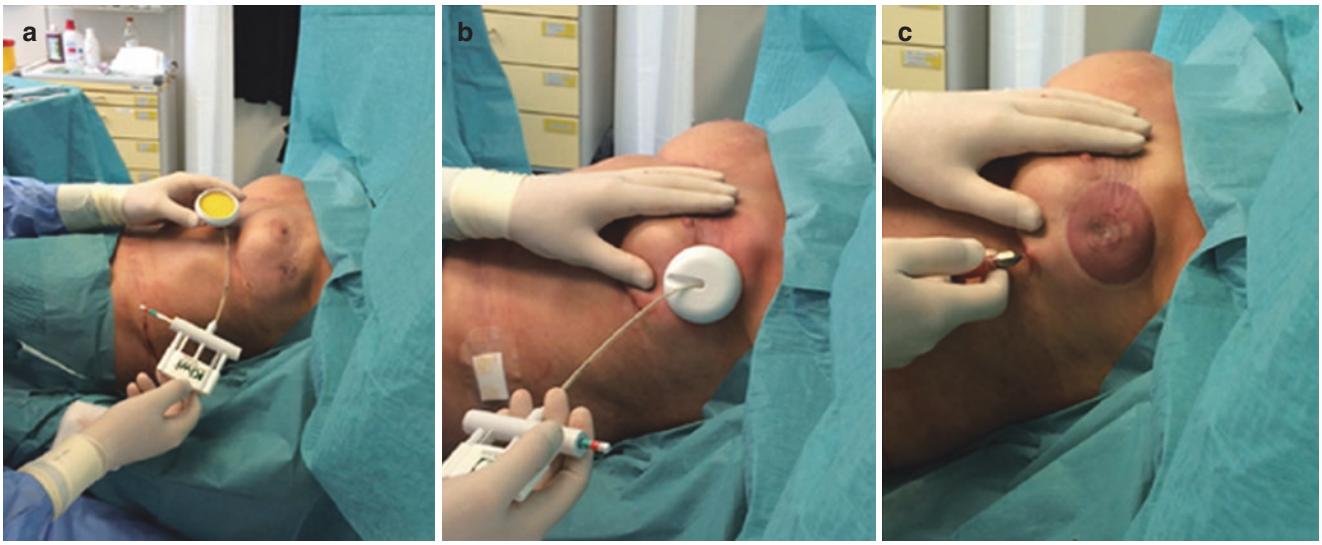

Fig. 10.2 (**a**, **b**) The Kiwi is applied on a scarred pre-irradiated breast. (**c**) During the repetitive stimulation, macroscopic swelling of the soft tissue is observed. (Reproduced with permission from Oranges et al. [20])

nected to a second empty 10-cc syringe at a 90-degree angle through a three-way stopcock (diameter, 2 mm; area, 3.1 mm^2; Becton Dickinson) [28]. The lipoaspirates are shuffled by transferring the content of one syringe into the other 10 times [28]. The injection of the fat graft is finally performed with a 10 ml Luer Lock syringe connected to one of the cannulas of the Coleman™ Microinjection System, chosen according to the characteristics of the recipient site.

Technical Variation

Khouri et al. described a megavolume fat grafting procedure [12, 29, 30]. The harvesting is performed over a large area with a 12-hole, 2.7-mm cannula connected to a 300-mmHg syringe (KVAK Syringe; Lipcosm, LLC, Key Biscayne, Fla.) through multiple needle puncture entry sites. The lipoaspirates are processed with centrifugation at 15 g for 2 min and then diffusely reinjected through multiple needle entry sites with 2.4-mm single-hole cannulas.

Postoperative Care

To hold open the graft construct and optimize the ideal graft-to-recipient volume ratio, the postoperative use Brava is recommended [29, 30]. In the published literature, the patients are asked to wear the device for a period ranging between 5 days and 4 weeks, for 10–24 h/day, only at night or for as many hours per day as tolerated [2]. The level of negative pressure was reported to be equal to −20 mm Hg or simply "low pressure." Also, the postoperative use of Kiwi VAC was recommended for 3 days with 3 applications per day of 1 min each.

It is very important to inform the patients regarding possible dermatologic complications, as observed by Hammer-Hansen [18]. On this regard, our comprehensive review found the following skin complications: temporal bruising and superficial blistering, 11.3%; erythema, 1.4%; ulceration necrosis, 1.4%; pruritus, 1.1%; phlyctens, 0.1% [2]. We also observed that the most common complications were localized edema (14.2%), temporary bruising and superficial skin blisters (11.3%), and fat necrosis (8.2%) [2].

Clinical Case

A 67-year-old woman presented with a complaint of contracted scar tissue on the right breast following breast-conserving surgery and radiation therapy (Fig. 10.3) [20]. The recipient site was prepared intraoperatively for AFG with application of Kiwi, which was also used 3 times/day for 3 days after the operation. A total amount of 40 ml fat was transplanted. Early postoperative pictures show scar release and volume restoration.

Conclusions

There is emerging evidence that the preparation of the recipient site through EVE can enhance outcomes of AFG. Its use can be recommended for both aesthetic and reconstructive indications in breast surgery. Preoperative selection of the appropriate candidate and treatment protocol is a key aspect for the success of the procedure. It is essential to verify the psychological compliance of the patient to the use of Brava and to identify the mechanical compliance of the recipient

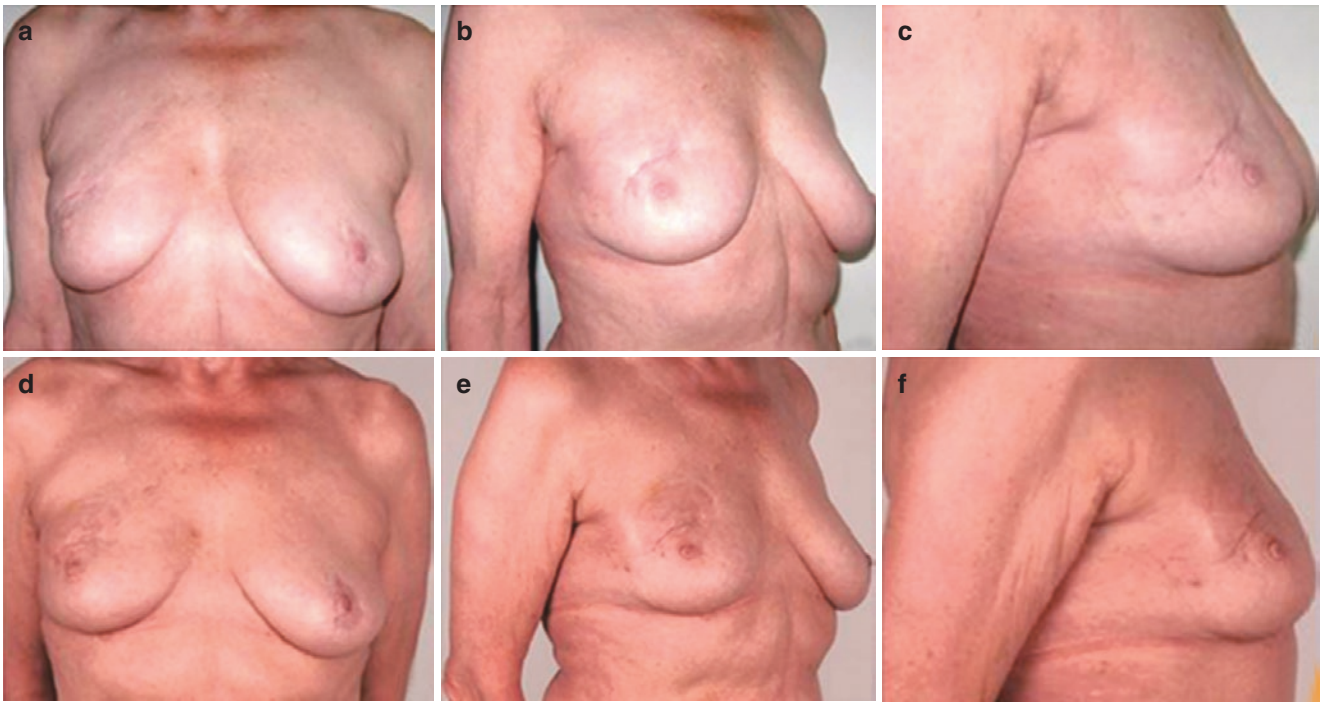

Fig. 10.3 Preoperative (**a**–**c**) and early postoperative (**d**–**f**) images of a patient receiving AFG after preparation of the right breast with Kiwi. (Reproduced with permission from Oranges et al. [20])

site to the expansion process, adequately plan an optimal number of AFG sessions, and eventually perform additional surgeries such as contraction release. A significant advantage of its use is the ability of preparing the breast to receive megavolume AFG (>300 ml). Although also supported by preclinical evidence, the relative low level of evidence of the studies conducted so far involves the need of further research. Finally, the use of Kiwi is a good option for cases characterized by contracted scars and breast contouring defects where small volume fat grafting is required (up to 80 ml).

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Breast Reconstruction with the Latissimus Dorsi Flap and Fat Grafting

11

Fabio Santanelli di Pompeo and Benedetto Longo

Introduction

The latissimus dorsi flap was first described in 1906 by Tansini [1]; it was then put apart for almost 70 years until it was proposed again from authors as Olivari, Schneider, Muhlbauer, and others [2–5]. It is a versatile flap due to its remarkable dimensions and easiness of dissection and the length of the vascular pedicle. It is very thin and can be easily adapted to correct any defect. It can be used as a simple muscular flap covered by a skin graft or also as a myocutaneous flap [6]. If the muscle alone is harvested, it can be raised either as a whole unit or only its anterior portion, preserving the nerve and the functionality of the unused muscle portion. For the presence of several muscular perforators, it is possible to raise large skin islands, variously oriented, but possibly not larger than 12 cm, to be able to close the defect in the donor site by direct approximation of the margins. Due to the anatomical relation of the vascular pedicle, this flap can be united with the anterior serratus muscle and a rib for a chimeric flap, and in certain conditions, such as the correction of large defects, it can be raised together with the scapular or parascapular flap as well.

Regarding breast reconstruction, the latissimus dorsi flap is a very reliable option, and it is one of the best options both for immediate and delayed breast reconstructions [3, 5, 7]. Nevertheless, its use has been traditionally limited by the reconstructed breast's desired size and therefore the need to use breast implants to achieve a bigger volume. Complications such as infection, implant exposure, rupture, capsular contracture, poor cosmetic outcomes following radiotherapy, and the connection with breast implant associated with anaplastic large-cell lymphoma are the main disadvantages of using implants [8–11]. Hokin in 1983 introduced the extended latissimus dorsi myocutaneous flap for autologous breast reconstruction by raising the whole muscle together with the lumbar fascia and the largest possible skin paddle, avoiding in such a way the need for an implant to achieve an adequate breast volume. He stated that 70 percent of the flaps offer more than 400 cc in volume [12]. The technique grew rapidly in popularity, and Delay et al. were among the pioneers reporting its advantages, disadvantages, and results in a consecutive sample of 100 patients [13]. The increased flap volume with this technique leads to a greater donor-site morbidity, such as wound dehiscence, skin necrosis, seroma formation, and an aesthetic contour defect of the dorsal donor area [14–17]. Autologous fat transfer, because of its relative cost, ease of use, low morbidity, and longevity, has recently become recognized as an essential and useful tool with which to achieve complete breast reconstruction [18–23]. Santanelli et al. in 2014 described the compound latissimus dorsi myocutaneous flap with fat transfer for total breast reconstruction, adding to the arsenal of autologous breast reconstruction an alternative technique [24].

Anatomy

The latissimus dorsi is a thin fan-shaped muscle that originates from the anterior surface of the last three ribs, from the posterior and lateral margin of the iliac crest, from the thoracolumbar fascia, and from the last 6 thoracic and lumbar vertebrae. It inserts in the medial margin of the bicipital groove of the humerus. It is almost completely subcutaneous except in its superomedial portion where it is covered by the trapezius and in its distal insertion where it is covered by the teres major. The subscapular artery, 4 cm after its origin from the third portion of the axillary artery, splits into the circumflex scapular artery and the thoracodorsal artery. The latter, after giving off a constant branch to the serratus anterior muscle, penetrates, at about 8–10 cm from the axillary artery, the deep surface of the latissimus dorsi muscle 2 cm posteriorly to its anterior margin. Secondary pedicles by the posterior intercostal arteries and

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lumbar arteries are also present. The flap can be sufficiently vascularized also by reverse vascularization from the branch of the serratus anterior muscle when the proximal thoracodorsal artery is not available. Once into the muscle, the artery splits into two branches running parallel to the anterior and superior margins of the muscle, giving off the largest number of myocutaneous perforators. The thoracodorsal artery has a diameter of about 1.5–2 mm at its origin and a length of about 10 cm. The venous drainage is assured by two venae comitantes that merge into one large thoracodorsal vein of 3–5 mm diameter. Motor innervation is assured by the thoracodorsal nerve (C6–C8) which runs behind the axillary artery and joins the vascular pedicle from which it splits (in about 90% of cases) giving off two separate neuromuscular branches which can be used together or singularly. The skin overlying the muscle receives its sensory innervation by the lateral cutaneous nerves that arise from the intercostal nerves at the midaxillary line. The latissimus dorsi flap is a muscular or musculocutaneous flap with a type V vascularization (1 dominant pedicle and secondary segmental pedicles) (Fig. 11.1). Together with the muscle, a randomly oriented and remarkably large island of skin can be raised and can be equal in length with the whole vertical size of the muscle and usually not larger than 12 cm, to allow closure by direct approximation of the margins [25].

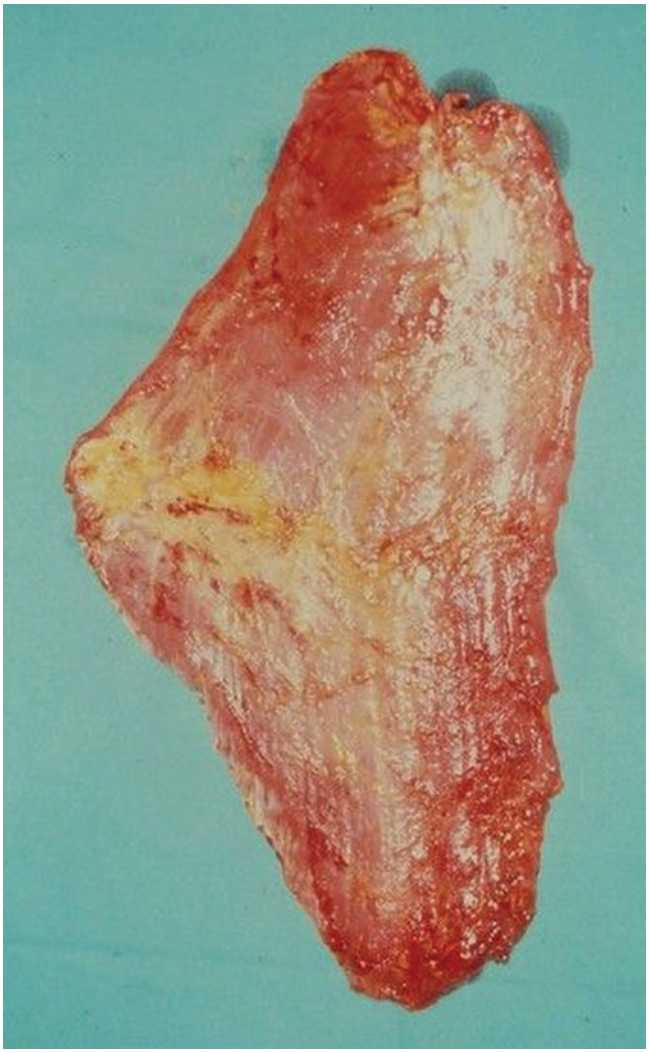

Fig. 11.1 The fan-shaped latissimus dorsi flap with its insertion to the humerus and the thoracodorsal pedicle on the top

Patient Selection

Breast reconstruction with the latissimus dorsi flap and fat grafting is indicated in patients with small-to-medium-sized breasts requiring unilateral or bilateral reconstruction or immediate or delayed reconstruction, no abdominal donor area, and high anesthesiology risk, in both young and old patients, and in patients with tumors that may need radiotherapy. It is contraindicated in patients with large breasts and little adipose tissue availability. Although the use of the latissimus dorsi flap leads to little functional defect, it is contraindicated in athletes that use the upper limb or in paraplegics [26]. The advantages of this technique include: a total autologous breast reconstruction, minimally invasive technique, good aesthetic results, low complication rates, low cost surgery, and aesthetic improvement of fat grafting donor areas. The disadvantages include the need of multiple surgical sessions for the augmentation of reconstructed breast volume with fat grafting and the unpredictable fat graft retention percentage.

Preoperative Planning and Patient Preparation

The week before the operation, the patient is advised to avoid any contact with persons that have a cold or any other infectious disease. Aspirin or other blood thinners should be avoided since they will reduce the capacity of blood to coagulate and thus could provoke excessive bleeding and the formation of hematomas. In addition, ideally, the operation should not take place during menstruation. All patients should receive a thorough clinical exam, standard laboratory exams, an x-ray of the thorax, and an ECG preoperatively. Moreover, it is necessary to perform a breast surgery visit and a radiological examination of the breast, by ultrasound of the breast and/or mammography and magnetic resonance imaging (MRI), to study breast cancer status in case of immediate breast reconstruction and breast cancer recurrence in case of delayed reconstruction. Right before the anesthesia, the measurements and surgical planning of the patient is performed, an important part of the preparation of the patient for surgery, that will be used during the operation as a guide. Markings, drawn in upright position, include standard anatomical landmarks such as jugular notch, sternal midline, inframammary fold, breast limits, and bra strap area. The anterior margin of the muscle is identified by a line that connects the posterior axillary pillar with the median portion of the iliac crest, and the superior margin is identified by a curved line going from

the axillary cavity to a point placed 4 cm superiorly to the scapular angle. In case of immediate reconstruction, the surgical planning commences with the breast surgeon that indicates type of mastectomy and necessity of skin, nipple-areola complex resection. For all types of mastectomy (nipple-sparing mastectomy, skin-sparing mastectomy, or modified radical mastectomy),latissimus dorsi flap skin paddle planning comprises the largest transverse skin paddle (approximately 10–12 cm wide) taking into consideration an easy closure of the donor site with low risk of seroma formation and the hiding of the scar under the bra strap line (Fig. 11.2). The transverse skin paddle is drawn on the back using the pinch technique and is centered on the middle to lower bra strap area. Based on type of mastectomy, the area to be deepithelialized is also marked. In case of delayed reconstruction, the skin area needed to be integrated is calculated by measuring the dimensions of the contralateral breast [27].

Surgical Technique

In unilateral reconstruction, mastectomy and latissimus dorsi flap harvesting procedures are performed simultaneously by the general surgeon and the plastic surgeon with the patient in the lateral decubitus position and the upper limb suspended at the right angles to provide adequate axillary access (Fig. 11.3). Flap raising begins with preoperative marking skin incisions. The skin paddle is totally deepithelialized in the case of nipple-sparing mastectomy, whereas in skin-sparing mastectomy and modified radical mastectomy, the exact defect is outlined from the pattern imprint on the planned skin paddle, and the rest is deepithelialized if necessary. Dissection begins on the superficial muscular plane to ensure that the latissimus dorsi muscle is divided from the skin above and subcutaneous tissue from its origin to its insertion. The anterior muscle margin is then identified, and a submuscular undermining plane is prepared separating the muscle from the thoracic wall and, in particular, from the anterior serratus muscle and the last three ribs. At this point it is possible to disinsert the muscle inferiorly and to identify and splay the vascular branch of the anterior serratus. The thoracodorsal artery can now be displayed and followed together with the veins comitantes until their origin

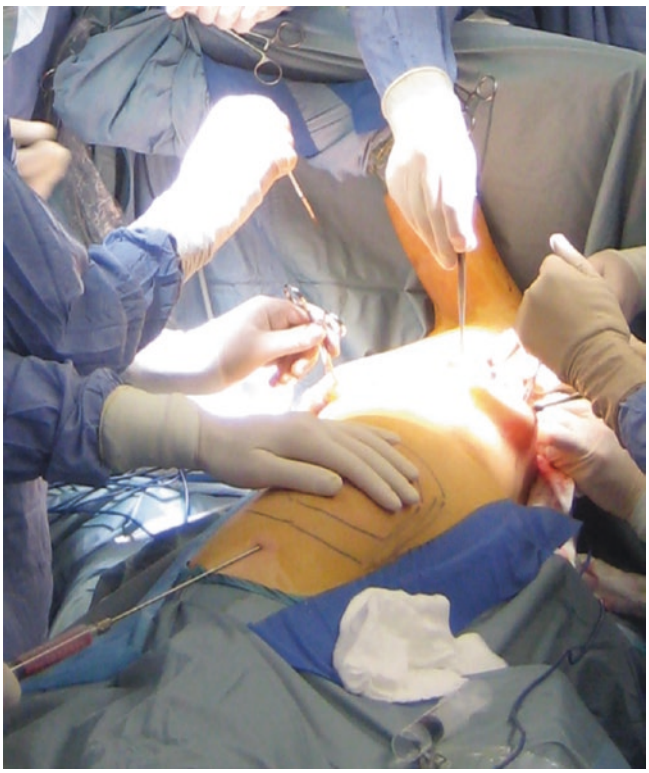

Fig. 11.3 Both surgical teams can easily work contemporaneously in unilateral reconstruction

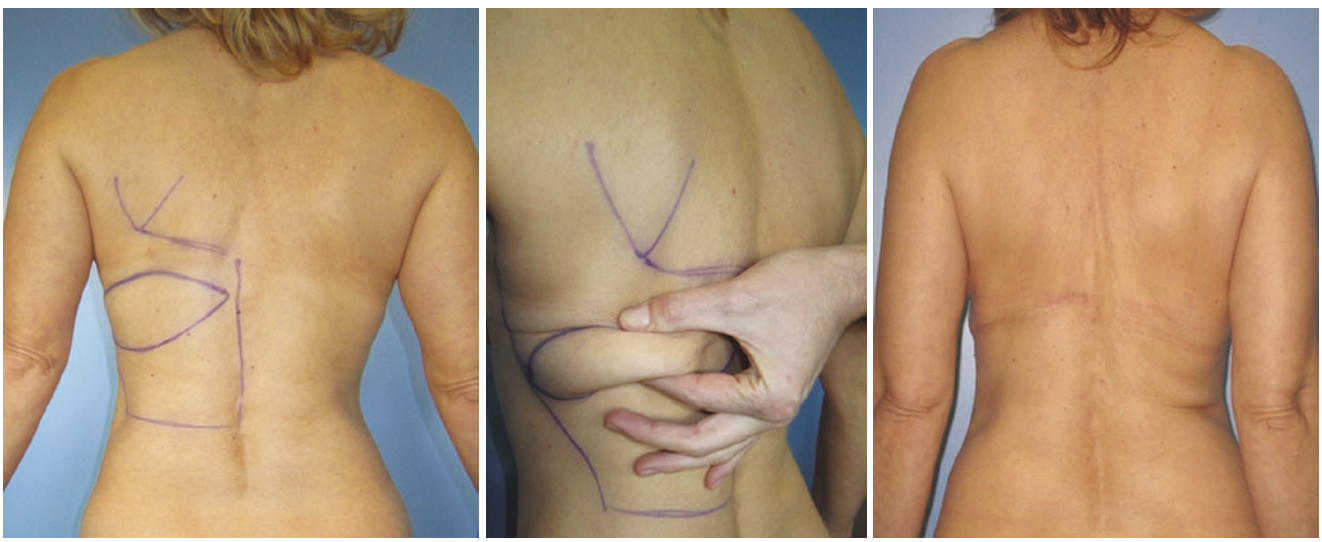

Fig. 11.2 Preoperative planning with skin island placement so that resulting scar is easily hidden by a bra. (Request from PRS https://doi.org/10.1097/PRS.0000000000000859)

in the axillary cavity. The thoracodorsal nerve is not divided [28]. With 2-0 polyglactin (Vicryl, Ethicon Inc., Somerville, N.J.), simple stitches to the Scarpa's fascia, 3-0 Vicryl Plus (Ethicon Inc., Somerville, N.J.), and continuous suture to the superficial dermis, the donor area is closed in two layers. A suction drain remains in place, and at the same time fat is harvested. The patient is then turned to the supine position, and the flap is rotated through the axilla to the anterior chest wall area. In bilateral reconstruction, first, plastic surgeons harvest both flaps with the patient in the prone position, and, afterwards, the general surgeons carry out the mastectomy procedure simultaneous with fat harvest with the patient in the supine position. Fat tissue is harvested using the Coleman technique with a 2- to 3-mm cannula and a 10-ml syringe; it is centrifuged at 3000 rpm for 3 min and finally injected into the superficial and deep adipose layer of the latissimus dorsi flap skin paddle and muscle fascia with 1-ml syringes (Fig. 11.4) [29]. The fat is distributed in such a way that the lower part of the skin island to be placed on the reconstructed breast's lower pole is thicker than the upper (Fig. 11.5). A reconstruction of the anatomical breast is offered in this way (Fig. 11.6). Some authors suggest that fat grafting should be done before raising the flap [30]. After fat expansion, the totally or partially deep latissimus dorsi skin paddle is secured under mild tension to the lower edges of the breast pocket, and the distal muscle portion is folded onto itself, resulting in extra bulk. Over the new mound, the breast skin is re-draped, and a suction drain is placed before closing the skin. If during the first operation the desired breast volume is not achieved or there are still some irregularities in the upper and medial aspects of the chest wall, further fat grafting sessions may be performed. The preservation of the thoracodorsal nerve in combination with muscle reinsertion into the inframammary fold is recommended in order to preserve muscle tropism, thus maintaining bulk and preventing the reconstructed breast from decreasing in volume during the first year after surgery. Complications are not frequent and include the following: bleeding is very rare (0.5%), but can present only during the first 12 h after the operation and does not depend on the ability of the surgeon; in such a case, it will be necessary to return to the operating room for a 30–60-min operation in order to identify the bleeding

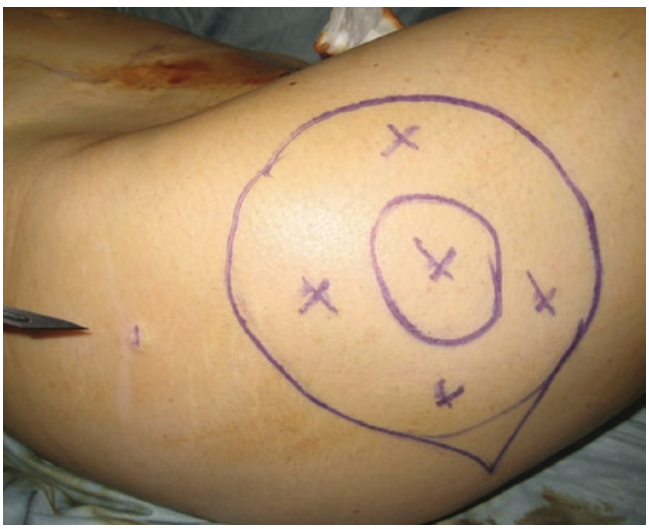

Fig. 11.4 Fat tissue is harvested using the Coleman technique

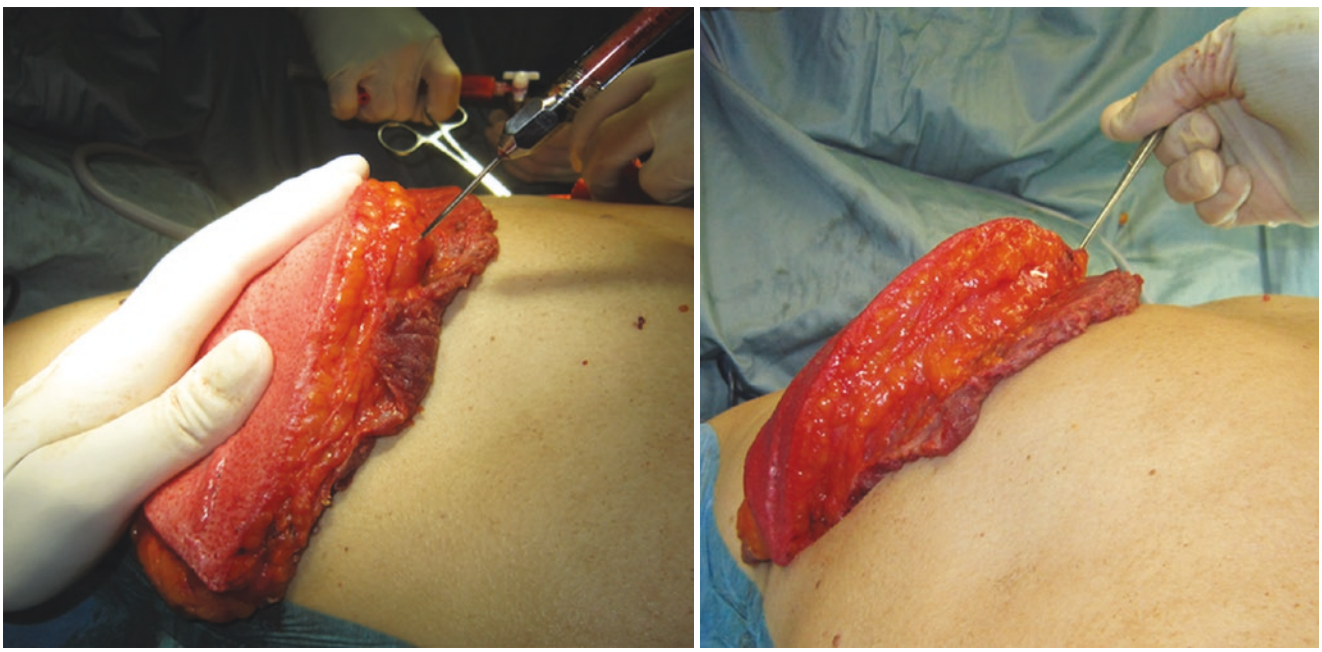

Fig. 11.5 Fat is distributed mainly on the lower part of the skin island to be placed on the reconstructed breast's lower pole. (Request from PRS https://doi.org/10.1097/PRS.0000000000000859)

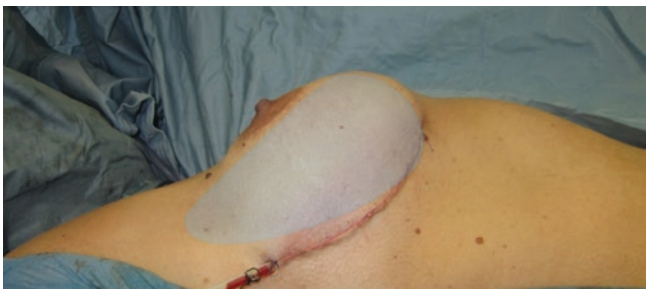

Fig. 11.6 A reconstruction of an anatomical breast is offered. (Request from PRS https://doi.org/10.1097/PRS.0000000000000859)

vessel. This complication, if it is managed well, will not provoke other inconveniences, and it will not prolong the hospital stay. Infection, thanks to antibiotics, is very rare, but if present, can be managed by adapting the antibiotic therapy. Various authors report upper limb disability after latissimus dorsi flap harvest. Severity varies according to patients' characteristics (sex, age, body habitus), type and site of the reconstruction (breast, extremities, head and neck), and the different associated procedures. Several studies have shown that latissimus dorsi muscle harvest for breast reconstruction has little effect on shoulder mobility. Glassey et al. report no significant range-of-motion loss at 1 year. Other authors have demonstrated some weakness, pain, and functional difficulties in the early postoperative follow-up [13, 15, 31–35].

Raising this flap requires that the patient is placed in a lateral decubitus with the upper limb held in an abducted position, sometimes being uncomfortable for the second surgical equipe operating in the receiving area. The breasts are never perfectly symmetrical neither during puberty nor afterwards, and as result a mild asymmetry, more pronounced initially, after the reconstruction should not be excluded. Such a situation could depend on the unfavorable anatomic/vascular conditions due to previous operations and often could be corrected with small operations performed in local anesthesia. At the donor area (dorsum), the resulting linear scar will be greater than the elliptical cutaneous island that is transferred, but it can be hidden under the bra or bikini strap. Instead, in the breast region despite the efforts to hide the resulting scars, some of them will be more visible according to the type of the mastectomy chosen. Finally, the quality of the scars cannot be predicted and will depend on the personal healing characteristics of the patient.

Postoperative Care

Right after the operation, the patient must stay for 30 minutes in the observation room, where she is controlled by the anesthesiologists before she can be permitted to return to her room. General anesthesia can have certain adverse effects such as vomiting and chills, and the patient can drink and eat the morning after surgery. It is necessary to remain in bed until the morning after. The patient receives antibiotics to prevent any infectious complications and analgesics for pain control. Usually during the third postoperative day, the patient is discharged and can return at home with appropriate treatment and indications for dressing change. The first postoperative control is performed after 3–5 days. Only after the removal of the suction drains the patient can have a shower. The sutures are partially removed after 1 week and completely after 2 weeks. Work and social activities should be suspended for 20 days after the operation. If the work of the patient is such to demand an increase physical activity (raising weights, etc.), it is necessary a longer period of abstinence. The patient can return to its daily physical activities only after the first 10 days postoperatively. Driving is allowed 1 month after surgery and sporting activities 2 months after surgery with caution.

Clinical Cases

Case 1

A 55-year-old woman with a left-sided breast cancer and an indication for nipple sparing mastectomy. The patient had inadequate abdominal donor site availability; therefore, an immediate reconstruction with the latissimus dorsi flap and fat grafting was planned. Flap dimensions were 7 × 15 cm, and 100 cc of immediate fat grafting were added. Two more fat grafting sessions of 150 and 145 cc were performed to increase flap volume and offer aesthetic refinements of the form (Figs. 11.7 and 11.8).

Case 2

A 37-year-old woman with a right-sided breast cancer and an indication for bilateral skin reducing mastectomy. The patient had inadequate abdominal donor site availability; therefore, immediate bilateral reconstruction with the latissimus dorsi flap and fat grafting was planned. Flap dimensions were 10x18 cm and immediate fat grafting of 140 cc on each side was done. No additional fat grafting sessions were needed to achieve final result (Figs. 11.9 and 11.10).

Case 3

A 42-year-old woman with bilateral breast cancer and an indication for bilateral nipple sparing mastectomy. The patient had inadequate abdominal donor site availability; therefore, immediate bilateral reconstruction with the latissimus dorsi flap and fat grafting was planned. Flap dimensions were 11x18 cm and immediate fat grafting of 90 cc per side were added. An additional session of 90 cc of fat grafting was performed for minor aesthetic refinements and volume increase (Figs. 11.11 and 11.12).

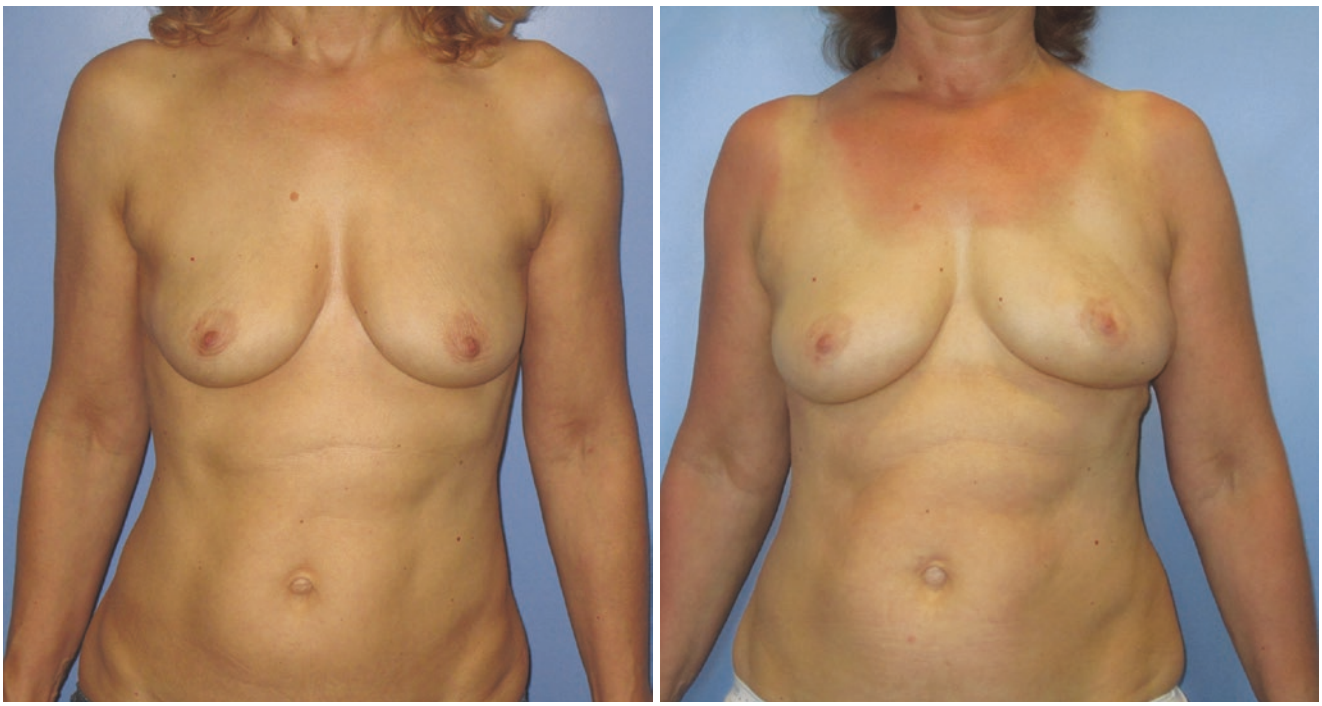

Fig. 11.7 Preoperative (left) and final postoperative (right) frontal view

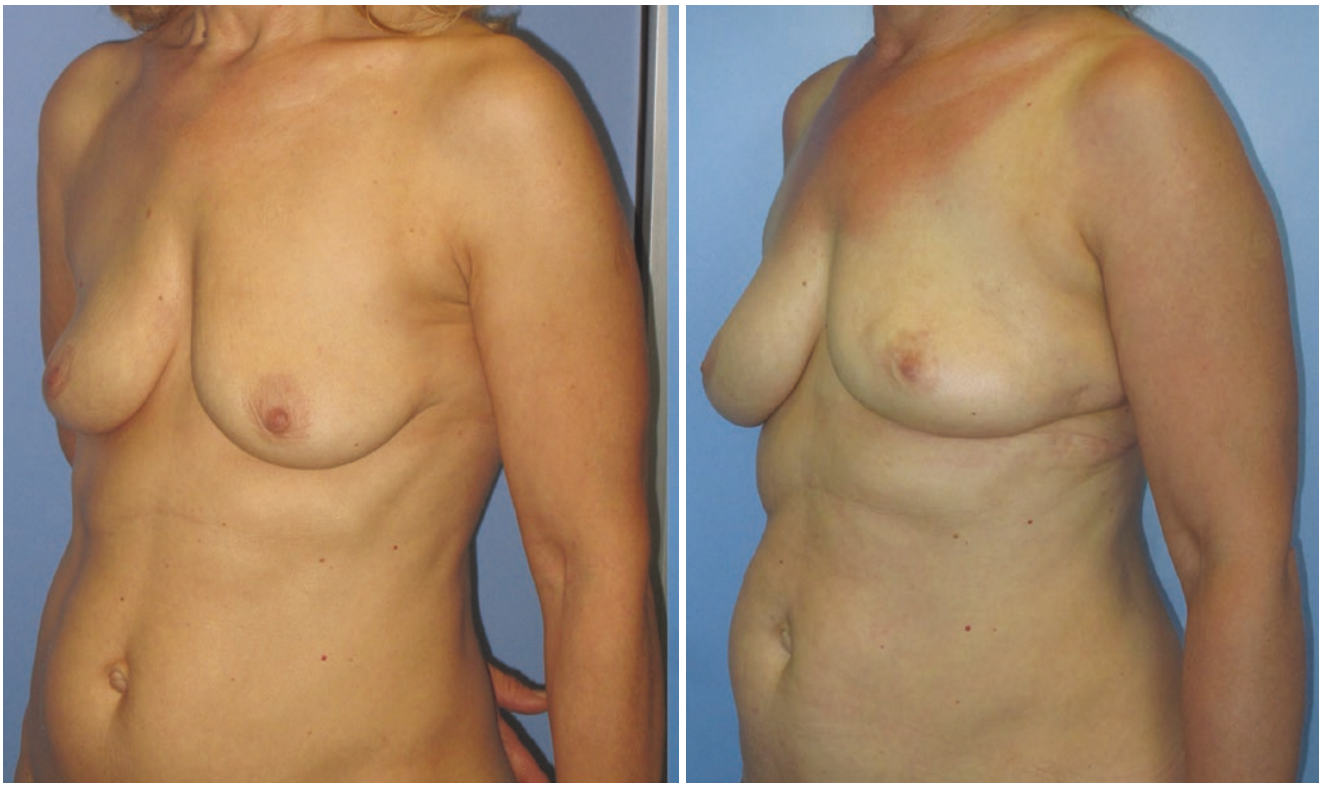

Fig. 11.8 Preoperative (left) and final postoperative (right) left oblique view

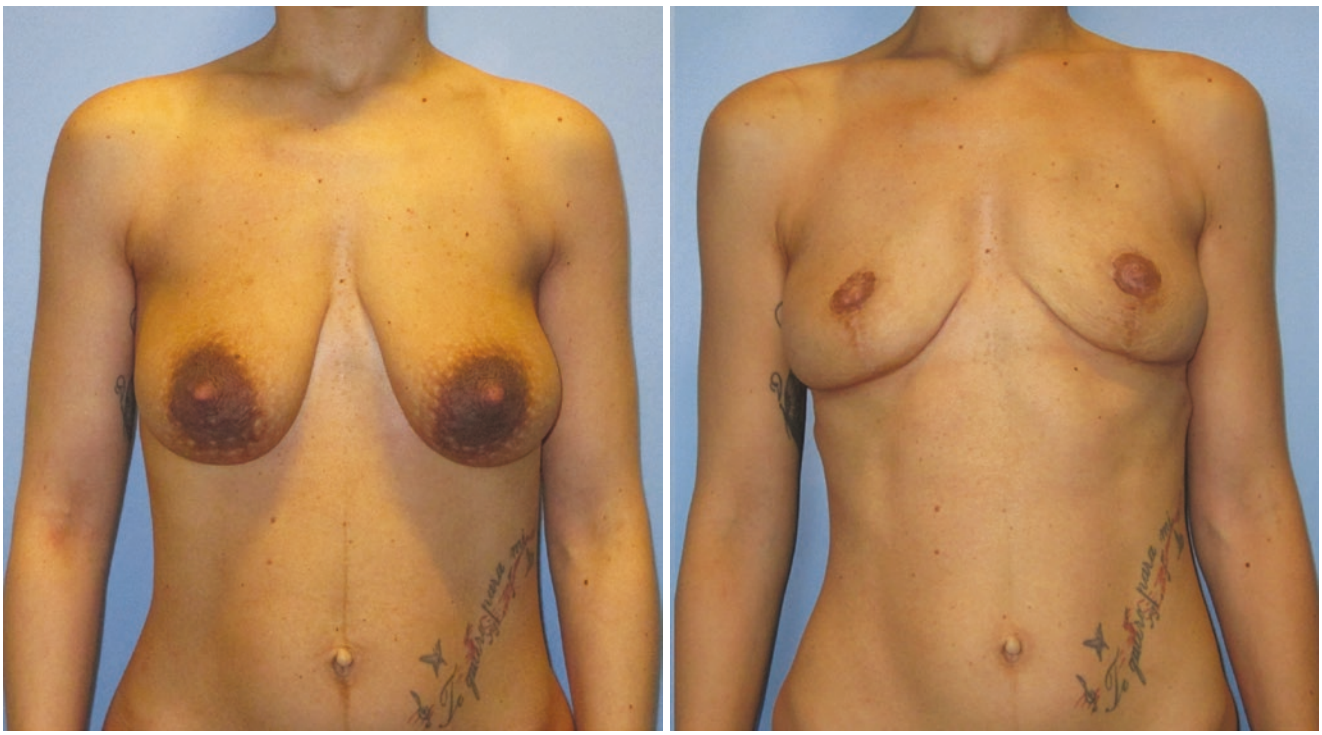

Fig. 11.9 Preoperative (left) and final postoperative (right) frontal view

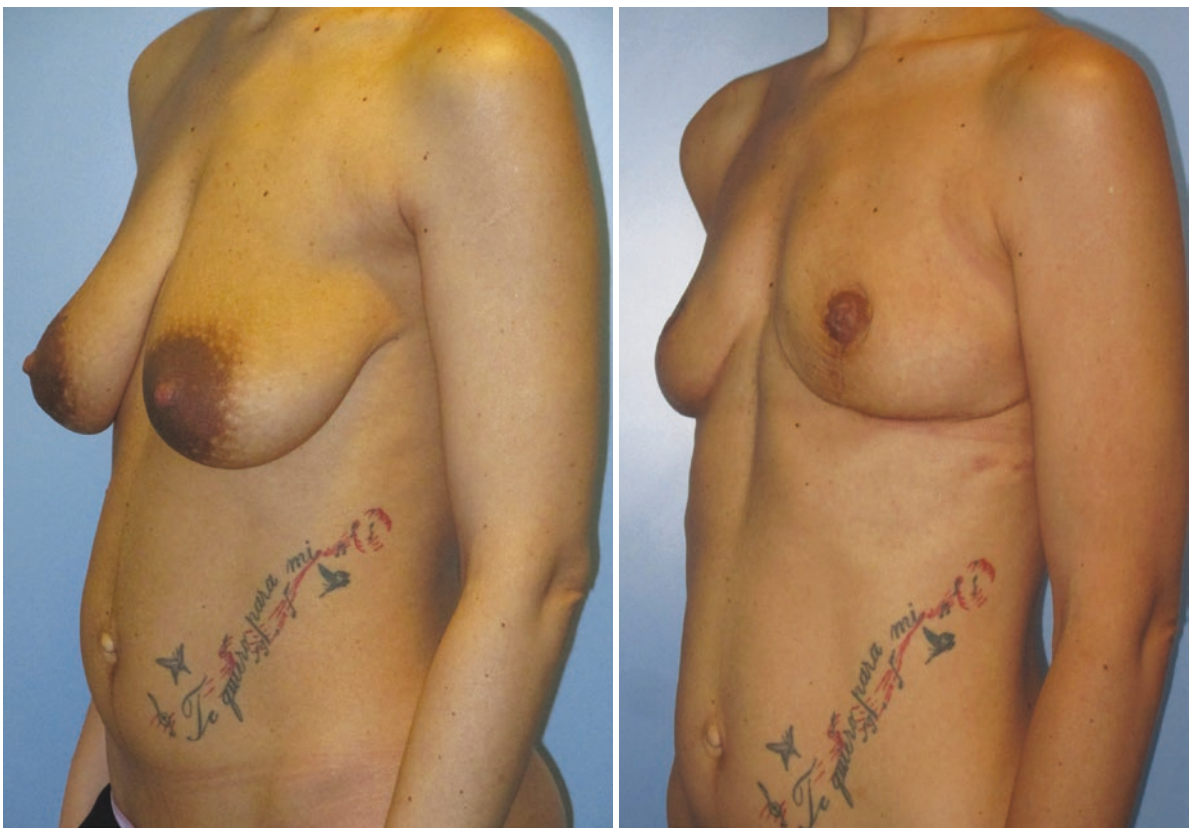

Fig. 11.10 Preoperative (upper left) and final postoperative (upper right) left oblique view. Preoperative (lower left) and final postoperative (lower right) right oblique view

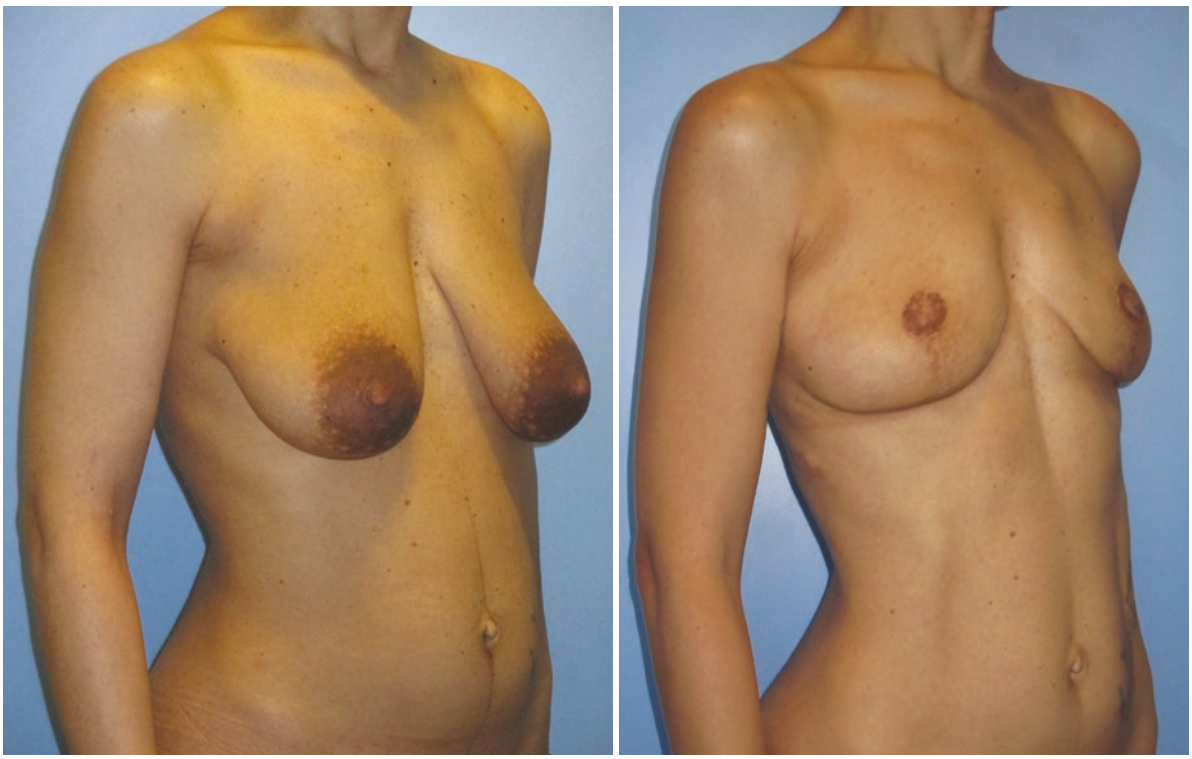

Fig. 11.10 (continued)

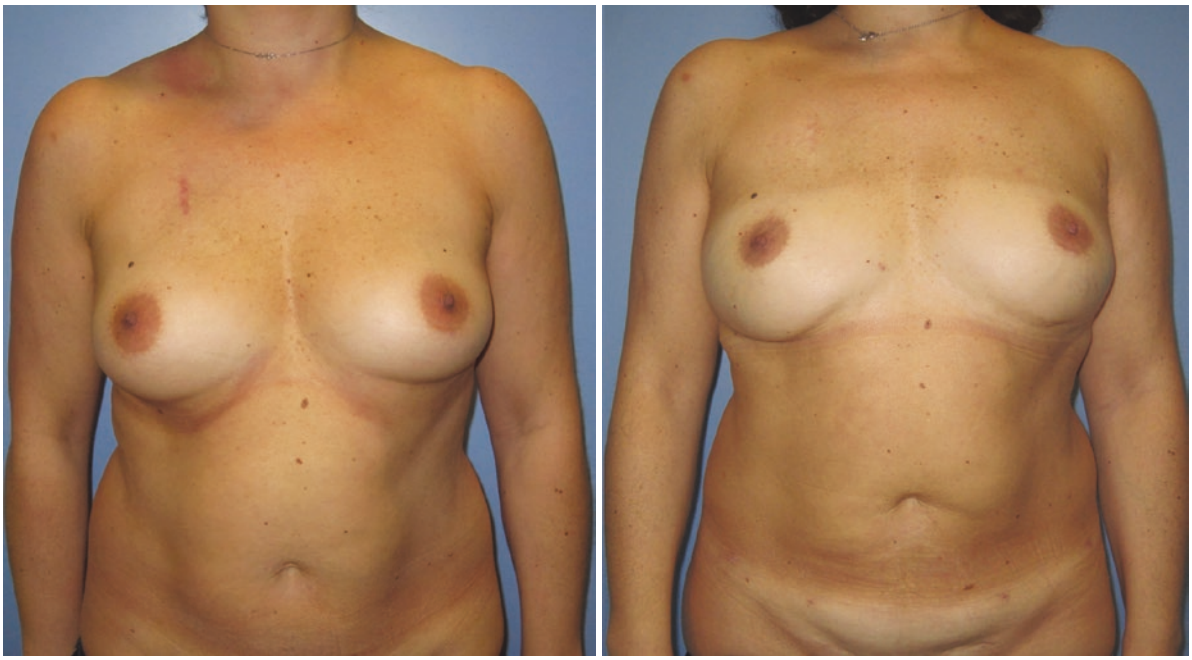

Fig. 11.11 Preoperative (left) and final postoperative (right) frontal view. (Request from PRS https://doi.org/10.1097/PRS.0000000000000859)

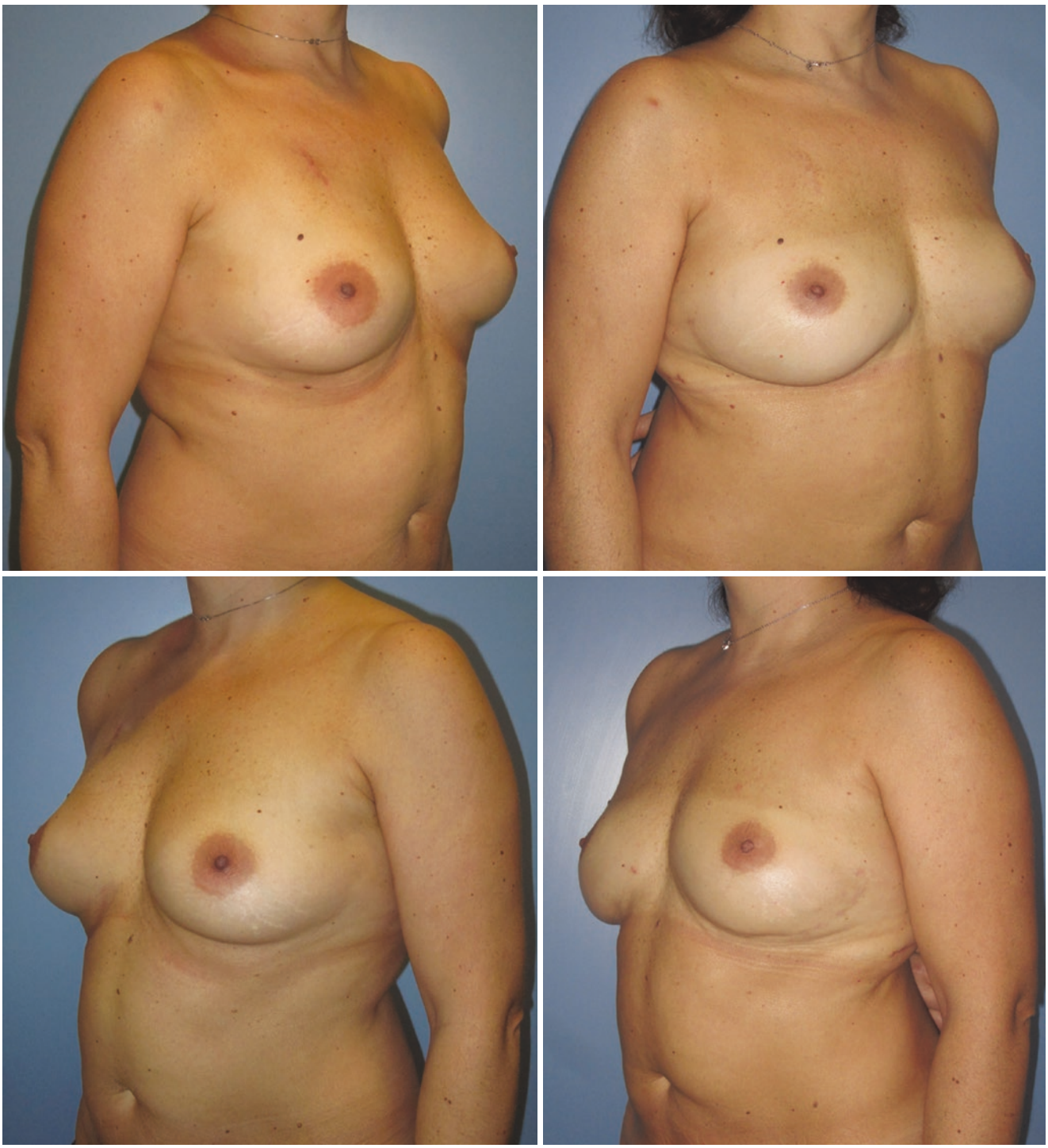

Fig. 11.12 Preoperative (upper left) and final postoperative (upper right) right oblique view. (Request from PRS https://doi.org/10.1097/PRS.0000000000000859). Preoperative (lower left) and final postoperative (lower right) left oblique view

Conclusions

The pedicled latissimus dorsi flap coupled with intraoperative fat grafting is a valid alternative for total autologous immediate breast reconstruction, using easy and time-tested techniques and avoiding implant-related complications when abdominal tissues are not available.

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Breast Reconstruction with the Endoscopically Harvested Latissimus Dorsi Flap

12

Horacio F. Mayer, Ignacio Stoppani, and Federico Notrica

Introduction

The latissimus dorsi flap (LDF) is one of the oldest variants in breast reconstruction, and it is the first myocutaneous flap used for this purpose. Described in 1906 by Tanzini [1], it remained forgotten for several decades until Schneider et al. [2] and Olivari [3] reintroduced it for breast reconstruction in the 1970s.

Nowadays, and according to the statistics of the American Society of Plastic Surgeons (ASPS), the LDF remains the second most popular flap in the USA after the DIEP flap [4]. The LDF is also a popular breast reconstruction choice in the UK, representing approximately 50% of procedures undertaken [5]. In the same fashion, in Argentina and many Latin American countries, the LDF is one of the most commonly used flaps for breast reconstruction [6].

The development of less aggressive mastectomies raised interest in reconstructive options that would be less invasive. As the traditional harvesting technique of the LDF requires a long donor-site incision on the back, a minimally invasive approach through endoscopic harvesting of the LDF was always desirable. However, the technical difficulties inherent to the endoscopic technique such as the line of sight around the curvature of the back, the need of specific endoscopic instruments, and the difficulty of creating and maintaining the optical cavity discouraged the development of this variant [7].

In 1993, Friedlander and Sundin demonstrated in a cadaver model the feasibility of minimally invasive harvesting of an LDF [8]. The optical cavity was created without insufflation by applying external traction on the skin. In 1994, Fine, Orgill, and Pribaz reported the first clinical experience with endoscopy-assisted dissection of the LDF for microsurgical reconstruction of the lower limb [9]. The optical cavity was then achieved by the use of special retractors. A balloon-assisted endoscopic harvest of the latissimus dorsi muscle, where the balloon performs most of the dissection under the muscle and creates an optical work space, was also later reported [10]. In 1998, Masuoka described the endoscopic approach for breast reconstruction for the first time [11], and a year later, Bostwick used it to reconstruct partial defects after quadrantectomy [12]. Pommel et al. later reported the endoscopic approach with an optic cavity generated by insufflation with CO_2 [13]. In this manner, the approach went from endoscopically assisted to fully endoscopic, emulating the minimally invasive abdominal surgery.

In recent years, interest in the endoscopic approach has resurged as a method to avoid skin scarring on the back. Kisski et al. recently presented a series of cases with its technical variant using an endoscopic approach to the muscle through an axillary incision for use as a microsurgical flap in limb reconstruction [14]. In 2017, Silva Vergara reported the first case of breast reconstruction with an endoscopic-wide dorsal muscle through a single port [15].

Most of the reported techniques are actually hybrid techniques, where the endoscopic approach is associated with an axillary open approach and the use of special retractors [13, 14, 16]. In our center, we use a totally endoscopic technique based on the technique published by Xu and by applying some operative modifications [17]. We believe that it is a reproducible surgery with reasonable costs and satisfactory results when properly performed. This article presents our variant of the totally endoscopic approach and the lessons learned while developing and utilizing the technique.

Anatomy

The muscular anatomy and its references become fundamental when it comes to orientation during dissection, as it will show the surgeon the following subsequent steps. Endoscopic vision requires a certain level of abstraction since it does not have a direct view of the structures. However, unlike what

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happens with abdominal laparoscopic surgeries, when working in a subcutaneous plane, palpation helps us to identify anatomical landmarks. Bony repairs such as the scapular angle, the vertebral spinous processes, or the iliac crest guide us in the extension of the dissection and location of the endoscopic instruments.

The latissimus dorsi (LD) is a triangular muscle that occupies the central and upper external part of the back. It originates from the last six spinal processes of the thoracic vertebrae medially, the thoracolumbar fascia, and the superior border of the iliac crest and the posterior-superior iliac spine [18]. The upper fibers cross horizontally, the middle fibers run obliquely upwards, and the lower ones travel almost horizontally until they all converge into a thick fascicle, which crosses the lower angle of the scapula. The muscle then curves around the lower edge of the teres major muscle and wraps around itself so that the upper fibers become first posterior and then lower, while the vertical fibers turn around becoming first anterior and then superior to insert themselves in the minor tubercle of the humerus. The medial insertions are partially covered by the trapezius muscle and the lateral ones by adhesions to the serratus anterior, the release of the latter being an important step for its endoscopic dissection, as detailed below.

Patient Selection

The indications of the endoscopic approach are basically all indications for the classical technique of LDF harvesting. These include irradiated patients that are not candidates for abdominal-based flap reconstruction because they do not have a proper donor area, patients who refuse to add further scars to their anatomy, and implant-based cases complicated with exposure or capsular contracture. Additionally, recent therapeutic and surgical advancements such as the nipple-sparing and skin-sparing mastectomies not requiring additional skin from the back [19], modern radiotherapy techniques that produce lesser or minimal actinic cutaneous damage allowing subsequent tissue expansion [20], and associated lipofilling procedures [21] are all excellent candidates for this approach. Women who desire breast reconstruction and who are at an increased risk for conditions necessitating postmastectomy radiotherapy following the delayed-immediate approach as proposed by Kronowitz [22] could also benefit from this minimally invasive variant. Those patients with early breast cancer who undergo a conservative approach with an external quadrantectomy are also good candidates for immediate reconstruction with the endoscopic LDF [16, 23]. The main indications are summarized in Table 12.1.

Table 12.1 Main indications for endoscopic approach

Slender patients without a proper abdominal donor area
Patients reluctant to have additional scars in their body
Patients with implant-based reconstructions complicated with exposure or capsular contracture
Patients who undergo nipple sparing or skin sparing mastectomy not requiring additional skin from the back
Patients initially not reconstructed and irradiated without great actinic damage to the skin, which can be successfully expanded
Patients who undergo the delayed-immediate approach
Immediate partial breast reconstruction after external quadrantectomies

Patient Preparation and Preoperative Planning

Presurgical clinical and radiological exams are carried out according to the usual protocols. On the day of the surgery, preoperative marking is performed with the patient standing and with the arm extended (Fig. 12.1). The medial and lateral boundaries of the muscle are marked as well as the inferior angle of the scapula and the posterior-superior iliac spine. The following markings are made on the mastectomy site at the midline, the contralateral inframammary fold, and the ideal position of the fold on the side to be reconstructed. This delimits the pocket if we are going to place a tissue expander or the changes in the pocket if the position of the expander or implant is not adequate employing the pocket work maneuvers previously reported [24].

Occasionally, a preoperative/intraoperative ultrasound can be performed to locate and mark the thoracodorsal pedicle and thus avoid accidental injury during endoscopic LDF dissection. Compression elastic stockings, sequential pneumatic compression boots, and a urinary Foley catheter are placed.

Surgical Technique

Step 1: Creation or Revision of the Breast Pocket

The patient is placed in the supine position with the arm abducted at 90 °. If the case is a revision of a complicated implant-based reconstruction with capsular contracture, the required pocket work may include partial or total capsulectomy or only capsulotomies. If it is a delayed reconstruction, a prepectoral or subpectoral pocket is created to accommodate the expander or implant. If we opt for subpectoral placement, the pectoralis major muscle must be released from its inferior insertions while maintaining its sternal ones.

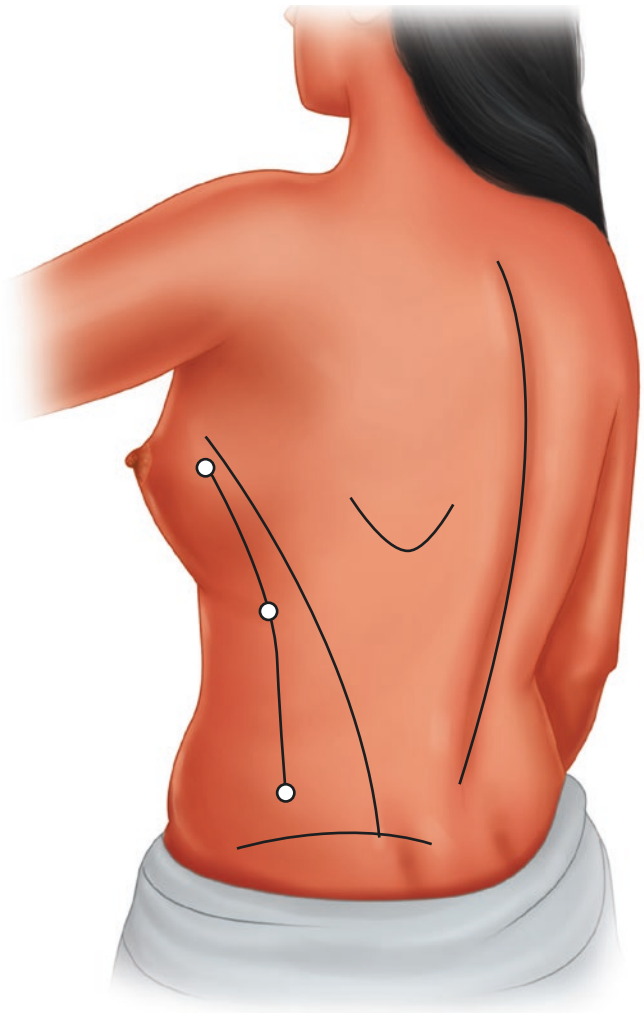

Fig. 12.1 Preoperative markings The medial and lateral border boundaries of the muscle are marked, as well as the inferior angle of the scapula and the posterosuperior iliac spine. Three ports are placed between the middle and posterior axillary line, a superior port at the nipple areola complex projection, a middle port 2 cm below the inframammary fold projection and an inferior port 5 cm above the iliac crest

Laterally, we identify the serratus anterior muscle and the lateral border of the LD, releasing its adhesions to it. As this plane is often misleading, we must take special care not to inadvertently raise the serratus anterior, being the oblique orientation of its muscle fibers a guide. A reference suture is placed on the lateral border of the LD to facilitate its identification later during the endoscopic phase.

The anterior dissection in supine decubitus is carried on as far posterior as possible, separating the muscle from the subcutaneous adipose layer of the back. The use of long retractors is recommended for this maneuver. The importance of this stage is to free the space in which the optical cavity will be generated by direct vision and facilitate the trocars entrance. Three incisions are made for the trocars between the middle and posterior axillary lines. They can be 5 or 10 mm in length depending on the type of trocars that are used (Fig. 12.1).

In Xu's original technique, the first two incisions are made along the anterior axillary line and the remaining one on the posterior axillary line [17]. Due to the curvature of the thorax, it is preferable to locate the upper and lower trocars between the middle and posterior axillary lines in order to avoid technical difficulties with the thoracic curve anatomy.

Wet sponge gauzes are placed on the mastectomy site, and the incision is temporarily closed by a running 4–0 nylon suture and a transparent dressing. The function of the gauze is to prevent the escape of CO_2 and serve as a sponge for the washing performed in the endoscopic time, improving vision by hindering the accumulation of liquid. The patient is then rotated to the lateral or prone decubitus position.

Step 2: LD Endoscopic Dissection

LD endoscopic dissection can be performed with the patient in lateral decubitus or with the patient in the ventral decubitus position, the latter being preferred to allow a more comfortable manipulation of the laparoscopic instruments. Whatever the decubitus chosen, the arm is raised in the swimmer position (Fig. 12.2).

The first surgical maneuver is the placement of the upper trocar where the camera will initially go. Ideally, the dissection performed from the previous plane should allow the entrance of the trocar without major problems. We perform the admission with a transparent trocar that allows direct vision (Fig. 12.3). The CO_2 insufflation (pressure between 8–12 mm Hg) is connected creating an optical cavity, and the second trocar is placed under endoscopic control (Fig. 12.4). If dissection is missing, it can be completed with Metzenbaum-type scissors.

Although 5-mm trocars can be used, we recommend the use of 1- or 1.2-cm trocars, especially in the first cases when the surgeon is still developing experience with the procedure. It is important not to generate tunnels or multiple cavities during the entrance of the trocars. Unlike laparoscopic abdominal surgery, where the creation of the cavity takes virtually no surgical time, in this procedure, it is extremely important and will determine much of the success of the procedure. Once the middle trocar enters under direct vision, the dissection with a 5-mm hook is initiated in the direction of the entrance site of the low trocar, which is also introduced under direct vision. To facilitate the movement with the laparoscopic instruments, we rotate the surgical table laterally between 30 and 45 degrees. By exerting countertraction on

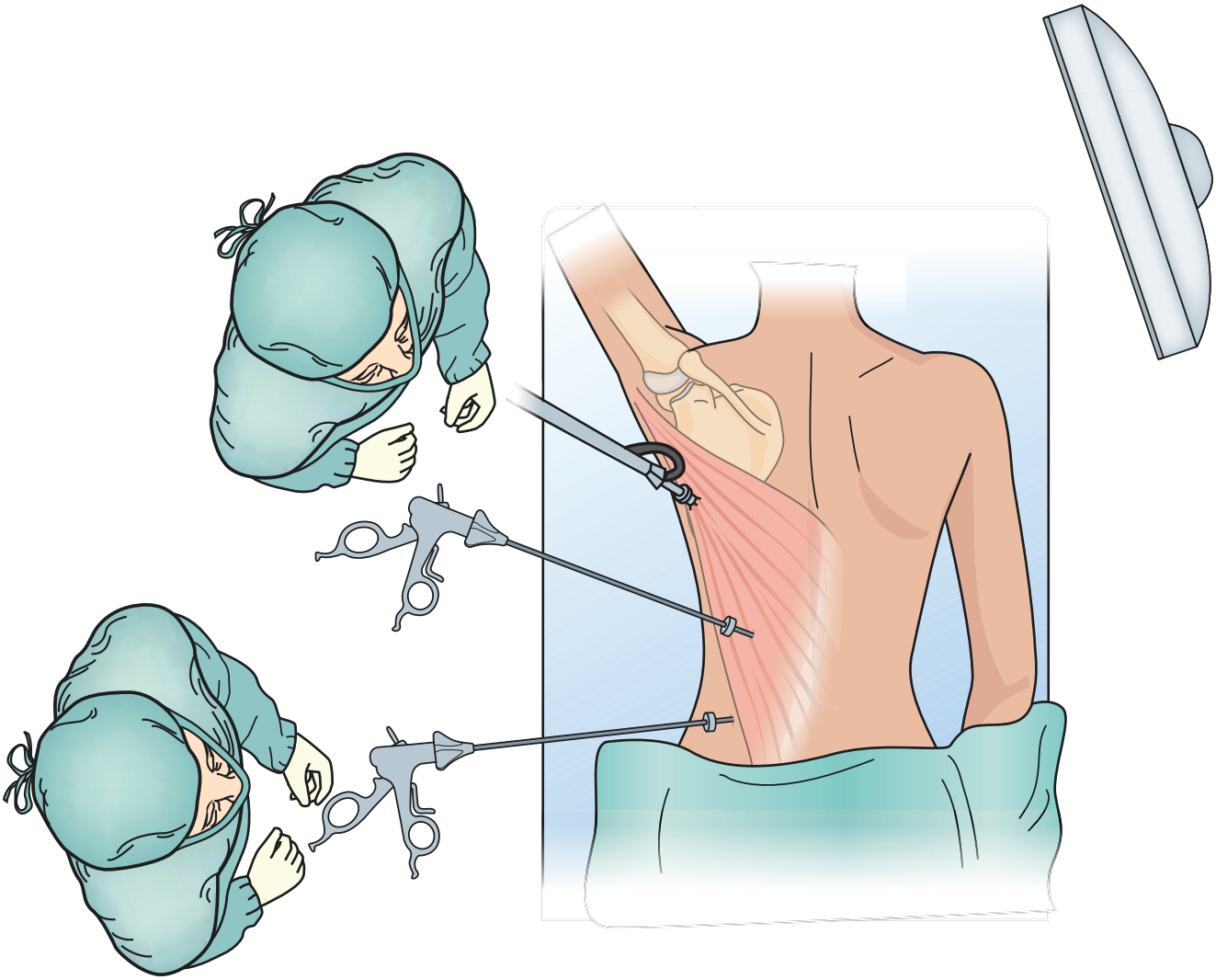

Fig. 12.2 Patient positioning and surgeon and assistant locations

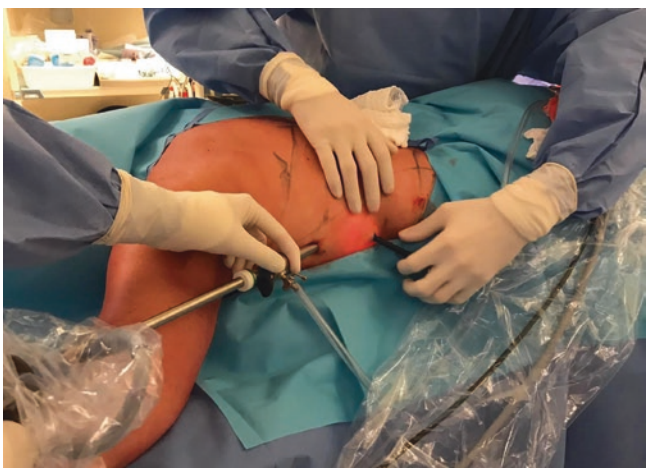

Fig. 12.3 The first maneuver is the placement of the upper trocar where the camera will initially go. The remaining trocars are placed under endoscopic control

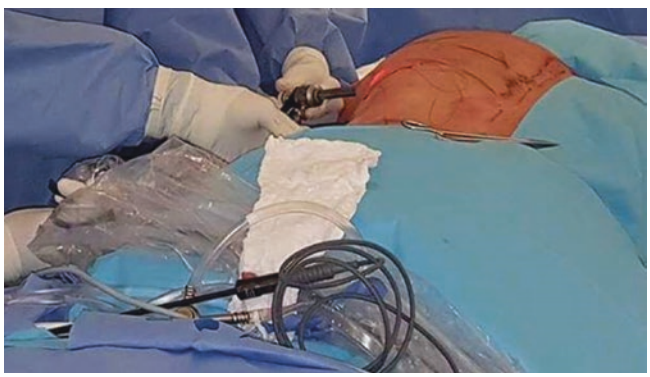

Fig. 12.4 The CO2 insufflation (pressure between 8 and 12 mm Hg) is connected creating the optical cavity

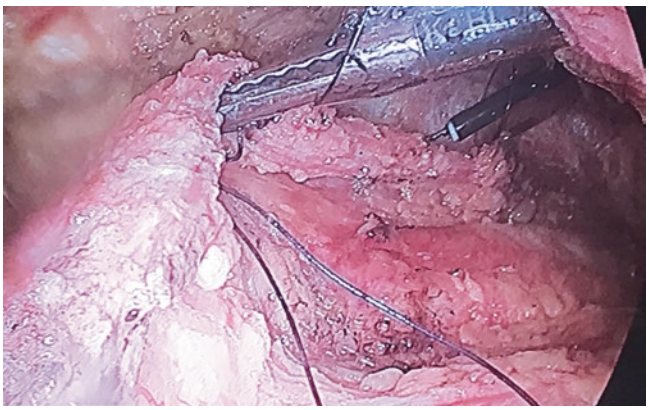

Fig. 12.5 By exerting countertraction on the muscle with a Maryland laparoscopic clamp and by using the hook, dissection of the supra-muscular plane proceeds. A reference suture is placed on the lateral border of the LD to facilitate its identification

the muscle with a Maryland laparoscopic clamp and by using the hook, dissection of the supra-muscular plane proceeds until the thoracolumbar insertion medially and to the tip of the scapula superiorly (Fig. 12.5).

We identified the repair suture we placed initially on the lateral edge of the LDF, and taking it with a laparoscopic clamp, we began to cut the muscle with a high-energy device such as the harmonic scalpel that, in our hands, saves valuable time when cutting and coagulating at the same time. In our experience, we use both ultrasonic and advanced bipolar technology. Ultrasonic technology allows to cauterize vessels of 5–7 mm in diameter and causes less tissue damage and less smoke and improves surgical times compared to conventional bipolar technology [25].

Once we reach the paravertebral level, we separate the posterior plane from the thoracic wall and finally its paravertebral insertions. For this last gesture, we usually change the cutting instrument place to the lower trocar using a high-energy device with an articulated tip that facilitates the maneuver. When reaching the inferior tip of the scapula, we must often cut a poorly defined plane of fusion between the LD insertions and the teres major so that the muscle is only attached to its lateral insertion in the humerus.

Hemostasis control is performed and, if necessary, washing and subsequent aspiration. Trocar removal is performed under direct vision, and the lower incision is used for a drainage. The remaining incisions are temporarily covered with transparent dressings.

Step 3: LDF Inset

The inset of the LDF can be done in the lateral or dorsal decubitus position. The mastectomy incision is opened, and the endoscopically dissected muscle is exteriorized (Fig. 12.6).

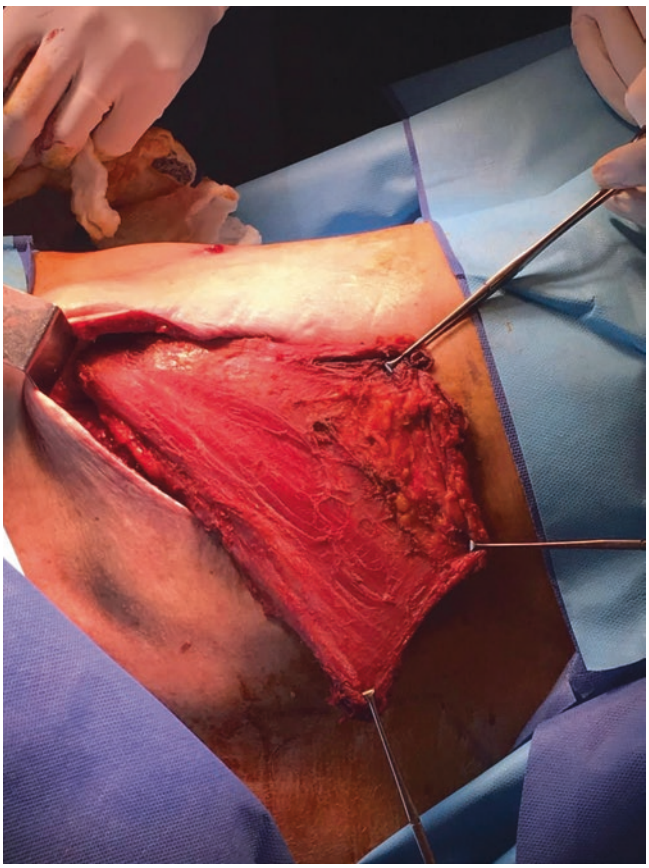

Fig. 12.6 The LDF is exteriorized through the mastectomy incision

If necessary, the dissection can be completed from the previously open approach to optimize full muscle extension and implant coverage. If the pocket is prepectoral and the LDF dimensions allow it, full muscular coverage of the device of the tissue expander can be obtained. This is not usually possible when employing a direct-to-implant approach.

If the pocket is subpectoral, which is our preference, we achieve full muscular coverage by first suturing the LDF to the periphery of the pocket with 2/0 polyglactin sutures and after placing the device to the previously freed inferior border of the pectoralis major. Prior to the placement of the device, the pocket is washed using Adams antibiotic solution and povidone-iodine solution instillations, and a silicone drain is placed and exteriorized through the middle port incision. Once the device is placed, the pectoralis major and the superior border of the LDF are sutured together, closing the full muscular pocket with a 2/0 polyglactin suture, followed by the subcutaneous plane and the deep dermal plane with 4/0 and 5/0 Nylon and the dermal plane with a running suture of 5/0 poliglecaprone. When using a temporary tissue expander, a second stage, usually 4 months later, is required to replace it by a permanent implant as in the classical open technique. A video is available as supplemental digital content, showing the flap harvest.

Postoperative Care

All of these procedures are performed as inpatient procedures. All patients are usually discharged on the next day. This is basically because, by avoiding the long scar on the back through this minimally invasive approach, the pain is considerably lessened and well managed with non-narcotic analgesics. As all surgical wounds and drain exits are covered with adhesive transparent dressings, the patient is allowed to shower on postoperative day 2. Drain output levels are monitored and recorded daily, and once they are less than 25 cc/day over two consecutive days, drains are removed one at a time per site.

The most common complication in breast reconstruction with the LDF is donor site seroma at the harvest site [26]. Seromas are usually treated with prolonged suction drainage or aspiration on an ambulatory basis, if the drain was already removed. The patient is also encouraged to avoid strenuous activity with the upper extremity use during the early postoperative period. To prevent this complication, the use of quilting sutures, a fibrin sealant, or both at the donor site defect at the time of wound closure has been recommended [27]. All of these methods can be potentially applied when using the endoscopic approach, although the use of high-energy devices such as the harmonic scalpel instead of conventional bipolar electrocautery seems to reduce the tisular damage and, theoretically, the risk of seroma, yet clinical studies have failed to confirm this [25].

Additional donor site morbidity includes loss of shoulder mobility and weakness. Although LDF reconstruction does cause impaired shoulder range of motion, strength, and functioning, all of these morbidities generally resolve by 12 postoperative months [28]. A study compared patients in whom the LDF was harvested using the endoscopically assisted technique with patients in whom the traditional technique was used. The results revealed that endoscopically assisted harvest of the latissimus dorsi muscle produced less pain and allowed earlier and better movement of the upper extremity of the donor site and greater overall satisfaction with the procedure, mainly due to the absence of a scar on the back [29].

Clinical Cases

Case 1

In 2010, a 54-year-old patient presented with a history of infiltrating ductal carcinoma of the left breast with positive estrogen receptors. She underwent quadrantectomy; sentinel lymph node biopsy, which was negative; and radiotherapy. In 2017, the patient presented a recurrence with the same histological pattern. In the right breast, there were multiple foci of ductal carcinoma in situ, and a bilateral mastectomy with negative ganglion biopsies was carried out somewhere else. Tissue expanders were placed in both mastectomy sites. Chemotherapy was required due to a high-risk Oncotype score. Postoperatively, she evolved a skin ulceration on the left breast that triggered tissue expander exposure. Device removal was performed, and the reconstruction was deferred.

The use of LDF with endoscopic harvesting was proposed as a reconstructive option since the patient did not have enough tissue (skin and pannus) at the abdominal level. Also, her mastectomy site skin, despite the ulceration, did not show stigmata of severe vascular and trophic compromise (Fig. 12.7a–c).

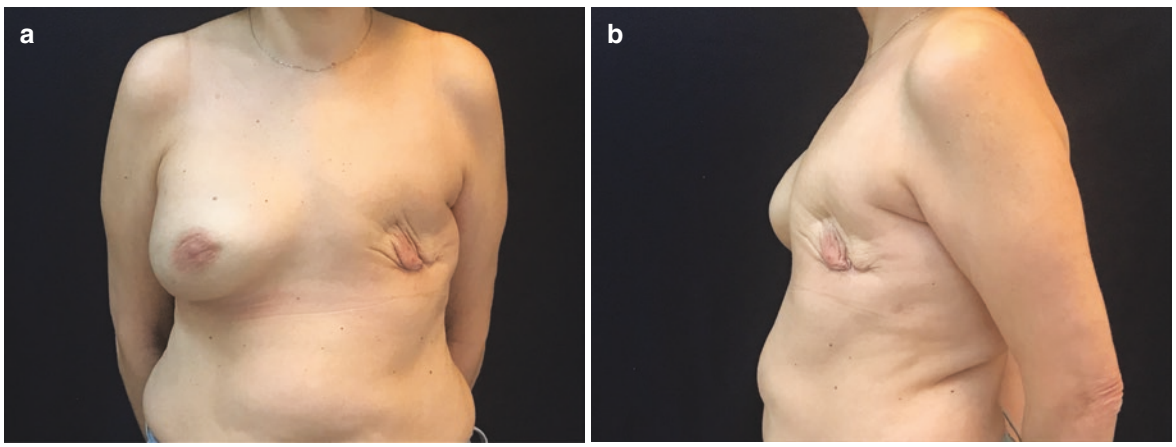

Fig. 12.7 Preoperative views of a 54-year-old female undergoing endoscopic LDF reconstruction after expander exposure and extrusion: (**a**) frontal view, (**b**) lateral view, and (**c**) posterior view. A 350-cc tissue expander was placed and completely expanded at 3 months (**d**). Postoperative views at one-year: (**e**) frontal view, (**f**) lateral view, and (**g**) posterior view

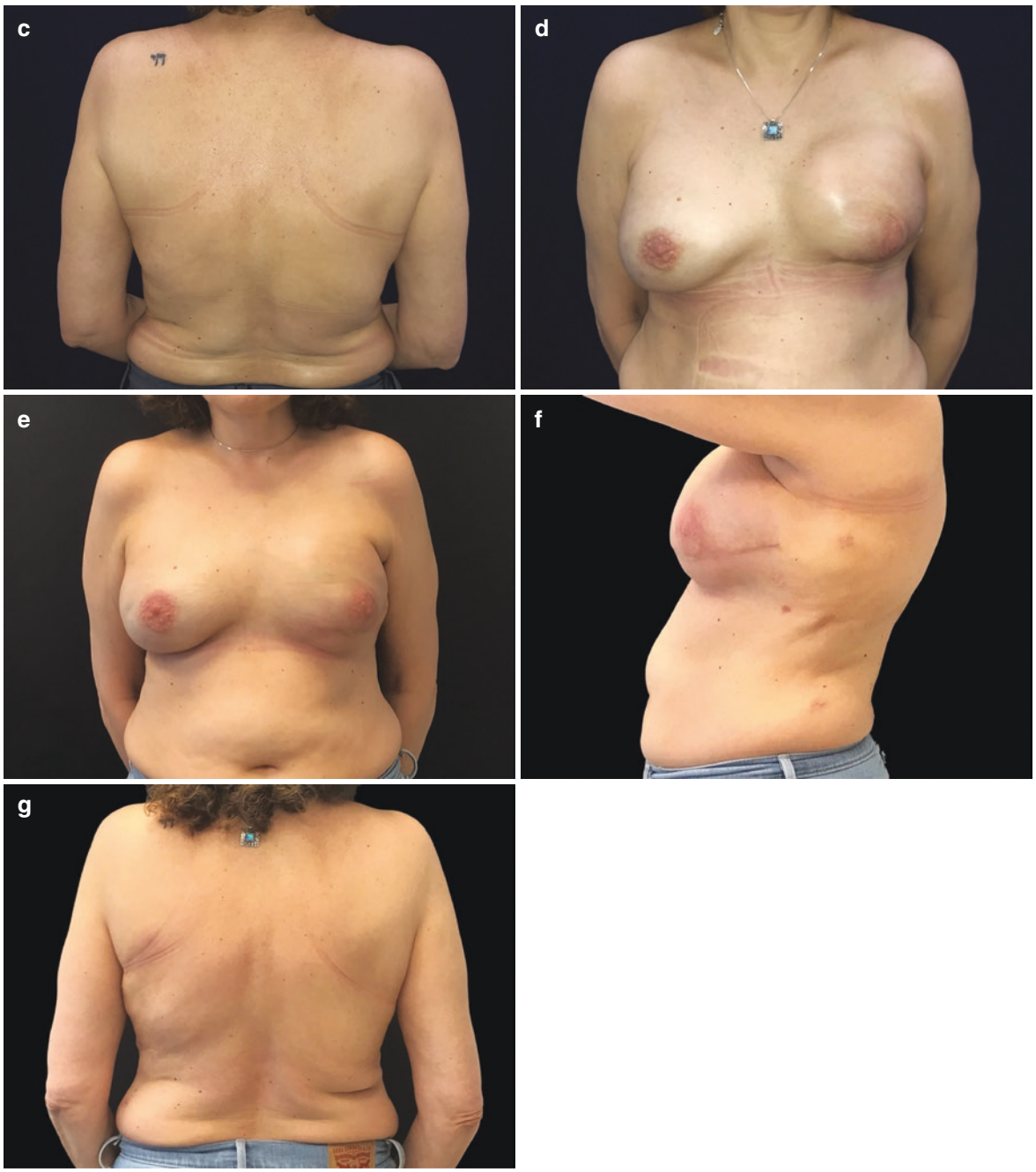

Fig. 12.7 (continued)

The surgery was performed as previously described in this chapter. A 350-cc tissue expander was placed. Postoperative evolution was satisfactory, receiving discharge the following day. Drain removal took place on day 7. On postoperative day 16, a small effusion was detected at the donor site level that we successfully drained by aspiration, obtaining 30 cc of a clear serum. Posteriorly, no further complications were recorded (Fig. 12.7d).

After 4 months, the second stage was performed with the replacement of both tissue expanders for breast implants, placing a 495-cc shaped implant on the left side and a 515-cc shaped implant on the right side. No postoperative

complications were recorded. The result obtained was considered satisfactory for the patient and the team (Fig. 12.7e–g).

Case 2

A 55-year-old patient with a history of infiltrating ductal carcinoma of the left breast presented in 2014. She was treated with mastectomy and axillary lymph node dissection with micrometastasis positive in 3 nodes. A first-stage implant-based breast reconstruction was performed. A 450-cc tissue expander with integrated port was placed, and in a second stage, a 465-cc shaped implant was placed. Symmetrization with a 275-cc textured round breast implant was performed on the contralateral breast. She underwent chemotherapy and breast and axillary radiotherapy.

After three postoperative years, she presented capsular contracture (Fig. 12.8a, b). When offering abdominally based autologous breast reconstruction, the patient refused because she did not want further scarring; an LD with an endoscopic approach was proposed.

The described technique was performed, a shaped 415-cc implant placed, and full muscular coverage was obtained with the latissimus dorsi flap providing well vascularized tissue and reducing the risk of a new capsular contracture. Drains were removed after 10 days. The result was satisfactory, and there were no signs of capsular contracture after a 12-month follow-up (Fig. 12.8c–e).

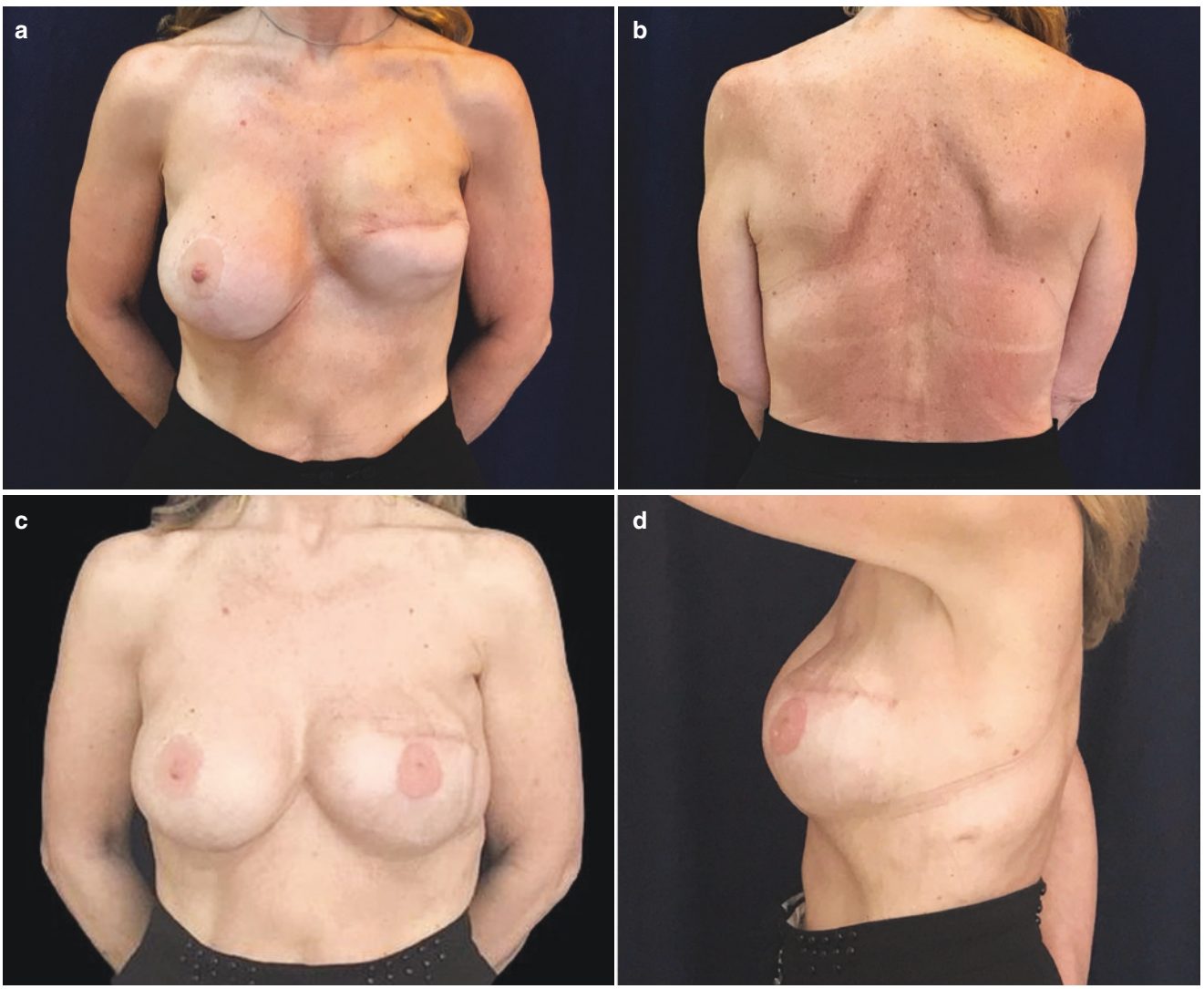

Fig. 12.8 Preoperative views of a 55-year-old female undergoing endoscopic LDF reconstruction after capsular contracture: (**a**) frontal view, (**b**) posterior view. Postoperative views at one-year: (**c**) frontal view, (**d**) lateral view, and (**e**) posterior view

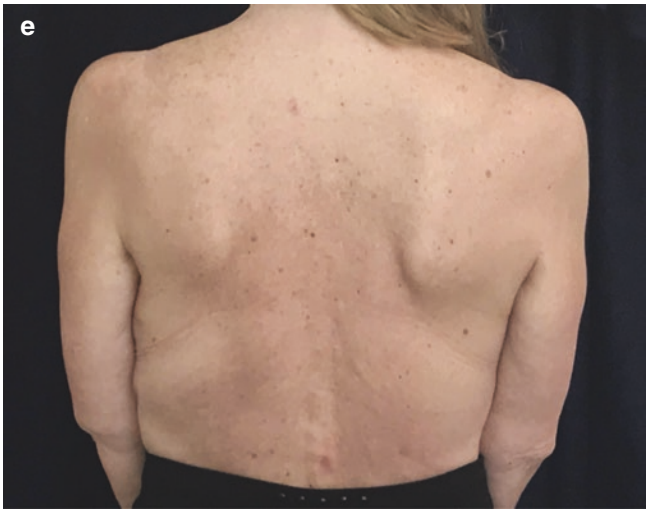

Fig. 12.8 (continued)

Conclusions

Breast reconstruction invariably entails a high expectation for aesthetic results. In this sense, avoiding a large scar on the back is not a minor feat. We should not underestimate the stigmata caused by the scalpel on the skin, as the back is a visible site both in public and private.

To manage and avoid its aesthetic consequences represents a challenge, and it is the plastic surgeon's duty to obtain the muscle with habitual endoscopic instruments. In this sense, the experience obtained during a general surgery residency is extremely important.

The current scenario of breast cancer treatment, with skin-sparing and nipple-sparing mastectomies and advanced radiotherapy techniques providing high-safety procedures make the endoscopic approach to LDF an increasingly attractive option.

It represents an excellent option in patients for salvaging failed implant-based breast reconstructions without having to reach microsurgeries or large abdominal-based reconstruction pedicle flaps. Another point of interest is that it can be used as an immediate, delayed, or delayed-immediate technique as well as for reconstructions of partial defects. Last but not least, the endoscopic approach also provides a valuable training platform for robotically assisted LDF harvesting.

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Breast Reconstruction with the Robotic-Assisted Latissimus Dorsi Harvest

13

Mark W. Clemens and Jesse C. Selber

Introduction

Surgeons have spent the better part of four decades attempting to do more with less, evolving from large open surgical procedures to laparoscopic approaches and now finally to robotic-assisted minimally invasive surgery. Robotic-assisted technology has allowed for significant advances in tumor ablation while minimizing surgical morbidity, essentially freeing physicians from the physical limitations of their own hands. Robotic techniques have been successfully integrated into urology, surgical oncology, gynecology, and thoracic surgery, but plastic surgical indications remain a relatively novel frontier. For two-stage, delayed-immediate reconstruction of the breast, robotic-assisted latissimus dorsi harvest (RALDH) is an excellent option for patients who wish to avoid a traditional latissimus dorsi donor-site incision. RALDH is associated with lower complication rates and reliable results for delayed reconstruction of the irradiated breast and eliminates the need for a donor-site incision. In this chapter, we will review indications for robotic-assisted surgery in breast reconstruction, pertinent anatomy, patient selection, technique, and institutional outcomes.

Radiation therapy is associated with significant deleterious effects on implant-based breast reconstruction such as malposition, capsular contracture, and device extrusion, and therefore the standard of care for reconstruction of the irradiated breast is an autologous tissue [1–3]. Autologous reconstructions should be delayed until after radiation therapy to prevent radiation sequelae such as fat necrosis and tissue fibrosis [4]. Commonly utilized autologous reconstructive options include abdominal-based flaps and the latissimus dorsi muscle flap combined with an implant. Abdominal-based flaps can create a totally autologous reconstruction; however, certain patients may not be surgical candidates due to previous abdominal surgeries, failed free flaps, or a paucity of abdominal tissue, and consequently these patients most benefit from a pedicled latissimus dorsi muscle flap breast reconstruction [5].

A two-stage delayed-immediate protocol has been previously described which allows patients that require external beam radiation therapy (EBRT) to receive a skin-preserving mastectomy while avoiding radiation effects associated with an immediate breast reconstruction [6–8]. For the properly selected patient, delayed-immediate breast reconstruction allows for optimal delivery of radiation therapy while still providing patients with the aesthetic benefits of preserving the mastectomy skin envelope and decreasing the adverse effects of radiation therapy.

Robotic-assisted latissimus dorsi harvest (RALDH) has emerged as an integral part of the delayed-immediate protocol at our institution for patients who have successfully completed EBRT with a tissue expander but are not candidates for abdominal-based flaps [9, 10]. The traditional open technique (TOT) of latissimus dorsi harvest can create an obvious donor-site scar between 15 and 45 cm in length. Endoscopic latissimus dorsi harvest has been previously shown to result in less subjective patient pain and allow for earlier and better movement of the upper extremity of the donor site [11, 12]. RALDH utilizes the da Vinci Robotic Surgical System (Intuitive Surgical Inc., Sunnyvale, CA) (Fig. 13.1) to assist in elevation of the latissimus dorsi flap with improved visualization and surgical dexterity over endoscopic harvest and superior cosmetic advantages over the traditional open technique (TOT) by avoiding a back donor-site incision.

Anatomy

RALDH requires familiarity with the pertinent anatomy of the back, the axilla, and the latissimus dorsi muscle. The latissimus dorsi muscle is the largest muscle in the upper body and is responsible for extension, adduction, transverse extension also known as horizontal abduction, flexion from

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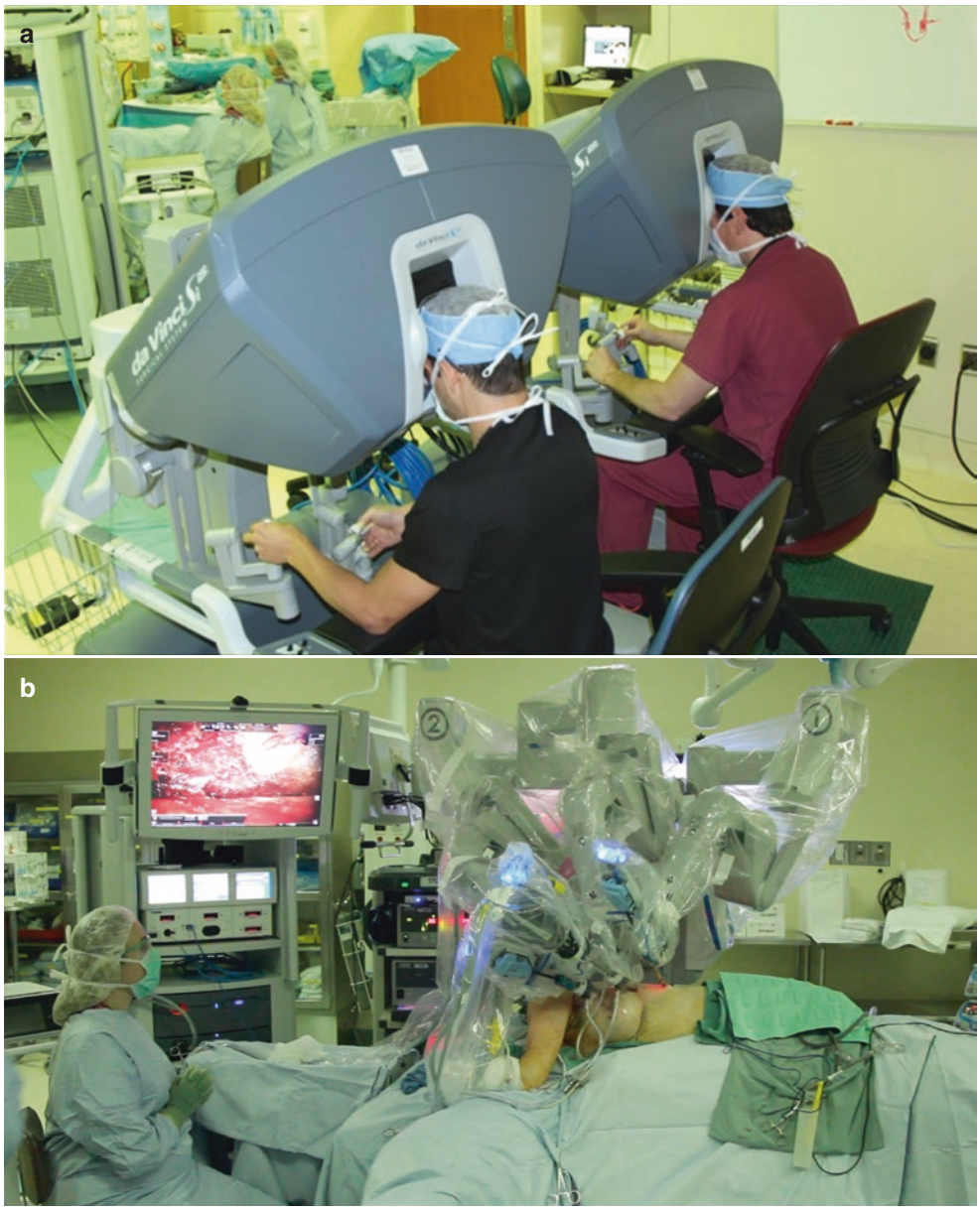

Fig. 13.1 Two da Vinci Robotic Surgical Systems (Intuitive Inc., Sunnyvale, CA) consoles are demonstrated within a large operating room. (**a**) Two systems allow for instructing surgical trainees with swapping of controls back and forth; however, only one system is required to perform the surgery. (**b**) The da Vinci robot docked during latissimus dorsi muscle elevation

an extended position, and (medial) internal rotation of the shoulder joint. The latissimus dorsi muscle derives much of its origin from the thoracolumbar fascia. The latissimus dorsi is innervated by the sixth, seventh, and eighth cervical nerves through the thoracodorsal (long scapular) nerve. The latissimus dorsi muscle has a dual blood supply (type V) from the subscapular artery and the posterior paraspinous perforators. Both circulatory systems are diffusely interconnected so that the muscle can survive in its entirety if either pedicle is interrupted. The dominant thoracodorsal artery is a branch of the subscapular artery.

With a length of 8.5 cm (range of 6.5–12 cm) and approximate diameter of 3 mm (range of 2–4 mm), the thoracodorsal artery courses from the axilla along the anterior border of the latissimus dorsi muscle, enters the muscle from underneath, and spreads into two or three major branches at the undersurface of the muscle.

Patient Selection

Patients most benefiting from breast reconstruction with a RALDH have a low BMI and thin body habitus and are athletic where secondary autologous donor sites may be unavailable for reconstruction of the breast. Previous transection of the thoracodorsal artery or vein during a lymphadenectomy

is an absolute contraindication and should be taken into account during patient selection. Patients with comorbidities such as smoking, diabetes, and collagen vascular diseases will likely have higher complication rates but are only relative contraindications.

Preoperative Planning and Patient Preparation

We perform evaluation of all patients in consultation by a multidisciplinary breast team, which included members of breast oncology, surgical oncology, radiation oncology, and plastic and reconstructive surgery. During surgical stage 1, patients undergo skin-sparing mastectomy and immediate placement of a tissue expander with or without bioprosthetic mesh. Patients are expanded weekly during the 4–6 weeks prior to radiation therapy and then were deflated to 1/3 total fill capacity just prior to initiation of EBRT as per radiation oncology request [13]. Within 1 week of the completion of EBRT, patients are reinflated to original volume. RALDH is performed after 6 months following radiation therapy to allow for soft tissue healing.

The following technical considerations are important for application of RALDH in the delayed-immediate breast reconstruction protocol (Fig. 13.2). Tissue expansion must be sufficient to allow for the desired volume of final implant and muscle flap, which may require additional expansions after the completion of radiation therapy. If additional volume is required, expansion should be continued at a slower rate, at an average of every 2–3 weeks, until the desired volume is met. For unilateral reconstructions, stage 2 may be combined with a contralateral mastopexy or augmentation for symmetry procedure.

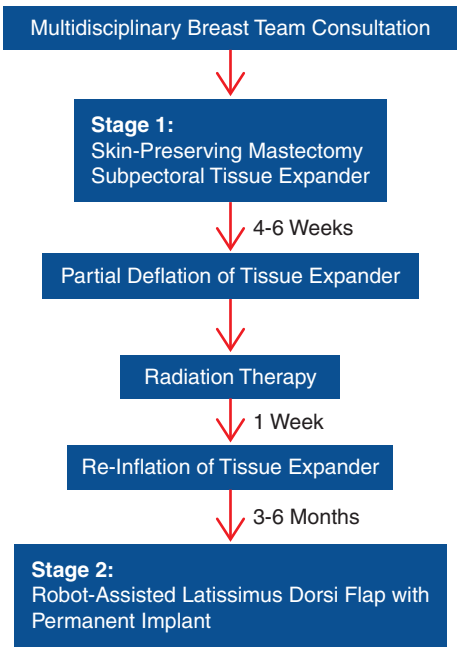

Fig. 13.2 Delayed-immediate breast reconstruction protocol. (Reprinted with permission from Clemens et al. [14])

Surgical Technique

Creation of an Optical Window

Surgery begins with the patient on a bean bag for stabilization in a lateral decubitus positioning. Incision is made through the patient's previous mastectomy skin scar and removal of the tissue expander. The dissection from the breast pocket to the lateral border of the latissimus creates an optical window for the robotic-assisted portion of the procedure. The optical window should extend superiorly up into the axilla and inferiorly approximately 8–10 cm. Dissection continues into the axilla where the lateral border of the latissimus dorsi muscle is identified. Patency of the thoracodorsal artery and vein is confirmed by Doppler evaluation (Fig. 13.3a). Four to six centimeters of dissection is performed on the superficial and deep surface of the latissimus dorsi muscle. The superficial aspect of the muscle should be left in contact with the overlying skin as overdissection allows the muscle to fall down into the field of view during robotic elevation. Therefore, superficial dissection should be limited to 2–3 cm onto the latissimus. Deep dissection is only limited by the reach of the surgeon prior to using the robot. The lateral edge of the latissimus can be resuspended to the overlying skin using full-thickness marionette sutures to assist with the deep dissection, and then they are cut and released when transitioning to the superficial portion of the dissection. Once the thoracodorsal vessel patency has been verified and the deep dissection of the muscle has reached surgical limits, the procedure transitions to robotic-assisted.

Robotic-Assisted Elevation of the Latissimus Dorsi Muscle

Robotic assistance is made utilizing a da Vinci Robotic Surgical System (Intuitive Surgical Inc., Sunnyvale, CA). Robotic harvest technique is performed completely through three access ports/drain sites for robotic instrumentation with no additional incisions required (Figs. 13.3b and 13.4). Ports are placed approximately 1–2 cm lateral to the lateral border of the latissimus dorsi muscle starting from the level of the tip of the scapula and spaced 6 cm apart. A 12-mm camera port is placed centrally and flanked by two 8-mm ports for a monopolar Maryland retractor dissector and an electrocautery scissors. Partially recessing the

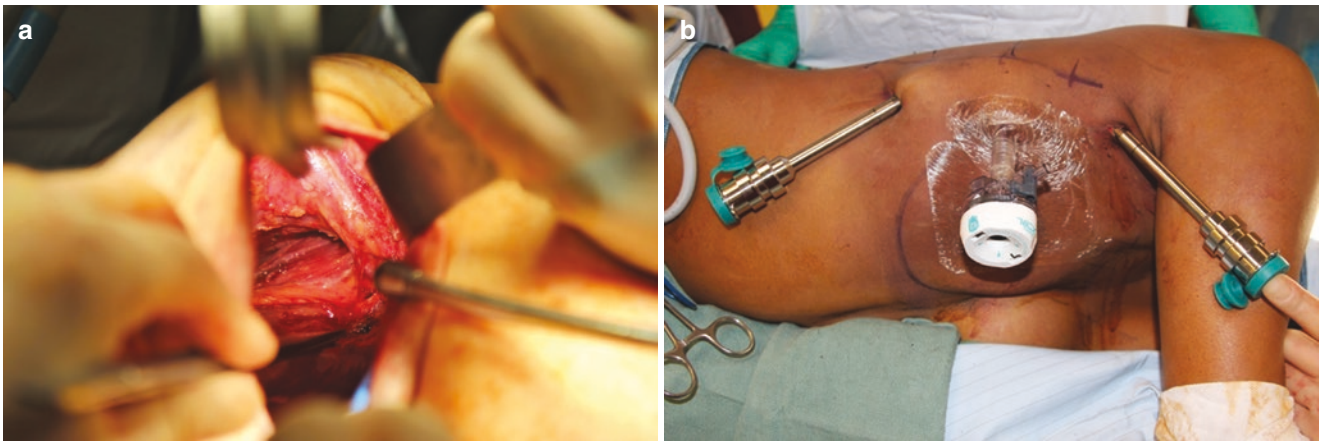

Fig. 13.3 Intraoperative views during RALDH. (**a**) Predissection of latissimus dorsi with exposure of thoracodorsal artery and vein. Note all dissection is accomplished through anterior mastectomy incision with no additional skin incisions required. (**b**) A 12 and two 8 French ports placed at the lateral border of the latissimus dorsi muscle. (Reprinted with permission from Clemens et al. [14])

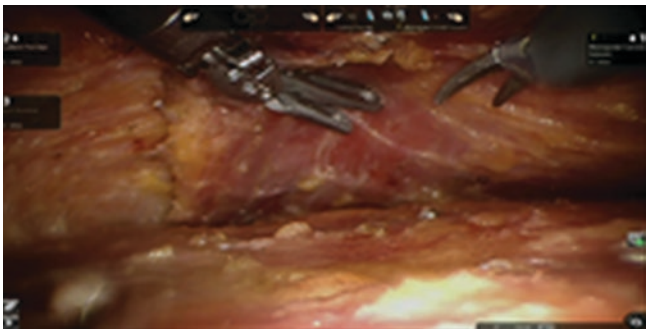

Fig. 13.4 Intraoperative view through the robot with superficial and deep dissection of the latissimus completed with only remaining attachment at the thoracolumbar fascia

central port at 1 cm facilitates visualization of the two arm ports. A smoke evacuator can either be connected to the central camera port or be placed through the mastectomy incision on the patient's chest. Placement of the port arms should always be performed under direct visualization to avoid inadvertent iatrogenic trauma to the rib cage. Once ports are in place, an insufflator is utilized to open the optical window to an average pressure of 10–15 mmHg. Port sights should be checked for air escape and can be patched with Tegaderm plastic adhesive dressing. At this point, the da Vinci robot is docked next to the patient and ports attached to the robotic arms. The surgeon then breaks sterility and transitions to the robotic console. An assistant facile with robotic techniques should remain at the bedside to troubleshoot any issues with the robotic arms. Once the surgeon takes control of the robot, dissection is on the deep surface of the latissimus. Dissection proceeds in a proximal to distal fashion down to the thoracodorsal fascia and medially to the paraspinous fascia. Clear color changes of the red muscle to white fascia help to delineate anatomic boundaries. Once the deep dissection is completed, the arms are transitioned to a superficial position between the muscle and the skin. If marionette sutures were utilized for muscle elevation, they are cut and released at this point. Superficial dissection proceeds to the same anatomic barriers of fascia. Once the superficial and deep dissections are completed, the distal edge of the muscle is released from the thoracolumbar fascia and extending along the paraspinous fascia. Once the latissimus muscle is completely released, the entire pocket should be inspected to ensure hemostasis. The camera and robotic arms are then removed with their ports. All three port sites are utilized for 15 French drain placement. Two drains are placed within the back and one drain brought anteriorly to the breast pocket. At this point, the patient is repositioned into a supine position to complete the breast reconstruction.

Muscle Transposition and Breast Reconstruction

During muscle transposition, the thoracodorsal nerve is left intact, but the humeral insertion of the muscle is partially divided (80%) to allow for advancement of the muscle and to decrease animation deformity (Fig. 13.5a). The pectoralis major muscle that has been providing temporary expander coverage may be fibrosed or constricted from radiation therapy and should not be transected but instead released from the skin envelope and resewn back to the chest wall. Release of the pectoralis muscle from the mastectomy skin flap provides a noncapsular surface for the

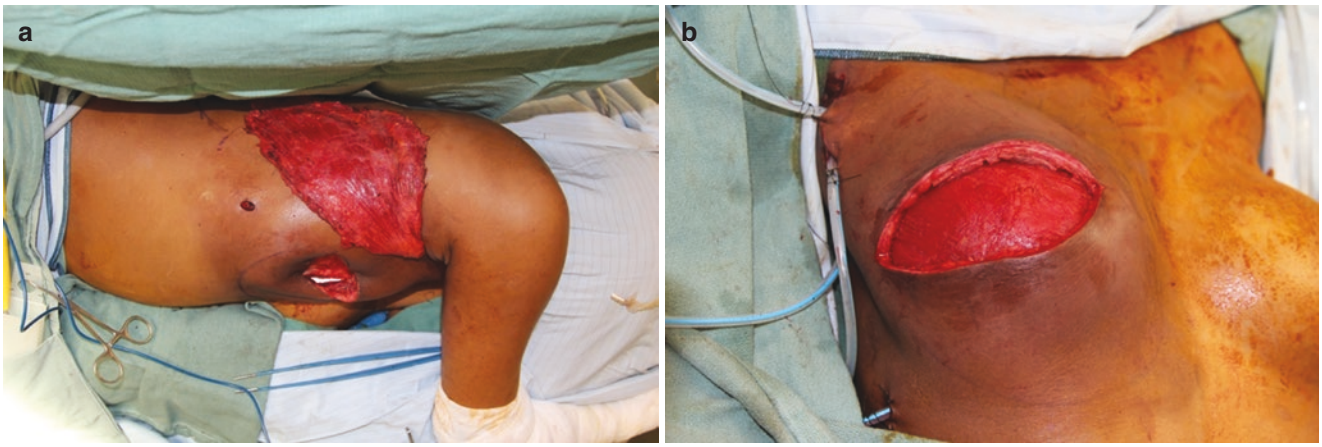

Fig. 13.5 Intraoperative views during RALDH. (**a**) Transposition of latissimus dorsi muscle underneath a subcutaneous skin bridge. (**b**) Latissimus dorsi muscle achieves total muscle coverage over a permanent silicone shaped implant (410 FF 425 cc, Allergan Corporation, Irvine, CA). Note previous port sites are utilized for drain placement. (Reprinted with permission from Clemens et al. [14])

latissimus flap to adhere. The pedicled latissimus dorsi muscle is pulled from the back through the axilla and delivered to the breast pocket. The pocket is then irrigated. Capsulectomy or capsulotomies help to shape the surrounding skin pocket, and then an implant is placed into the pocket. For RALDH opposite a prosthetic reconstruction, the same-sized implant should be used for both breasts. The latissimus dorsi muscle is then sutured in place circumferentially utilizing 3–0 PDS suture. Despite the addition of the latissimus dorsi, the muscle volume becomes negligible with atrophy and the resolution of swelling. Radiation therapy tends to elevate the IMF and required lowering in almost all cases. Care should be taken to attempt total latissimus dorsi muscle coverage of the implant from the inframammary fold (IMF) to the clavicle (Fig. 13.5b). Finally, skin is closed over the muscle in a multilayered fashion.

Postoperative Care

Postoperative care includes deep venous thrombosis prophylaxis with low-molecular-weight heparin initiated on postoperative day one. Hospital course was in general 2–3 days. Routine follow-up included physical examination in an outpatient clinic weekly until drain removal and then at 1 month, every 3 months for 1 year, and annually thereafter.

We performed a retrospective review of a consecutive series of 146 pedicled latissimus dorsi muscle flaps performed for breast reconstruction, of which 17 were performed with da Vinci robotic assistance during the study period (average follow-up of 14.6 ± 7.3 months).

Table 13.1 Patient characteristics and outcomes

Variable	RALDH (N = 12)	TOT (N = 64)
Average age (years)	54.3	56.1
Previous radiation (%)	100	100
BMI	25.4	25.9
Comorbidities (%)	16.6	18.8
Smokers (%)	25	21.9
Stage 1 bioprosthetic mesh (%)	100	71.2
Surg complication (%)	16.7	37.5
Seroma	8.3	8.9
Delayed healing	0	7.8
Infection	14.1	8.3
Unplanned reoperation	8.3	12.5
Capsular contracture	0	4.7
Ave. follow-up (months)	12.3	16.4

Reprinted with permission from Clemens et al. [14]
Abbreviations: RALDH robotic-assisted latissimus dorsi harvest, *TOT* traditional open technique, *BMI* body mass index

Latissimus dorsi breast reconstruction following radiation was performed in 76 patients, of whom 64 (84.2%) are traditional open technique (TOT) patients (average follow-up of 16.4 ± 6.9 months) and 12 (15.8%) are RALDH patients (average follow-up of 12.3 ± 8.3 months) (Table 13.1). All patients received a stage 1 skin-sparing mastectomy with immediate tissue expander reconstruction. Oncologic indications included invasive ductal (85.5%) and invasive lobular carcinoma (14.5%). Patients received an average of 2.8 (range of 0–4) expansions initiated between 1 and 2 weeks postoperatively. Radiation therapy was on average 60 Gy with routine inclusion of internal mammary nodes. Stage 2 reconstruction with latissimus dorsi muscle harvest and placement of a permanent implant was performed at an average of 7.1 months (range of 3–11 months). All pedicled flaps resulted in successful breast reconstructions.

Average time of latissimus dorsi harvest in the TOT technique was 58 min (range of 42 min to 1 h and 38 min) compared to RALDH harvest at 1 h and 32 min (range of 1 h and 5 min to 2 h and 35 min). Average length of hospital stay of the TOT technique was 3.4 days (range of 3–6 days) compared to RALDH harvest at 2.7 days (range of 2–3 days).

Surgical complication rates were statistically equivalent: 37.5% TOT versus 16.7% RALDH (p = 0.31) which included seroma (10.9% vs. 8.3%), infection (14.1 vs. 8.3%), wound healing (7.8% vs. 0), and capsular contracture (4.7% vs. 0). No RALDH muscle flaps required converting to an open technique, and all flaps resulted in successful breast reconstructions. Formal muscle strength testing was not performed.

Clinical Case

Delayed-Immediate Reconstruction of an Irradiated Breast Using a RALDH

A 42-year-old female was diagnosed with invasive ductal carcinoma of the right breast with positive lymph node metastasis. She was treated with bilateral mastectomies, right axillary dissection, and immediate reconstruction using tissue expanders (133MX 400 cc, Allergan Corporation, Irvine, CA) followed by external beam radiation therapy (EBRT, 60 Gy) to the right chest wall (Fig. 13.6). At 6 months, she received breast reconstruction with a RALDH over a round silicone implant, and her postoperative course was without any complications or need for revision (Fig. 13.7).

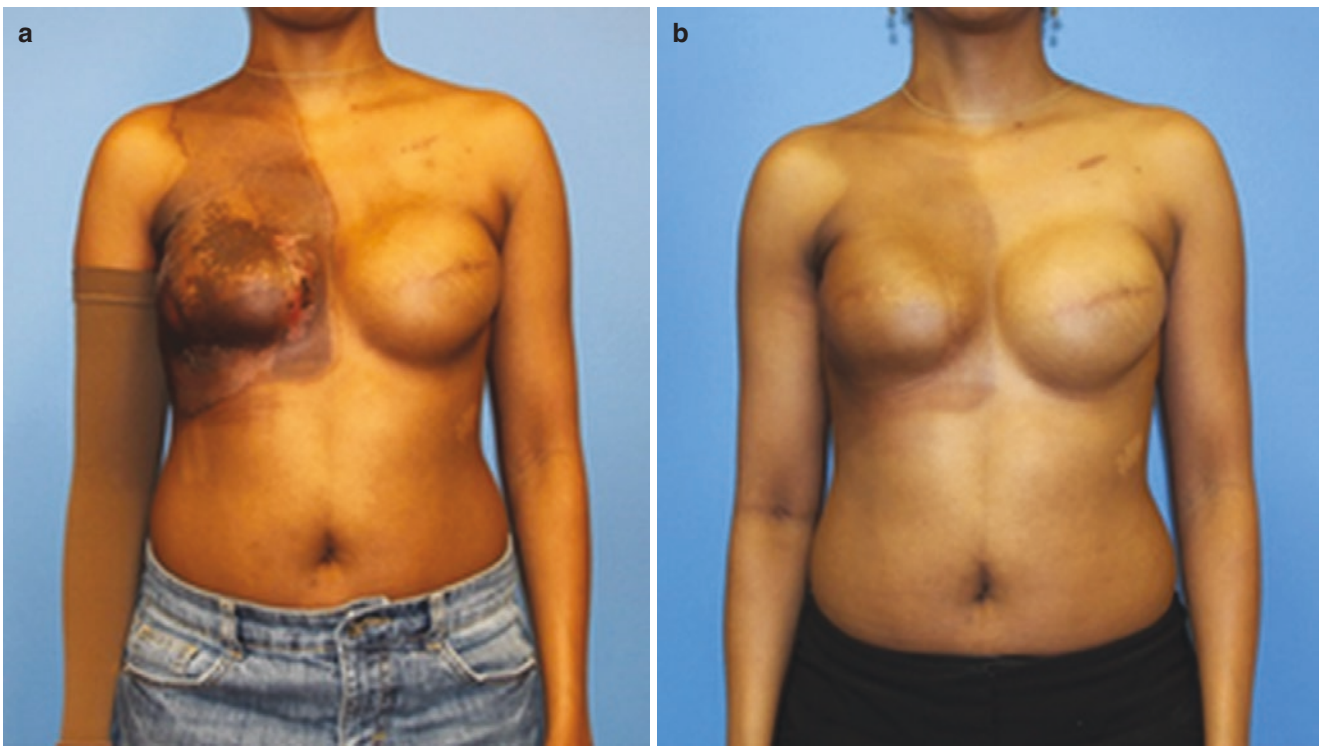

Fig. 13.6 Case example. Delayed-immediate reconstruction of an irradiated breast using a robotic-assisted latissimus dorsi harvest (RALDH). Preoperative views: (**a**) immediately and (**b**) 6 months following radiation therapy. Note radiation-induced constriction and elevation of the right inframammary fold, which must be corrected. (Reprinted with permission from Clemens et al. [14])

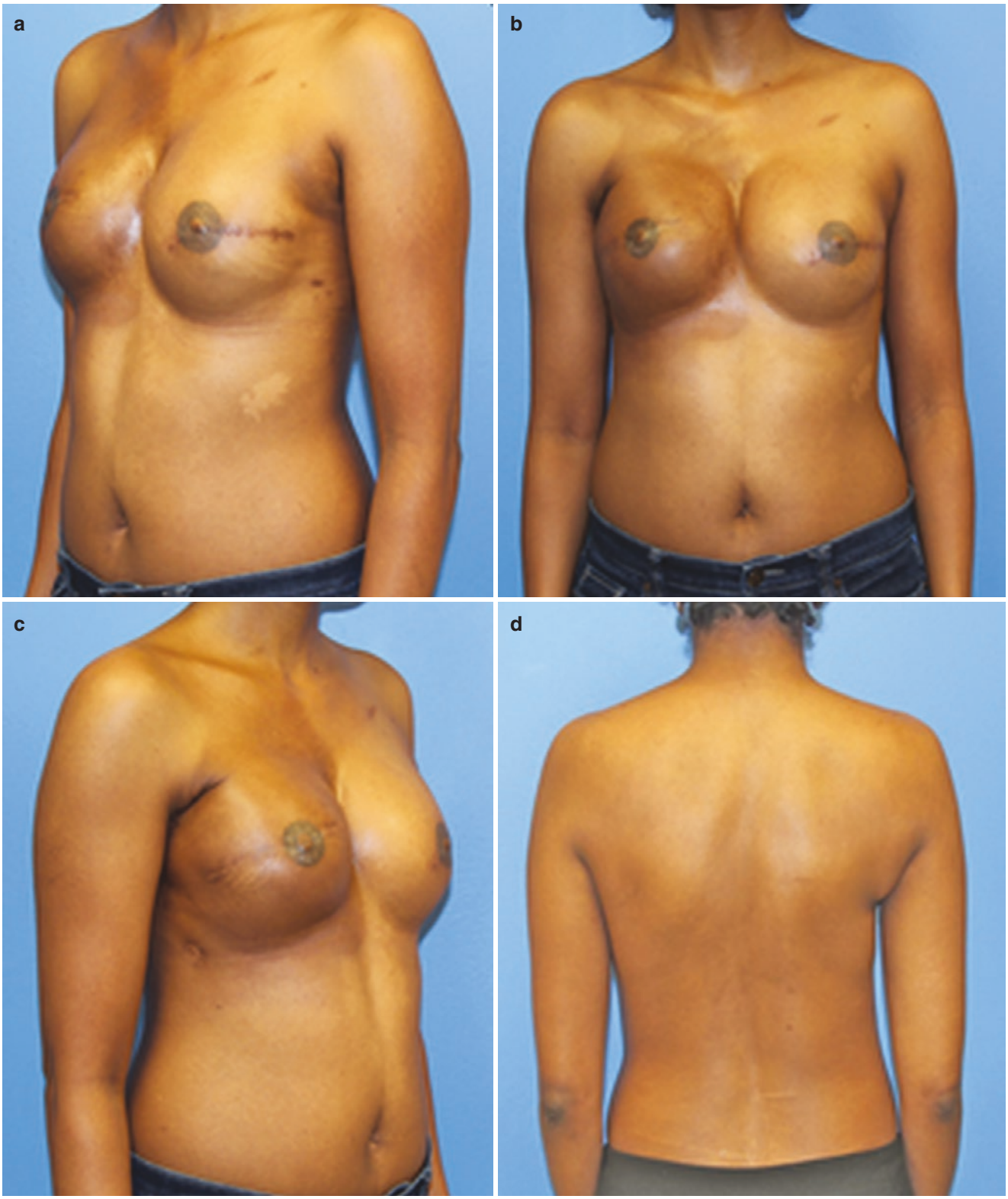

Fig. 13.7 (**a**–**c**) Postoperative results: Patient is 10 months postoperative and has now received nipple construction with areolar tattoing. Patient was noted to have a minor contour defect of her donor site. Her postoperative course was without complication. (Reprinted with permission from Clemens et al. [14])

Conclusions

Robotic-assisted surgical techniques have applications in reconstructive surgery of the breast for select patients. The surgical robot is a valuable additional instrument for the reconstructive surgeon's toolkit when approaching challenging cases. Patients most suited for these techniques such as two-stage delayed-immediate breast reconstructions are low-BMI patients where primary autologous options may be unavailable. Robotic-assisted latissimus dorsi harvest has demonstrated less incisions and scars, faster recovery, and improved complication profile, all with modest tradeoffs in cost and operative time. We are confident that plastic surgery indications for the surgical robot will continue to expand, and this technology will become an essential component in the armamentarium of the reconstructive surgeon.

Conflict of Interest None of the authors have any relevant financial relationships or affiliations to disclose.

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Total Breast Reconstruction Using the Thoracodorsal Artery Perforator Flap TDAP

14

Fabio Santanelli di Pompeo and Michail Sorotos

Introduction

Tansini described, 100 years ago, the latissimus dorsi muscle or musculocutaneous flap [1]. It quickly became a workhorse flap for reconstruction of various defects by providing vascularized muscle, fat, and skin [2]. It can be also used alone with additional fat or with an implant to provide an adequate breast size [3]. Although technically reliable and safe, the consequences of harvesting such a large muscle are not negligible. Donor-site seroma is a commonly described postoperative complication of the latissimus dorsi flap, and together with aesthetic contour defects of the dorsal donor area and pain, shoulder function disturbances may discourage its use [4–8]. The thoracodorsal artery perforator flap (TDAP) was first described by Angrigiani et al. as a free flap for postburn cervical resurfacing [9] and later by Hamdi et al. as a pedicled flap for breast reconstruction [10]. The TDAP is a perforator flap based on the perforators that originate from the thoracodorsal pedicle. It offers a well-vascularized skin paddle that can be harvested in several dimensions. Raising the flap without sacrificing the muscle or the nerve is essential, and by sparing the muscle and motor nerve, no dead space is left eliminating almost completely seroma formation, and minor muscle scarring is produced significantly decreasing functional morbidity. The TDAP flap may be used pedicled or free. The indications for the free TDAP flap are multiple. It has been described as a coverage option for head and neck, trunk, and extremity reconstruction, especially when a thin flap is with a long pedicle and there is low donor-site morbidity. One of the great advantages of the free TDAP flap lies in the versatility of tissue options provided by the thoracodorsal system. Compound flaps can be created with a split of latissimus dorsi muscle, serratus anterior muscle, thoracodorsal fascia, scapular and parascapular skin flaps, and scapular bone. It may also be thinned for resurfacing extensive superficial defects. As a pedicled flap its main indications are restricted only by the arc of rotation and may include breast, upper extremity, axillary, and chest wall reconstruction. Many of the patients traditionally treated with the pedicled latissimus dorsi musculocutaneous flap are suitable for pedicled perforator flaps. Breast surgery is one of the areas where the pedicled TDAP has important applications, and its indications include partial breast reconstruction, whether immediately or delayed after breast-conserving surgery (tumorectomy and radiotherapy), thoracic coverage after radical excision, salvage procedure after failure of other methods of breast reconstruction, postmastectomy breast reconstruction in combination with implant, and autogenous breast augmentation. Although an expander or implant can be safely placed under a thoracodorsal artery perforator flap, the surgeon has to apply some technical tricks to avoid compromising the perforators. Moreover, use of an implant can potentially result in complications from infection; capsular contracture; implant migration or malpositioning, especially in the setting of radiation therapy; and the connection with breast implant-associated anaplastic large-cell lymphoma that are the main disadvantages of using implants [11–15]. Nevertheless, in selected cases, the TDAP can offer total autologous breast reconstruction without the need of an implant [16].

Anatomy

The latissimus dorsi is a thin fan-shaped muscle that originates from the anterior surface of the last three ribs, from the posterior and lateral margin of the iliac crest, from the thoraco-lumbar fascia, and from the last six thoracic and lumbar vertebrae. It inserts in the medial margin of the bicipital groove of the humerus. It is almost completely subcutaneous

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except in its supero-medial portion where it is covered by the trapezius and in its distal insertion where it is covered by the teres major. The subscapular artery, 4 cm after its origin from the third portion of the axillary artery, splits into the circumflex scapular artery and the thoracodorsal artery. The latter, after giving off a constant branch to the serratus anterior muscle, penetrates, at about 8–10 cm from the axillary artery, the deep surface of the latissimus dorsi muscle 2 cm posteriorly to its anterior margin, and divides into the descending or vertical branch and the horizontal branch. These branches give several perforators to the skin of the back. Secondary pedicles by the posterior intercostal arteries and lumbar arteries are also present. Anatomical studies on cadavers have shown that the vertical intramuscular branch provides two to three cutaneous perforators. The proximal perforator pierces the muscle and enters the subcutaneous tissue approximately 8 cm below the axilla in the posterior axillary line and 2–3 cm posterior to the lateral border of the muscle and is oriented obliquely as it passes from the deep to the superficial. The second perforator originates 2–4 cm distal to the origin of the first perforator. The first and second perforators are found consistently in most people. However, our clinical experience with the TDAP free flap showed that the direct perforator of TD may be found to arise at the anterior border of the LD muscle passing into the skin in some cases. In other words, the perforator sometimes does not pierce the LD muscle, which makes the dissection much easier and quicker [16, 17].

Patient Selection

The TDAP flap offers an alternative for patients in whom abdomen-based flaps are high-risk or unavailable options or even more as a primary option in patients with small to medium breast size. The TDAP flap can be applied both for immediate and delayed reconstruction and in cases of radiotherapy. It is contraindicated in patients with large breasts. Furthermore, thin patients with large breast defects may not be suited to perforator flap due to a lack of sufficient flap volume. Defects located in the inferomedial quadrant of the breast are difficult to reach using a pedicled TDAP flap and may be better corrected by other techniques. Damage to the thoracodorsal pedicle due to previous axillary or thoracic surgery is an absolute contraindication to raising a TDAP flap, as it is for the traditional latissimus dorsi flap. The advantages of this technique include a total autologous breast reconstruction, minimally invasive technique, good aesthetic results, low complication rates, and low-cost surgery. The disadvantages include the learning curve for the dissection technique and the preoperative planning.

Preoperative Planning and Patient Preparation

The week before the operation, the patient is advised to avoid any contact with persons that have a cold or any other infectious disease. Aspirin or other blood thinners should be avoided since they will reduce the capacity of blood to coagulate and thus could provoke excessive bleeding and the formation of hematomas. In addition, ideally the operation should not take place during menstruation. All patients should receive a thorough clinical exam, standard laboratory exams, an X-ray of the thorax, and an ECG preoperatively. Moreover, it is necessary to perform a breast surgery visit and a radiological examination of the breast, by ultrasound of the breast and/or mammography and magnetic resonance imaging (MRI), to study breast cancer status in case of immediate breast reconstruction and breast cancer recurrence in case of delayed reconstruction. Right before the anesthesia, the measurements and surgical planning of the patient are performed, an important part of the preparation of the patient for surgery, which will be used during the operation as a guide. Markings, drawn in upright position, include standard anatomical landmarks such as jugular notch, sternal midline, inframammary fold, breast limits, and bra strap area. In case of immediate reconstruction, the surgical planning commences with the breast surgeon that indicates type of mastectomy and necessity of skin and nipple-areola complex resection. For all types of mastectomy (nipple-sparing mastectomy, skin-sparing mastectomy, or modified radical mastectomy), the skin paddle planning comprises the largest transverse skin paddle (approximately 10–12 cm wide) taking into consideration an easy closure of the donor site with low risk of seroma formation [18] and the hiding of the scar under the bra strap line. Based on type of mastectomy, the area to be deepithelialized is also marked. In case of delayed reconstruction, the skin area needed to be integrated is calculated by measuring the dimensions of the contralateral breast. The patient is positioned in lateral decubitus with the shoulder in 90° abduction and the elbow in 90° flexion. In this position the anterior border of the latissimus dorsi muscle is palpated through the skin and marked. A 5–8 MHz Doppler probe allows accurate location of the perforators in the posterior axillary line, 8 cm below the axillary crease and within 5 cm from the anterior border of the latissimus dorsi muscle (Fig. 14.1). Subsequently, the skin island is designed to include the audible perforators and can be oriented in different directions depending on the reconstructive needs. The flap paddle is better oriented to fit into the skin lines and parallel to the rib direction, which provides the best inclusion of the angiosome territory according to Taylor. In

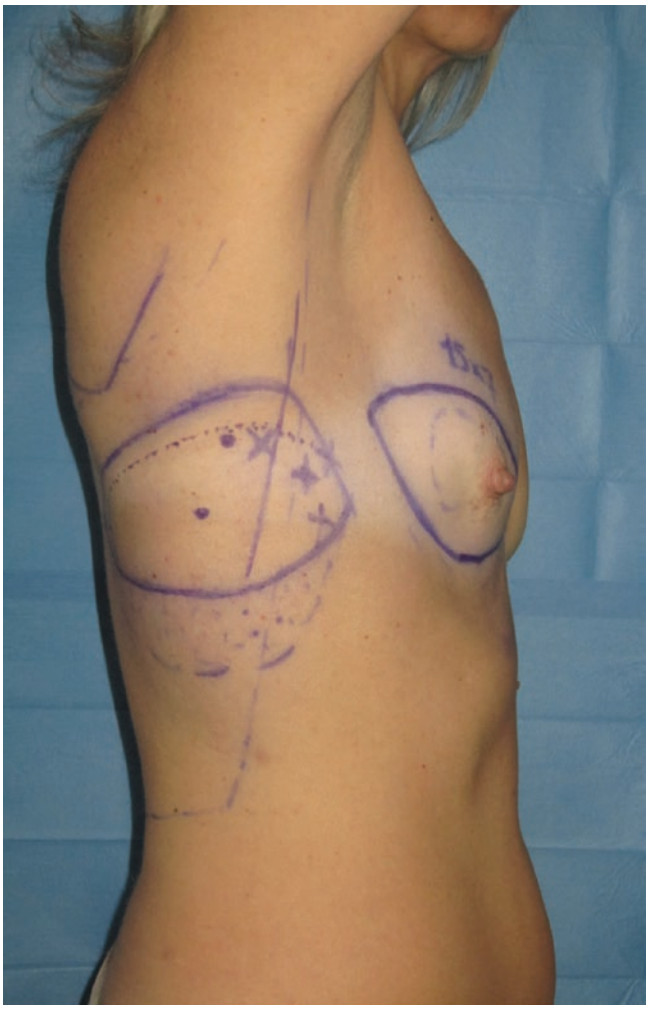

Fig. 14.1 Preoperative planning with mastectomy and flap markings together with perforators

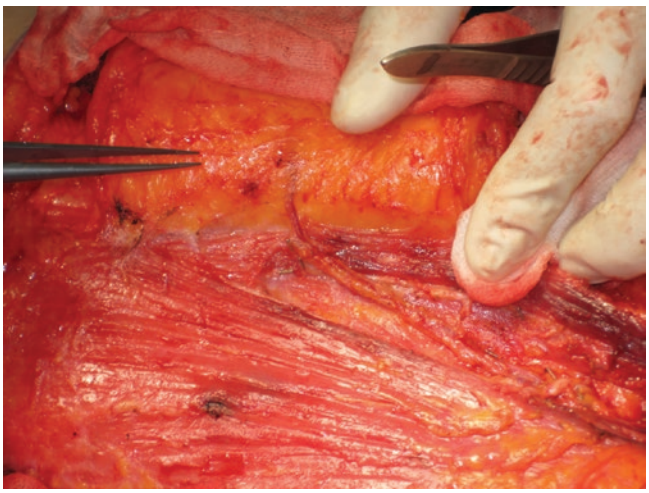

Fig. 14.2 Intraoperative suitable perforator identification

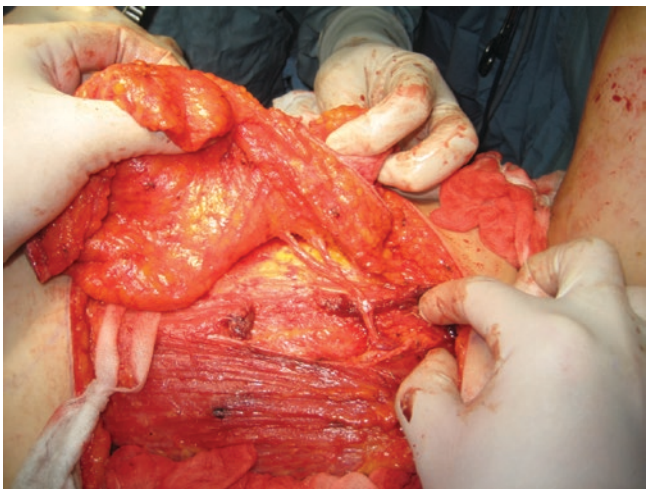

Fig. 14.3 The perforator is followed through its intramuscular course

the female patient, it is better to design the flap horizontally in the skin line in order to obtain a better scar hidden by the brassier. The extent of the skin flap is mainly limited by the possibility of primary closure and skin paddles of 14 by 25 cm have been used without problems. The perforator flap should always extend over the anterior border of the latissimus dorsi muscle to include any premuscular perforators that may be present.

Surgical Technique

Mastectomy and flap harvesting are carried out at the same time with a two-team approach with the patient in the lateral position. The incision starts at the inferior anterior border of the flap, which allows for identification of the anterior border of the latissimus dorsi muscle and eventual repositioning of the anterior border of the flap. The dissection proceeds from distal to proximal and from medial to lateral at the level just above the latissimus dorsi muscle fascia until a suitable perforator is identified. A perforator originating from the vertical branch is preferred because dissection is easier due to fewer connections with other vessels and a shorter intramuscular course (Fig. 14.2). If two perforators lie along the same line, both can be incorporated within the flap without cutting additional muscle. Once a suitable perforator is identified, intramuscular dissection is rather straightforward. The muscle is split longitudinally and the perforator dissected cranially (Figs. 14.3 and 14.4). The next step is to free the anterior border of the latissimus dorsi muscle and look underneath. Total pedicle length depends on the location of the perforator on the muscle, as the length of the intramuscular course

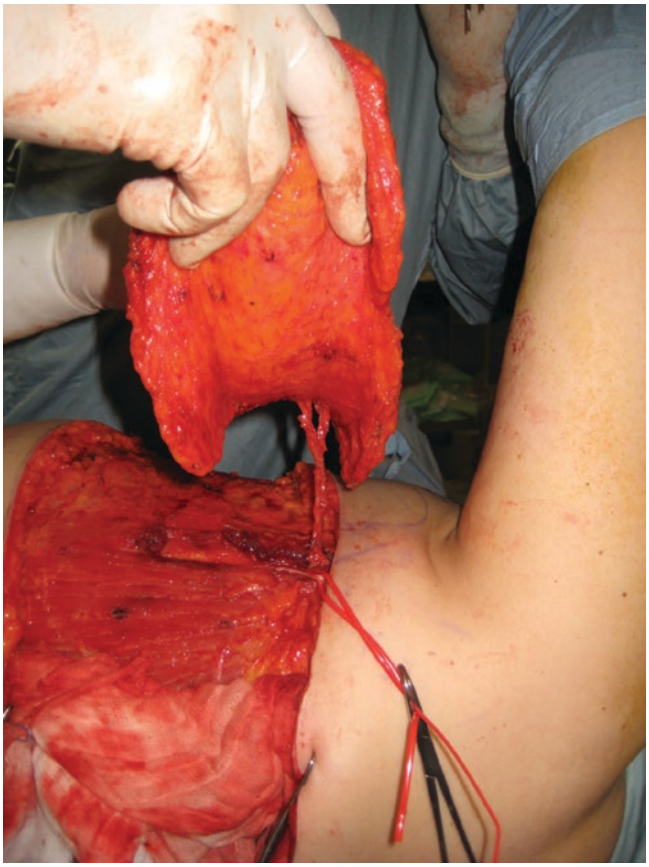

Fig. 14.4 Flap harvesting completed and ready to be transposed (Request from PRS https://doi.org/10.1097/01.prs.0000436843.15494.ad)

adds up with the length of the oblique course on top of the muscle and the length of the thoracodorsal pedicle itself. This usually allows for a pedicle length of 14–18 cm. The motor nerves to the latissimus dorsi run on a deeper plane, which allows for completely freeing of the pedicle without injuring the nerves. The skin paddle is then rotated anteriorly, through the split latissimus dorsi muscle, into the breast area under the skin bridge between the axilla and the thoracic region. The flap is rotated 180 degrees and is fixed at the inner axillary line first laterally and then attached to the pectoral major muscle by a few fixations. The skin flap is deepithelialized, leaving only a paddle of skin to replace the resected skin of the breast. The flap is completely deepithelialized in the case of nipple-sparing mastectomies, saving a small skin paddle for flap monitoring. Ultimately, the anterior border of the latissimus dorsi muscle is sutured back into its original position, closed suction drains are placed, and donor site is closed primarily in three layers after further undermining to allow minimal tension to close the skin. The donor site is left with drains. The flap on a vascular pedicle with an average length of 14 cm can be transposed to the breast defect, possibly raised to 25 cm if the flap is based on a distal perforator. In addition, additional volume of flaps can be added by the addition of additional subcutaneous tissue. When it is planned to include more subcutaneous tissue in the flap, it is recommended that two or more perforators be included to maximize blood supply. Furthermore, the use of fat grafting in autologous vascular matrix has become a very useful and reliable technique in the forming of secondary breast, improving contour, shape, and volume. While harvesting a thoracodorsal perforator flap requires meticulous dissection of the perforator, with careful preoperative planning, the procedure becomes more predictable. The key point of the procedure is perforator mapping. The flap can be converted into a muscle-sparing latissimus dorsi flap if suitable perforators are not available. It has been proposed to use color duplex flowmetry or multidetector row computed tomography to facilitate the dissection of reliable perforators while decreasing the likelihood of missing vessels. As a result, the precise location of thoracodorsal perforators has a high impact on the ability to harvest a thoracodorsal perforator flap safely and quickly. The thoracodorsal artery perforator flap spares the latissimus dorsi muscle, which results in less donor-site morbidity, shoulder function preservation, lower incidence of seroma formation, and no need for transcutaneous needle aspiration. In addition, its pedicle length allows for total autologous breast reconstruction without micro-vascular technique. Complications are not frequent and include the following: bleeding is very rare (0.5%), but can present only during the first 12 h after the operation and does not depend on the ability of the surgeon; in such a case, it will be necessary to return to the operating room for a 30–60-min operation in order to identify the bleeding vessel. This complication, if it is managed well, will not provoke other inconveniences and it will not prolong the hospital stay. Infection, thanks to antibiotics, is very rare, but if present, can be managed by adapting the antibiotic therapy. At the donor area (dorsum), the resulting linear scar will be greater than the elliptical cutaneous island that is transferred, but it can be hidden under the bra or bikini strap. Instead, in the breast region, despite the efforts to hide the resulting scars, some of them will be more visible according to the type of the mastectomy chosen. Finally, the quality of the scars cannot be predicted and will depend on the personal healing characteristics of the patient.

Postoperative Care

Right after the operation, the patient must stay for 30 min in the observation room, where she is controlled by the anesthesiologists before she can be permitted to return to her room. General anesthesia can have certain adverse effects such as vomiting and chills, and the patient can drink and eat the morning after surgery. It is necessary to remain in bed until the morning after. The patient receives antibiotics to prevent any infectious complications and analgesics for pain control. Usually during the third postoperative day, the patient is discharged and can return at home with appropriate treatment and indications for dressing change. The first postoperative control is performed after 3–5 days. It is only after the removal of the suction drains that the patient can have a shower. The sutures are partially removed after 1 week and completely after 2 weeks. Work and social activities should be suspended for 20 days after the operation. If the work of the patient is such to demand an increase in physical activity (raising weights, etc.), a longer period of abstinence is necessary. The patient can return to her daily physical activities only after the first 10 days postoperatively. Driving is allowed 1 month after surgery and sporting activities 2 months after surgery with caution.

Clinical Cases

Case 1

This case involves a 54-year-old woman with left-sided breast cancer. The general surgeons proposed a nipple-sparing mastectomy, and a reconstruction with the TDAP flap was chosen. The TDAP flap was chosen because the patient already had right-sided breast reconstruction with the DIEP flap. The flap's dimensions were 39 × 14 cm and it was raised on two perforators and transposed to the breast region to reconstruct the mastectomy defect (Fig. 14.5). Healing was uneventful (Fig. 14.6). No further surgery was required.

Case 2

This case involves a 55-year-old woman with right-sided breast cancer. Indication for nipple-sparing mastectomy was given, and a TDAP flap was chosen due to patient's will to avoid abdominal scar. TDAP flap's dimensions were 25 × 9 cm and the flap was on one perforator. The patient received an additional surgery of 60 ml of fat grafting for aesthetic refinements (Figs. 14.7 and 14.8).

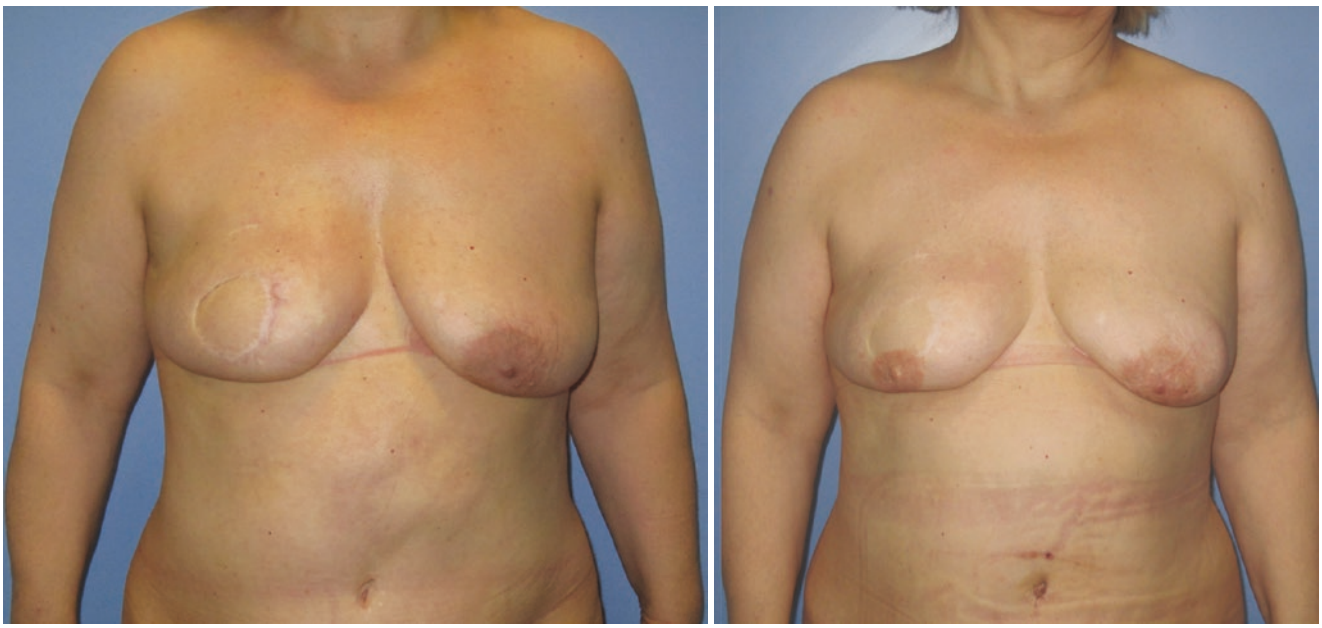

Fig. 14.5 Preoperative (left) and final postoperative (right) frontal view (Request from PRS https://doi.org/10.1097/01.prs.0000436843.15494.ad)

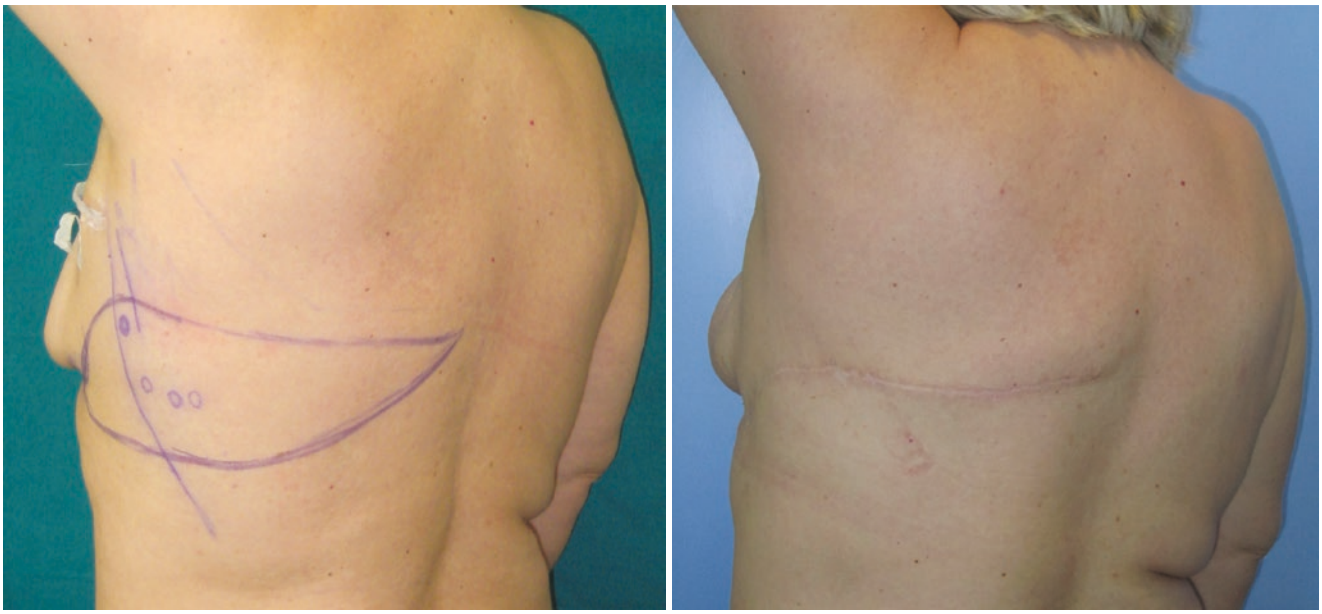

Fig. 14.6 Preoperative planning (left) and postoperative scar result (right)

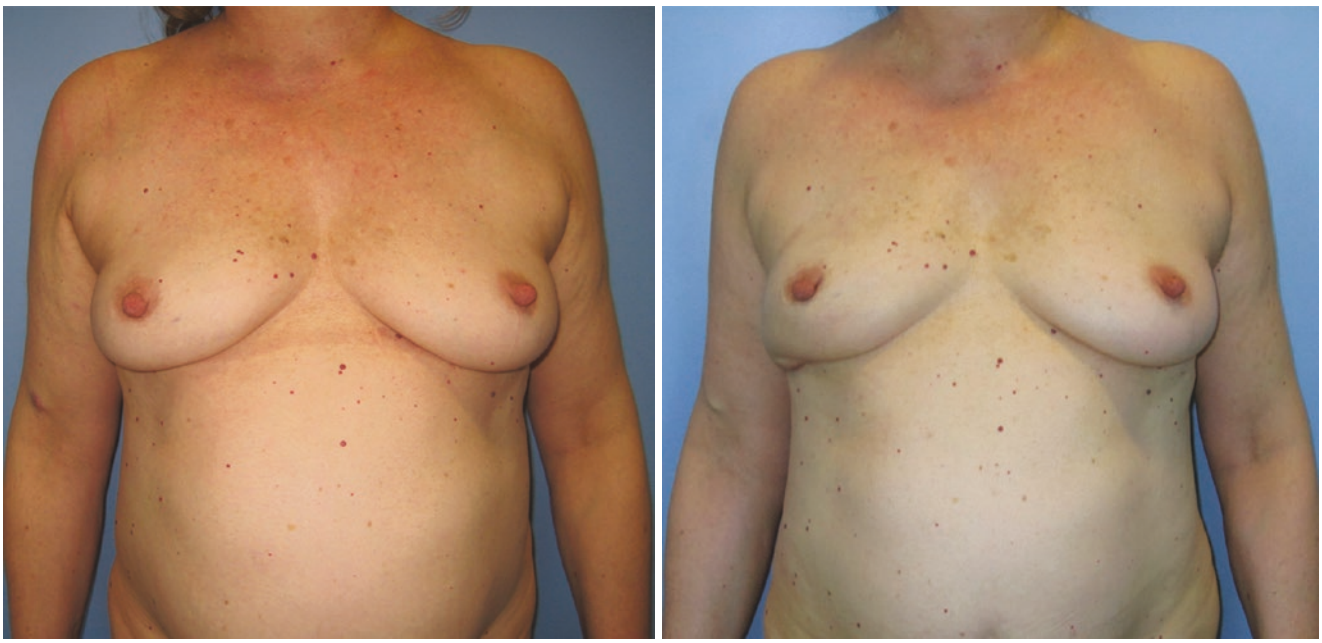

Fig. 14.7 Preoperative (left) and final postoperative (right) frontal view

Case 3

This case involves a 43-year-old woman with right-sided breast cancer and indication for radical mastectomy. Patient had a small-sized breast and, because of no abdominal donor area, the TDAP flap was preferred. TDAP flap was 15 × 7 cm and raised on three perforators. The patient healed uneventfully (Fig. 14.9). The patient is currently listed for NAC reconstruction and tattoo (Fig. 14.10).

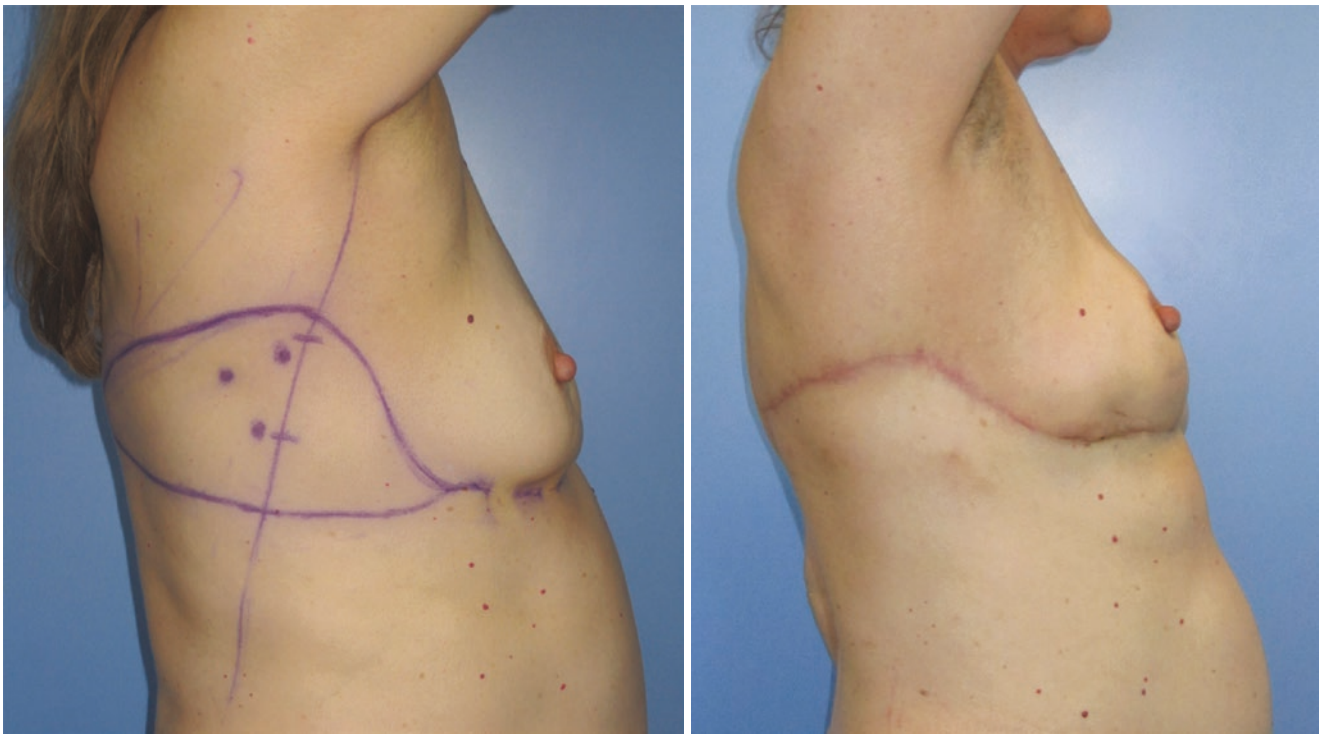

Fig. 14.8 Preoperative planning (left) and postoperative scar result (right)

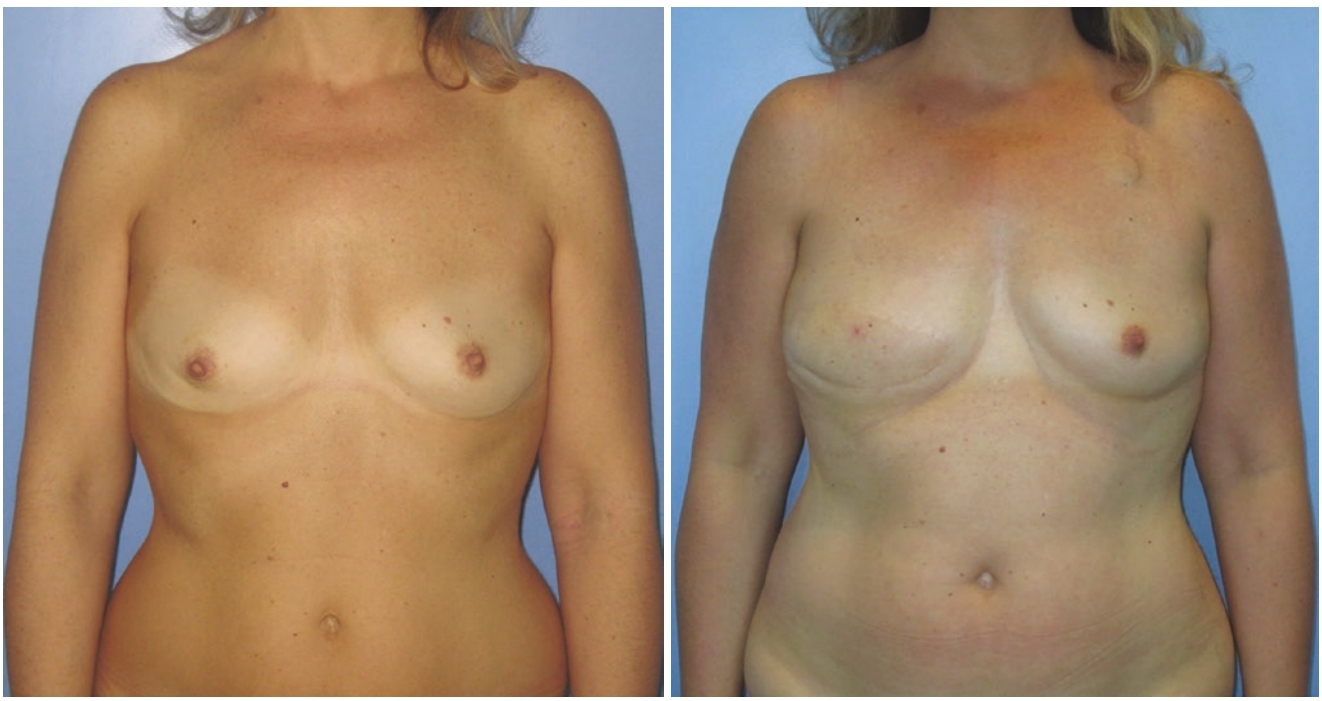

Fig. 14.9 Preoperative (left) and final postoperative (right) frontal view

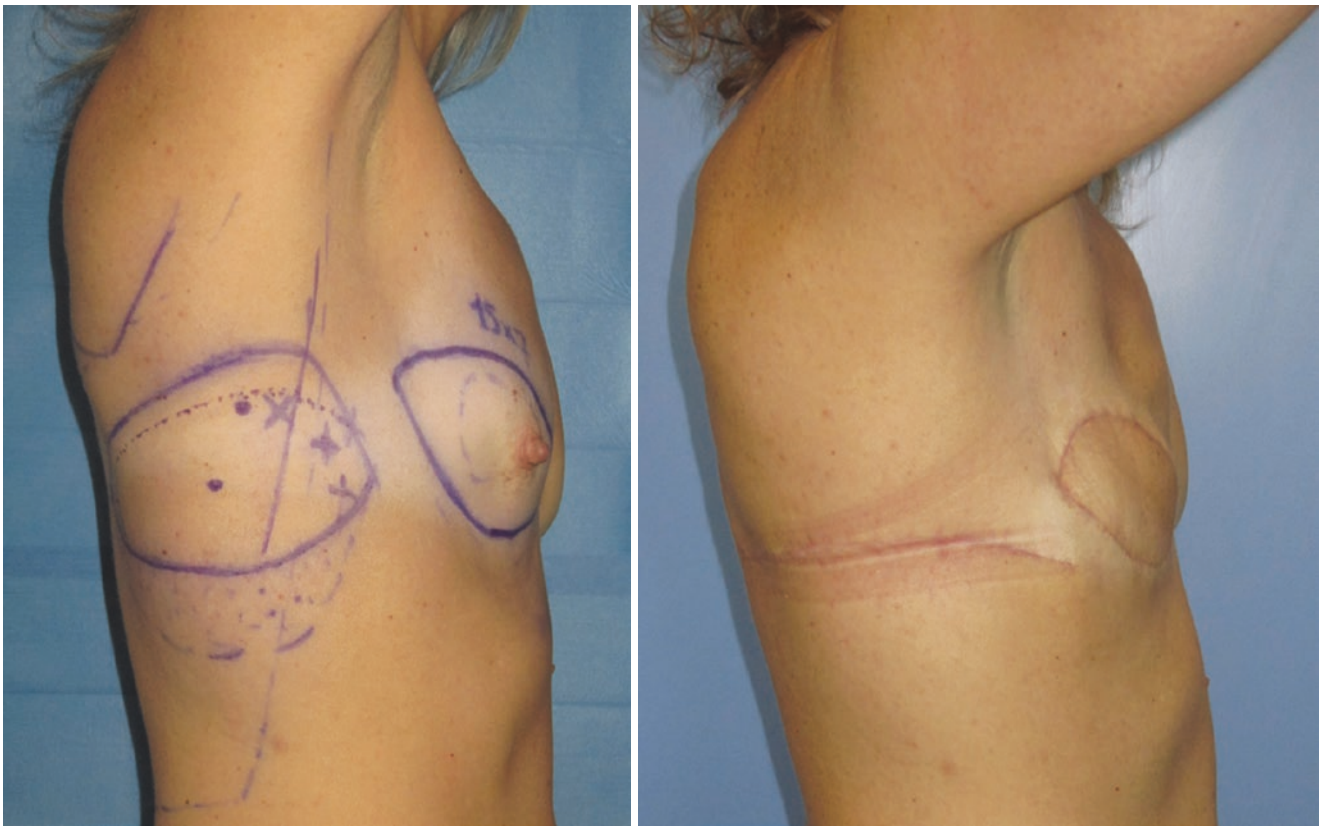

Fig. 14.10 Preoperative planning (left) and postoperative scar result (right)

Conclusions

The TDAP flap is a primary option for total autologous breast reconstruction in patients with small to medium breasts who do not have abdominal tissues or are reluctant to microsurgical reconstructions. As a secondary procedure, autologous fat grafting may be required to maximize the reconstructed breast's shape, contour, and volume.

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Breast Reconstruction Using the Muscle Sparing Lattisimus Dorsi Flap with Alloplastic Devices

15

Kenneth L. Fan, Hatcher G. Cox, Cara K. Black, James Economides, and David H. Song

Introduction

The subscapular artery system is the reconstructive warehouse of the back. The thoracodorsal artery, a branch of the subscapular artery, provides pedicled flaps with a wide range of applications, including breast reconstruction [1], upper extremity and trunk reconstruction [2], and physiologic lymphedema operations [3] (Fig. 15.1). With microvascular anastomosis, it can provide a myocutaneous free flap [4] or a chimeric flap for bony and cutaneous defects [5]. Traditionally, the latissimus dorsi (LD) muscle flap has been utilized extensively in breast reconstruction. However, 39% of patients report moderate weakness and significant difficulty with vigorous activities of daily living following harvest of the entire latissimus for breast reconstruction [6]. Activities affected include reaching over head, lifting groceries, and swimming [6]. While the teres major is critical in compensating for LD loss [7–9], dynamic shoulder function tests demonstrate significant long-term differences in both muscle power and endurance of shoulder extension and adduction [10]. The concerns of donor site morbidity, seroma, and weakness of the upper extremity led to the introduction of muscle sparing options.

The thoracodorsal artery perforator (TDAP) flap was first introduced by Angrigiani et al. in 1995 to reduce donor site morbidity associated with full LD flap harvest [1, 11]. Schwabegger in 2003 described a vertically oriented muscle sparing latissimus dorsi (MS-LD) flap based on the descending branch of the TD artery to protect perforating vessels and reduce partial flap loss, while maintaining muscle function [12]. Hamdi et al. championed the transverse MS-LD or TDAP, when available, flaps for oncoplastic reconstructions [13]. Saint-Cyr in a series of studies described the vascular reliability of the pedicled MS-LD [1, 14, 15].

Within breast reconstruction, the MS-LD flap can be used for partial mastectomy defects [13], postmastectomy coverage of expanders/implants [1], or revisionary procedures. Some authors prefer to use a full LD flap in the setting of preoperative irradiation for increased vascularized tissue [1]. Previously, the senior author demonstrated the noninferiority of the MS-LD/TDAP flap to enhance outcomes of alloplastic breast reconstruction in the setting of preoperative irradiation by comparing it to full LD harvest [16]. Patients either failed initial reconstruction, had contour abnormalities after reconstruction, or had no reconstruction. Similar to that described by Hamdi et al. [13], a TDAP was performed if a >1 mm, palpable perforator was identified. Alternatively, an MS-LD flap with a small cuff of muscle is maintained around the perforator to prevent injury if distinct perforators are not readily identifiable. There was no statistically significant difference in any complication, including implant loss, wound break down, seroma, or capsular contracture between LD and MS-LD/TDAP groups.

In the evolution of the senior author's practice, the MS-LD with a thin strip of muscle has supplanted the TDAP flap due to low rates of partial flap necrosis as a result of muscle protecting the vessels. When considering donor site morbidity, the MS-LD based on the descending branch of the thoracodorsal artery has been found to have no significant difference in function and strength compared to the nonoperated side after 2 months [12]. No statistical significance was observed between operated and nonoperated sides on dynamic shoulder function tests or disabilities of the arm, shoulder, and hand (DASH) scores [1]. Compared with the total LD flap, the MS-LD flap has significantly less rates of donor seroma and functional limitations [17]. The ease of harvest [18], low morbidity [1, 17], reliable anatomy [14, 15], and ample soft tissue makes the MS-LD flap a valuable addition for any plastic surgeon's armamentarium.

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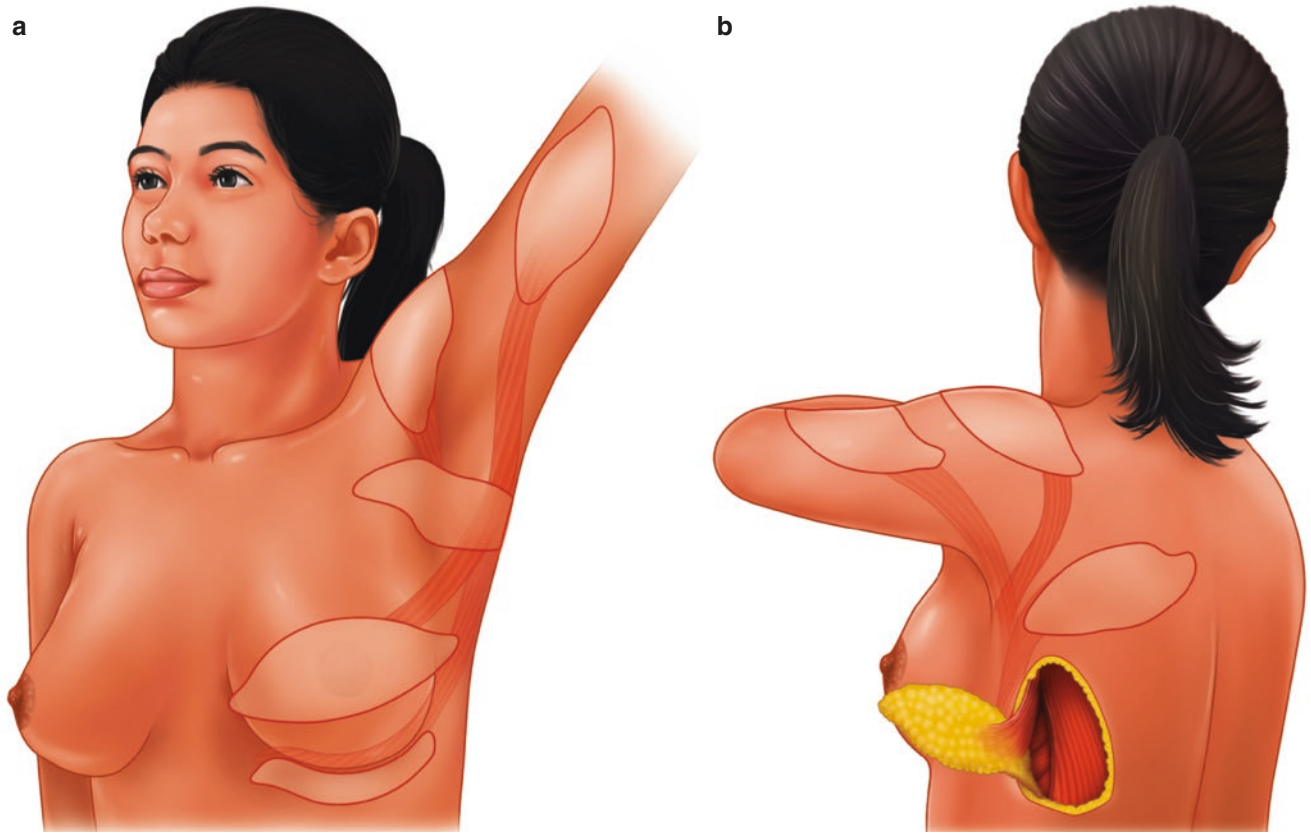

Fig. 15.1 (**a**, **b**) The pedicled MS-LD has several applications in breast reconstruction, upper extremity and trunk reconstruction, and upper extremity lymphedema

Anatomy

Muscle Anatomy and Function

The latissimus dorsi (LD) muscle is broad and flat, originating from the thoracodorsal fascia attached to the posterior rim of the iliac crest, and from aponeurotic attachments to spinous processes of the sacrum through T7, it extends across the back to its attachment on the humerus. It is a superficial back muscle and is only partially covered superiorly by the trapezius toward the spinous process. The wide base gradually converges as the muscle courses superolaterally toward its attachment on the humerus, creating a triangular shape. As it converges to a tendinous band, the muscle twists 180 degrees and wraps from the medial aspect of the humerus to its anterior attachment within the intertubercular groove. This course allows the muscle to internally rotate, adduct, and extend the humerus at the shoulder. Pulling the humerus posteriorly behind the back is a unique function of the latissimus dorsi.

Although the literature is conflicting, loss of the LD is not without consequence. Most of the literature agrees that function returns to baseline after about 1 year, which is in large part due to compensation of the teres major [19, 20]. Furthermore, range of shoulder flexion and abduction appear to return to baseline at about 12 months postoperatively [21]. However, it has been shown that absence of the LD is most pronounced during vigorous activities of daily living (e.g., chores that involve reaching overhead, shoveling, vacuuming, and lifting groceries) and sports that involve humeral extension (e.g., golf, tennis, and skiing) [10, 19].

The muscle-sparing latissimus dorsi flap, introduced in 2003 by Schwabegger, involves harvesting a small cuff of LD surrounding a thoracodorsal perforator to the overlying skin while leaving the rest of the LD in place. The thoracodorsal nerve is separated from the thoracodorsal vascular bundle in order to spare LD function. Schwabegger found strength of humeral extension of the operative side and nonoperative side to be the same at 2 months postoperatively

[12]. Kim et al. performed a retrospective comparison of the donor site morbidity between the MS-LD flap and the traditional extended latissimus dorsi flap and found that active range of motion was significantly less affected in the muscle sparing group [17]. Saint Cyr et al. in an analysis found no statistical difference in strength or shoulder motion of the joint when comparing the operated with an MS-LD to the nonoperated side [1]. All patients returned to work 22 days after surgery, with low disability levels on the disabilities of the arm, shoulder, and hand questionnaire.

Blood Supply

The thoracodorsal artery, the main blood supply to the MS-LD/TDAP flap, is a branch of the subscapular system, the largest branch of the axillary artery. The subscapular arises from the third portion of the axillary artery at the lower portion of the subscapularis muscle, and 4 cm from its origin gives off two branches: the scapular circumflex artery, which travels posteriorly to supply the scapular and parascapular flaps, and the thoracodorsal artery. The axillary artery and subscapular artery are on average 7.9 cm and 3.9 cm, respectively, from the thoracodorsal bifurcation [14]. From the thoracodorsal bifurcation, the descending branch and transverse branch run for a total length of 9.6 cm and 7.4 cm, respectively.

The thoracodorsal artery enters the deep surface of the muscle in the posterior axilla 10 cm inferior to the muscle insertion of the humerus [22]. The thoracodorsal artery then bifurcates into the transverse and descending branches approximately 5.1 cm from the posterior axillary fold, at a mean of 2.2 cm from the lateral edge of the LD [1]. Saint-Cyr found at 5, 10, 15 cm from the posterior axillary fold, the descending branch was on average 2.0, 2.4, and 2.9 cm from the lateral edge of the LD muscle, respectively [1]. Therefore, harvesting 3–4 cm strip of muscle surrounding the descending branch and corresponding perforators protects the vessel and perforators (Fig. 15.2) [18].

In anatomical dissections, Saint-Cyr et al. found an average of 3.6 musculocutaneous perforators >0.5 mm in each flap, 70% (average 2.5) of all perforators originate from the descending branch, and 30% (average 1.1) of the perforators originate from the transverse branch [15]. There were no perforators from the transverse branch in 33% of patients. At least one perforator was found on anatomical dissection between 10 and 15 cm from the posterior axillary fold, within 4.3 cm of the lateral border of the latissimus. The most proximal perforator was consistently found to be the largest in diameter. Thomas et al. found

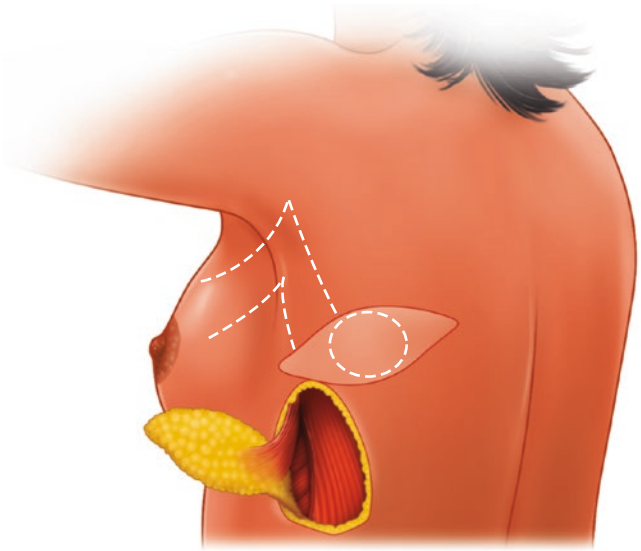

Fig. 15.2 The latissimus dorsi is harvested with a thin strip of muscle protecting the descending branch and perforators to the skin paddle. The skin paddle may be vertically or horizontally oriented. (Adopted from Saint Cyr et al. [1])

an average of 5.5 ± 1.8 perforators with a mean diameter of 0.9 mm [23]. The average ratio of musculocutaneous to septocutaneous perforators was 3:2. The thoracodorsal nerve splits into a descending and transverse branch on average 2.4 cm superior to the bifurcation of the thoracodorsal artery [14].

Based on injection studies, the average musculocutaneous perfusion territory of the descending and transverse branch are 341 cm [2] and 325.4 cm [2], respectively [14]. While some authors have described designing large skin paddle irrespective of perforator location [1], it is our preference to confirm perforating vessel within our skin paddle to mitigate risk of delayed wound healing, particularly when skin paddles are small. Barton et al. demonstrated small skin paddles rely on perforating vessels in an experiment where skin overlying the latissimus was portioned and fluorescein injections were performed [24]. Adding an implant may result on pressure on the perforators, resulting in compromise when a true TDAP is performed. When the perforator is based laterally, the flap can be turned 180 degrees to cover the prosthetic. In this scenario, the perforator will be on the lateral aspect of the breast, away from the pressure of the implant [25]. If the perforator is in the middle of the flap, a segment of LD has been recommended by some authors to protect perforators from pressure [25]. In the era of prepectoral reconstructions, the pectoralis major is unable to offload pressure in underlying implants. Consideration of perforator location is critical if the vessels are unprotected.

Patient Selections

Indications for breast reconstruction using flaps based off the thoracodorsal arterial system are broad and cover most clinical scenarios and patient preferences (Fig. 15.3). Within breast reconstruction, the MS-LD myocutaneous flap is a good option for patients with implant-based reconstruction and a history of radiation therapy, impending implant exposure due to mastectomy flap necrosis, deficits in breast envelope requiring skin, or patients requiring volume replacement after oncoplasty.

Implant-based reconstruction minimizes donor-site morbidity but is associated with capsular contracture, poor aesthetic outcomes, reconstructive failure, and the need for surgical revision in patients undergoing either neoadjuvant or adjuvant radiation therapy [26]. Autologous tissue is used to minimize radiation-associated complications of alloplastic reconstruction by supporting the mastectomy flaps. The addition of well-vascularized tissue improves wound-healing and gives the breast pocket more pliability during tissue expansion and during the reshaping that occurs with radiation [27]. LD muscle was traditionally used for this purpose. It was shown by the senior author that MS-LD and TDAP flaps have similar success rates in mitigating the deleterious effects of radiation on an alloplastic reconstruction [16].

MS-LD and TDAP flaps can be used to correct complications that occur with implant-based reconstructions in addition to preventing them. Revisions due to capsular contracture frequently require additional skin for the breast-pocket surface area and volume for the correction of contour deformities. Correction of mastectomy flap wounds frequently requires explantation of the prosthesis and wide excision of the mastectomy flap, leading to obliteration of the breast pocket. In this scenario, MS-LD and TDAP flaps are useful tools for wound coverage and salvage of the breast pocket if used in conjunction with a tissue expander.

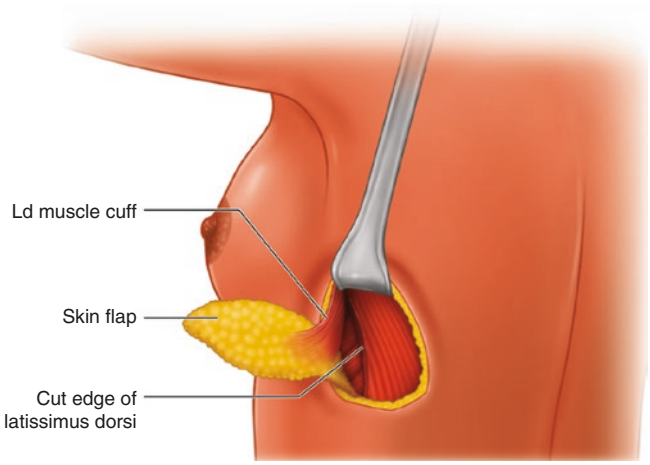

Fig. 15.3 The MS-LD has less morbidity as innervated, vascularized latissimus dorsi muscle is retained in situ. (Adopted from Saint Cyr et al. [1])

MS-LD and TDAP flaps can also be used for reconstruction for patients who require small to moderate volume restoration after lumpectomy. Oncoplasty and contralateral reduction mammoplasty are excellent options for shape restoration and wound closure following lumpectomy but leave the patient with smaller breasts. In patients who desire to maintain or increase their pre-lumpectomy breast size, restoration of volume and reshaping following lumpectomy can be achieved with a MS-LD or TDAP flap.

Contraindications to using the thoracodorsal arterial system are limited and depend on previous surgical history and whether muscle will be used. A history of prior posterior or lateral thoracotomy should prompt an investigation of the patient's operative reports, as the LD is frequently divided, but may be spared if a muscle-sparing approach was employed. The thoracodorsal neurovascular pedicle is also at risk in patients who have undergone axillary dissection. Muscle volume is not needed with the MS-LD or TDAP flaps, but the finding of an atrophic latissimus on physical exam is a clue that indicates that the thoracodorsal neurovascular pedicle may have been violated during previous procedures [28]. Patients who are dependent on their upper extremities for push off and transfers are not candidates for LD transposition but can still donate MS-LD flaps or TDAP flaps as long as the thoracodorsal nerve is preserved.

Preoperative Markings

Patients are marked standing up straight. Anteriorly, the midline is marked, bilateral IMF, and breast borders (Fig. 15.4a). The markings for the IMF and breast borders give the surgeon an idea of the dissection boundaries. Should the lateral aspect of the IMF be violated in dissection, it is resecured. On the back, the scapula tip is marked for the most superior extent of the dissection (Fig. 15.5). The spinous processes and iliac crest are marked as well to denote the extent of the LD. The most critical mark is the anterior border of the LD. This can be palpated by having the patient extend their arm forward and press down on the surgeon's hand, or shoulder. Repeated contraction and release can help. In larger women, pinching may be required to derive its location. We have found, in our experience, the anterior border of the latissimus is more anterior than one might imagine. A skin paddle is designed either vertically or horizontally, depending on the needs of the operation. The flaps apex should be located a few cm anterior to the latissimus dorsi muscle to maximize blood flow [1]. When vertical, we base the skin paddle over the anterior border of the latissimus at the approximate location of the descending branch. When horizontal, we base the skin paddle over the approximately

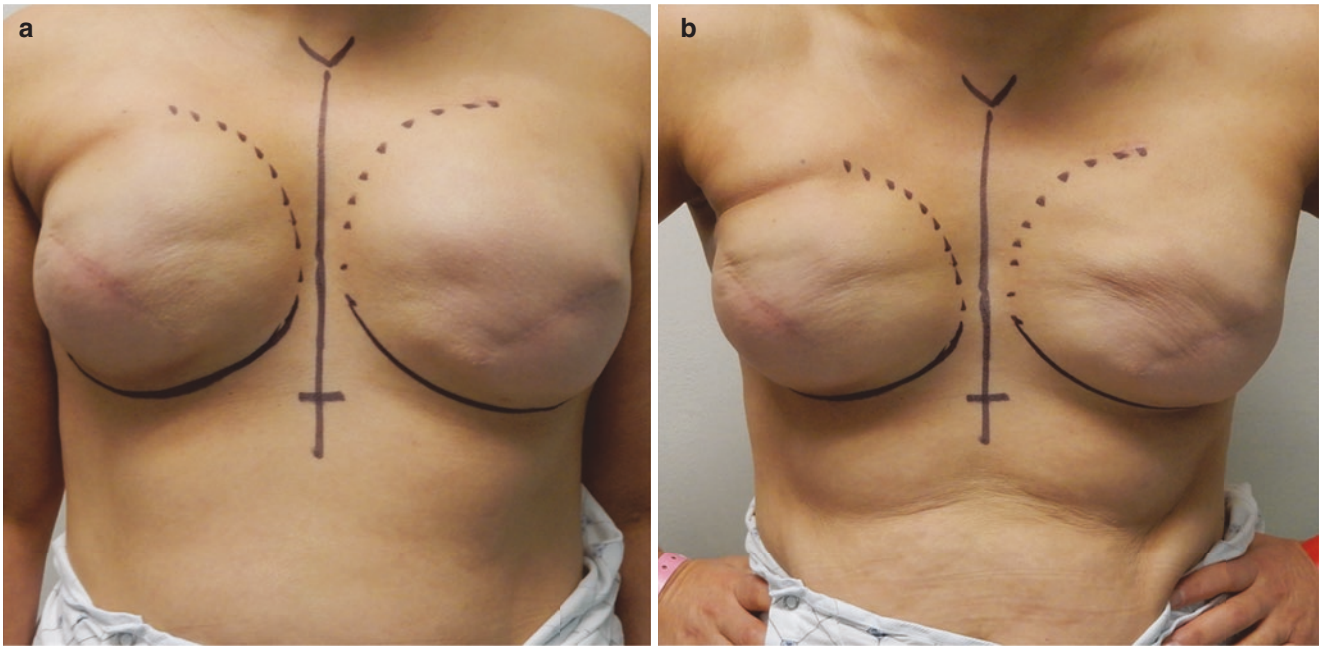

Fig. 15.4 Patient presents with Baker grade IV capsular contracture on the right and grade III on the left (**a**), with severe animation deformity (**b**)

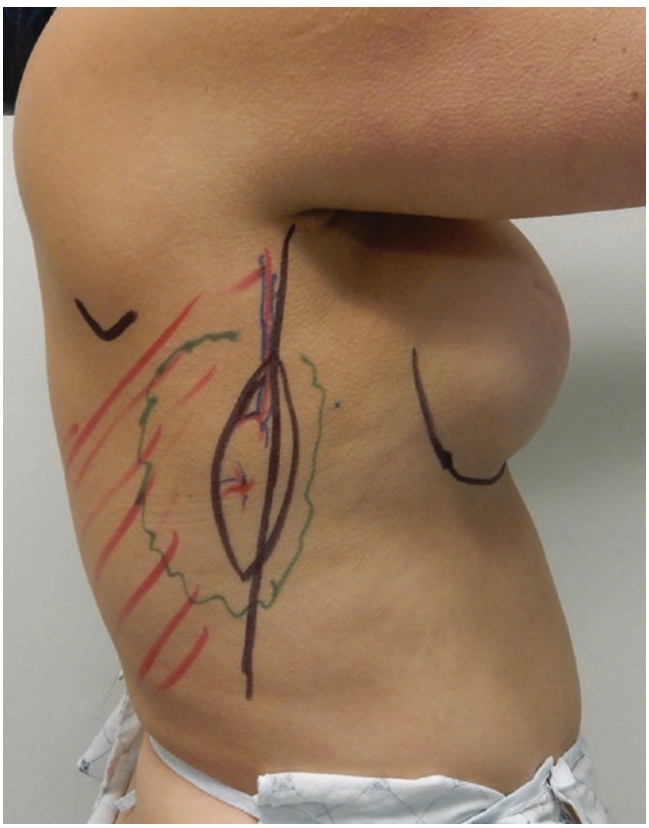

Fig. 15.5 Preoperative markings for the MS-LD flap. The anterior border of the latissimus dorsi is palpated by activating the latissimus muscle with the patient's arm extending. The skin paddle is centered slightly posterior. Additional fat is captured for volume. The scapula tip is marked

location of the transverse branch within the bra line or to capture a natural skin roll. The reach of the skin paddle is confirmed by measuring the distance of the proximal end of the flap to the proximal end of the planned skin paddle on the breast. Additional fat is routinely captured for bulk, as denoted by our green markings (Fig. 15.4b).

Surgical Technique

Vertically Oriented Descending Branch MS-LD

Generally, our patients are intubated with ET tube due to the position changes. A bean bag is on the bed, while we begin supine with implant work. Implants are removed and lane change and/or capsulotomies are performed. Recently, prepectoral plane changes have been common due to animation deformity and capsular contracture as a result of radiation's effect on the pectoralis muscle. In this scenario, a new prepectoral pocket is dissected, and the pectoralis is sutured to an anatomic location with 2–0 Vicryl stitches. In the supine position, we denervate the descending branch of the latissimus dorsi. However, in the obese patient, abundant adipose tissue may make this endeavor difficult. In this scenario, we denervate in the lateral position. Once complete, the adequacy of the newly dissected implant plane is verified by placing the implant with its anterior acellular dermal matrix wrap in location. We have found that using ADM allows better control of the implant position with our previously described suture tabs and may reduce incidence of

capsular contracture [29]. We staple the incision close and place Ioban (3 M, Maplewood, Minnesota) on the incision to maintain a sterile field.

The positioning of the patient is critical in the lateral position. For adequate visualization of the thoracodorsal trunk, the patient's arm must be slightly abducted, elbows bent, and arm forward, as if the patient was "reaching forward to give a hug." To achieve this, we place the patient in a sloppy lateral position with an axillary roll and padding over the common peroneal and ulnar nerves. The contralateral arm is placed on an arm board, and an arm positioner is placed above that arm board. The desired arm position is held by the surgeon. The arm positioner is completely loose at the joints, while the arm is secured to the arm positioner by a separate assistant. Once the ideal arm position matches the position held by the surgeon, the joints of the arm positioner are secured by the assistant.

Prior to dissection of the flap, we verify the perforators are within the skin paddle. Prior authors have demonstrated these small skin paddles are reliant on perforating vasculature [24]. We begin dissection at the anterior border with electrocautery. An assistant is holding Joseph skin hooks and then Murphy rake retractors. Fat within the superficial fascia is captured beveling the plane of dissection. Through this incision, a tunnel is created with care not to violate the lateral inframammary fold. If dissected, this area must be secured down to recreate the aesthetic normal of the breast. The vascular pedicle is further dissected to ensure tension-free transposition. Approaching from the contralateral side of the patient, the posterior aspect of the flap is dissected with additional fat capture. From this position, we approach the anterior aspect of the flap off the serratus fascia. Care is taken at this point to not elevate the skin and fat off the latissimus. Two visual clues are helpful in this situation. We identified the approximate location of the perforators, and know they are 3–4 cm within the anterior border of the latissimus [15]. Additionally, the direction of the serratus muscle fibers and the latissimus are different. If one is to follow the serratus fascia closely, with appropriate counter tension, the latissimus will peel off above the plane of dissection. The descending branch will be visualized overhead, and the plane is followed to define the amount of muscle harvested. Depending on the location of the descending branch and its concomitant perforators, this thin strip of latissimus ranges from 3 to 4 cm in width. We have observed very little functional morbidity with this harvest.

Next, we begin elevating the posterior aspect of the flap off the latissimus muscle in a subfascial plane, while the assistant is holding tension with Joseph skin hooks. Once we approach the posterior border of latissimus to the muscle being harvested, we perform the lateral disinsertion, while the muscle is kept attached distally to maintain tension. The location of the descending branch is constantly verified by visualizing the undersurface of the flap. Meticulous dissection is performed, particularly superiorly around the area of the transverse branch of the thoracodorsal artery. Once the posterior border is defined, we disinsert the muscle flap inferiorly and transpose the pedicled flap into the implant pocket. Occasionally, additional dissection will be necessary over the transverse branch of the thoracodorsal artery. We make every effort to retain this vessel. When we have to ligate the transverse branch for improved reach, we separate the artery from the nerve, to leave the remaining portion of latissimus innervated. Once inset, a key move is to release the skin overlying the proximal portion of the latissimus at its humerual insertion. If not done, patients will often complain of a bump in that area, with poor aesthetic contour. We place a 19 Blake drain separated by down its flutes, for one half in the breast pocket and one half in the back. We close with 2–0 PDS for the fascia, 3–0 monocryl for the subdermal tissue, and 3–0 Stratafix for the skin. Prineo skin adhesive is used.

Technical Variations

When no pocket work is required, we perform the operation in sloppy lateral. An instance as such would be salvage of implants after mastectomy flap necrosis. After the flap is dissected, we inset the pedicled myocutaneous flap prior to placement of the implant. After appropriate reach is verified, a Keller funnel (Allergan, Dublin, Ireland) is used to place the implant without undue trauma to the MS-LD flap.

Postoperative Care

For pain control, we employ our enhanced recovery after anesthesia protocol. We premedicate with 600 mg gabapentin, 200 mg celebrex, and 1000 mg tylenol. Intraoperatively, IV lidocaine or ketamine, euvolemic resuscitation, and field blocks with Exparel are used. Postoperatively, 24 h of 15 mg Toradol q6hours is given after which patient is discharged on 200 mg Celebrex q12hours. Gabapentin 300 mg q8hours and Tylenol 650 mg q8hours are continued for 1 week. Ten tablets of Vicodin are given for breakthrough. We have found patients rarely use the entire prescription.

Depending on pain tolerance and patient's comfort, patients are discharged the same day or the following day. Patients are allowed to shower 48 hours after surgery. Heavy lifting (>10 lbs) is restricted for 2 weeks; however, light cardiovascular exercise is encouraged. Additionally, ipsilateral range of motion exercises shoulder is encouraged to prevent frozen shoulder. The drain is removed when putting out less than 30 mL a day for 2 consecutive days. Generally, the drains take 2–3 weeks to remove.

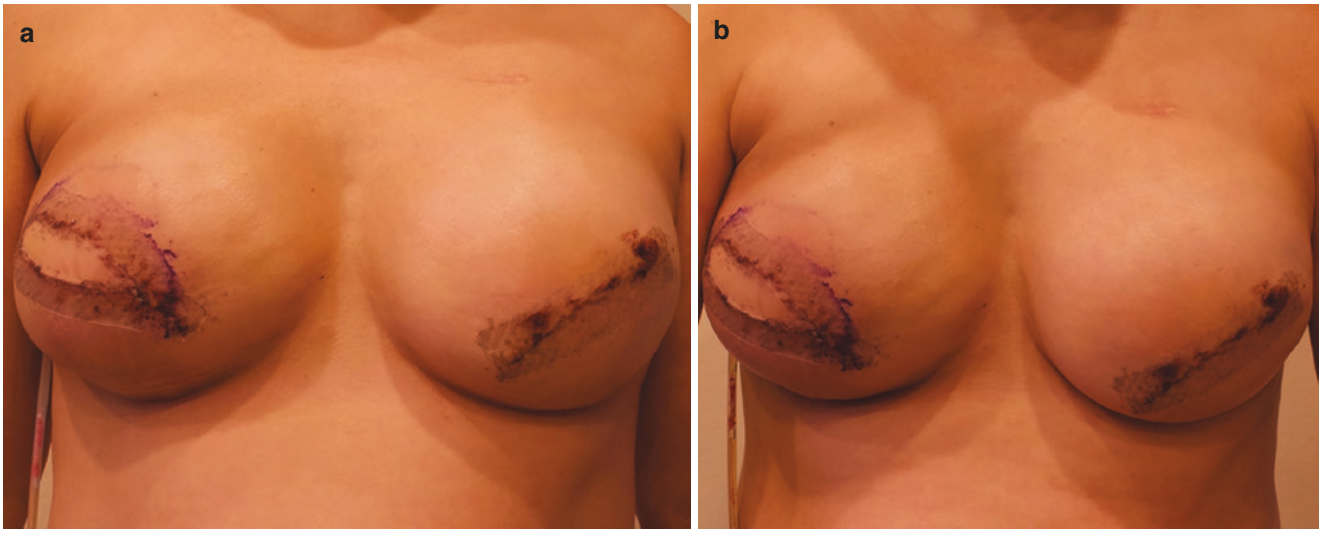

Fig. 15.6 On 1 month follow-up, patient healed well with symmetrical result (**a**) and resolution of animation deformity on pectoralis activation (**b**)

Clinical Case

A 46-year-old Caucasian female with a history of left breast cancer presented to our clinic with right capsular contracture and animation deformity. The patient had a radical bilateral mastectomy and subpectoral implant reconstruction with acellular dermal matrix (ADM) 3 years previously with subsequent radiation. She developed Baker grade IV capsular contracture on the right and grade III on the left within 7 months of the procedure (3 months after radiation). On physical exam, the right breast appeared firm and contracted and animation deformity was present bilaterally (left greater than right), with significant discomfort of the right breast (Fig. 15.4). Additionally, palpation revealed that the left implant was flipped.

The patient underwent a revision of her reconstruction with bilateral prepectoral implant replacement with ADM and a right MS-LD flap to replace the radiated tissue defect on the right breast. Anterior and posterior incisions were then made in a manner to capture subcutaneous tissue. The descending branch of the thoracodorsal artery was then identified and protected. Next, a 3 cm anterior slip of muscle was dissected from the bulk of the latissimus muscle. This dissection was carried superiorly until the bifurcation of the transverse and descending branches of the thoracodorsal artery was encountered. The inferior portion of the muscle was detached. A cutaneous Doppler signal was confirmed to be present on the flap prior to interpolating into the breast pocket. The flap was then inset and closed, and the surgery was successful without complications. On one-month follow-up, the patient healed well with a symmetrical result and reduced capsular contracture and animation deformity (Fig. 15.6a,b).

Conclusions

The MS-LD/TDAP flap is a viable option for patients with implant-based reconstruction and a history of radiation therapy, patients with impending implant exposure due to mastectomy flap necrosis requiring autologous tissue, or patients requiring volume replacement after oncoplasty. With time, the senior surgeon's experience has evolved from frequently performing TDAPs to MS-LD flaps; due to the low morbidity and the additional protection, the thin slip of muscle provides vascular supply. The flap is easy to harvest, provides good aesthetic outcome, and is a valuable addition to any plastic surgeon's armamentarium.

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Free and Muscle-Sparing Transverse Rectus Abdominis Myocutaneous Flap in Breast Reconstruction

16

Leo Lara Espinoza, Ricardo Cavalcanti Ribeiro, Rafael Garrido Costa, Luis Fernandez de Cordova, and Flavio Marques de Carvalho

Introduction

There are several breast reconstruction techniques. Each one has specific advantages and disadvantages. The transverse rectus abdominis myocutaneous (TRAM) flap was first described as a free flap by Holmstrom in 1979 [1]. Use of this flap gained popularity as a pedicled flap described by Hartrampf et al. in 1982 [2]. TRAM flap allows for the transposition of a considerable volume of autologous tissue suitable for reconstruction of the breast and satisfactory aesthetic results in the donor area. Among the disadvantages of this technique are complications, such as the partial necrosis of the flap, fat necrosis, and weakening of the abdominal wall due to impairment of the rectus abdominis muscle that accompanies the flap.

Scheflan and Dinner confirmed that predominant irrigation of the skin and adipose tissue of the lower abdomen is provided by the inferior epigastric artery [3]. Losken, using intraoperative angiography, showed that the free TRAM flap based on the inferior epigastric vessels has better perfusion than the pedicled TRAM flap [4]. Once the advantage of the free flap with respect to flap vascularization was demonstrated, another important point described the morbidity of the donor area. Even after preserving a larger superior segment of the rectus abdominis muscle at the free flap, a postoperative bulge and hernia incidence are similar when compared to the pedicled TRAM flap. With the objective of reducing morbidity in the donor area, the evolution of the technique began to spare additional segments of the rectus abdominis muscle.

A major advancement in the technique was the use of a deep inferior epigastric artery perforator (DIEP) flap described by Koshima and Soeda in 1989 [5]; however, this type of flap was not used for breast reconstruction in this study. Allen and Treece described its use for breast reconstruction in 1994 [6]. The advantages of this technique allowed a decrease in donor area morbidity since it allows the entire extension of the rectus abdominis muscle to be preserved. Anatomical studies of the trajectory of the perforating arteries of the rectus abdominis muscle were important for the planning of the free TRAM flap. In 1993, Itoh and Arai performed an anatomical study of the DIEP flap, where 34 straight abdominal muscles from 16 cadavers were studied [7]. The researchers concluded that deep epigastric vessels branched in 82% of cases, that the lateral branch is wider and predominant in 88% of the cases, and that there was a mean of 6.5 perforations >0.5 mm in the anterior sheath of the rectus abdominis muscle. Blondeeel et al. in 1999, in the description of the technical aspects of the DIEP flap dissection, made important observations regarding the type of intramuscular trajectory and the correlation with the location of the perforating artery [8]. Perforating arteries located in the lateral region of the rectus abdominis muscle presented an intramuscular trajectory perpendicular to the lateral branch of the inferior epigastric artery and thus provided an easier dissection and less damage to muscle fibers when compared to the perforating ones with a medial origin that present a longer trajectory crossing a larger number of muscle fibers.

The intraoperative findings of the caliber and location of these perforators often aid in the decision of the reconstruction technique that will be employed. Perforators with an adequate caliber located on the lateral portion are favorable for using the

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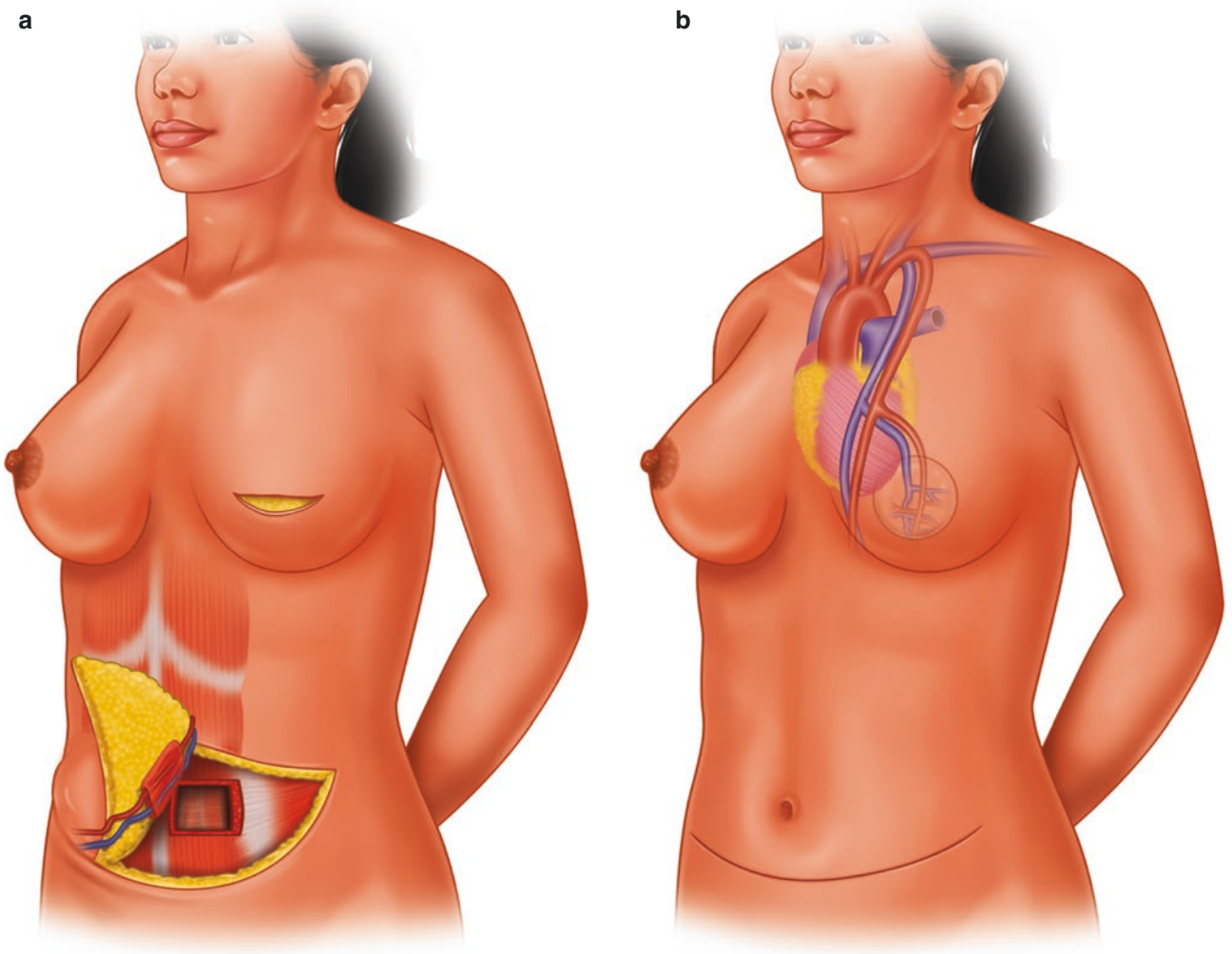

Fig. 16.1 (**a**) The free TRAM flap with non-muscle preservation (MS0); (**b**) internal mammary vessels are preferred as recipient vessels because they provide a better match in terms of caliber to the deep inferior epigastric vessels

DIEP flap. Perforators of smaller caliber but in greater number with central and lateral location favor the option of the muscle-sparing TRAM or free TRAM flap with non-muscle preservation (Fig. 16.1). The classification of Nahabedian et al. for free TRAM flaps helps to understand the degree of muscle preservation (Fig. 16.2) [9, 10]. It is important to note that some studies show no significant difference in relation to the incidence of bulge and hernia when compared to DIEP flap and muscle-sparing free TRAM flap [11].

Anatomy

The rectus abdominis muscle runs vertically through the abdomen and extends from the pubic symphysis, pubic crest, and pubic tubercle inferiorly to the xiphoid process and costal cartilages of the fifth, sixth, and seventh ribs superiorly. Based on the classification of Mathes and Nahai, it is a type III flap with two dominant pedicles and can be used as a muscle flap, a musculocutaneous flap, or a perforating flap [12]. The upper dominant pedicle is irrigated by the superior epigastric artery and the inferior dominant pedicle by the deep inferior epigastric artery. Motor and sensory innervation occurs through the intercostal nerves of the seventh to the tenth rib. The upper and lower epigastric arteries communicate through a choke vessel system. Taylor described this system with three anatomical variations: (1) a single vessel communicating the systems in 29% of cases, (2) two vessels in 57%, and (3) several smaller vessels communicating the two systems in 14% of the variations [13].

The free TRAM and the muscle-sparing TRAM flaps have a pedicle that is formed by the deep inferior epigastric artery, which originates from the external iliac artery and

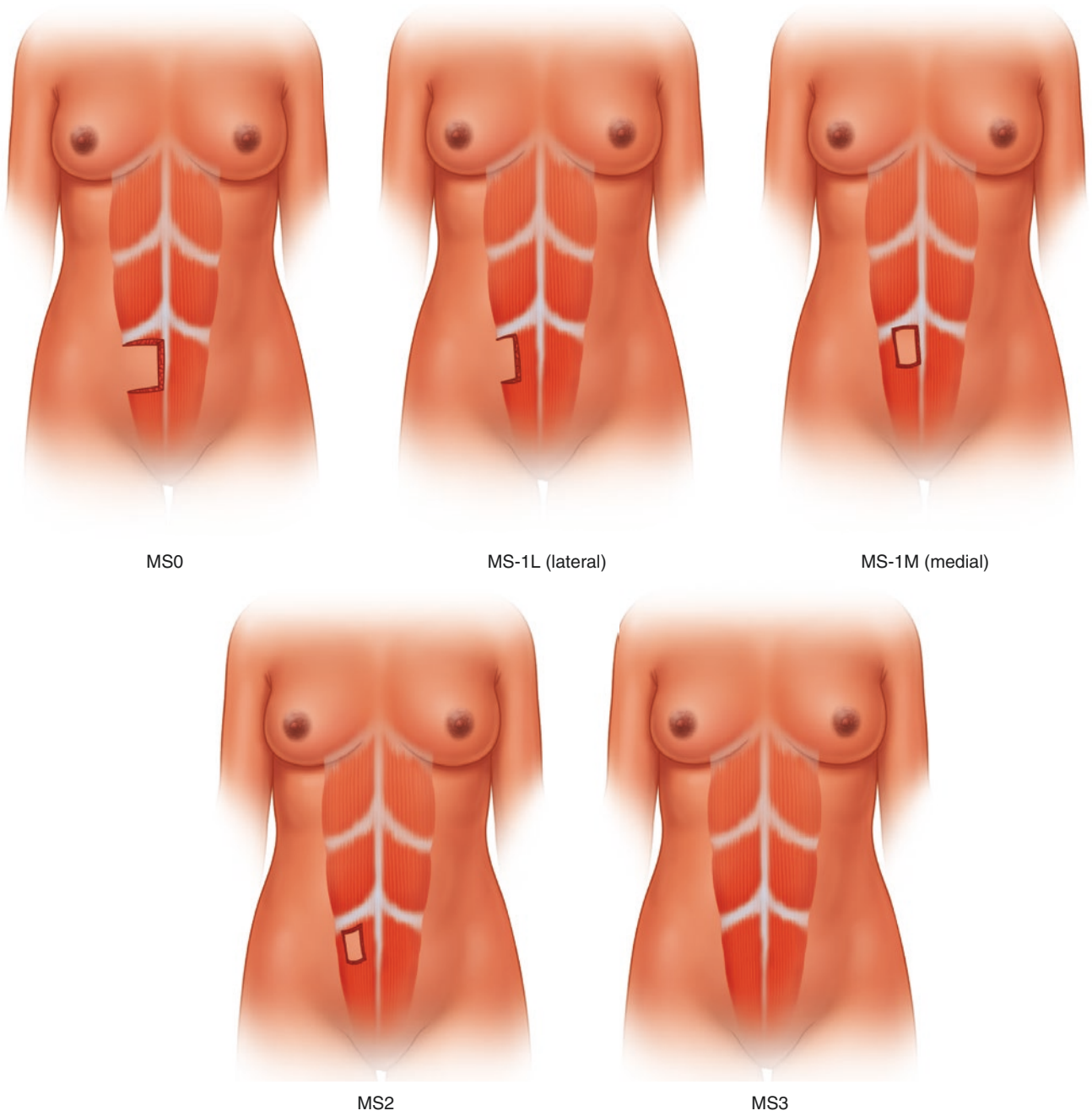

Fig. 16.2 Nahabedian's classification of free TRAM flaps: (1) MS-0 non-muscle preservation of the rectus abdominis muscle; (2) MS-1 preserves the lateral (MS 1-L) or medial (MS 1-M) portion of the muscle; (3) MS-2 preserves the lateral and medial portion, sacrificing only the central portion of the muscle; and (4) MS-3 preserves the entire muscle, which is equivalent to the DIEP flap

the venous drainage performed through two veins that join to form a larger-caliber vein before entering the external iliac vein.

There are two main classifications for TRAM skin island blood irrigation. The first and best known is Hartrampf's classification, which is divided into four zones (Fig. 16.3).

Ninkovic's classification exchanges the numbering of zone II with zone III (Fig. 16.4), considering that the territory located ipsilateral to the pedicle would have a better blood supply than that located on the opposite side of the midline. Holms et al. conducted a study of deep inferior epigastric artery perforator flaps in which perfusion of the indocyanine green dye flap was monitored in vivo [14]. The authors concluded that although zone I remained the most reliable portion of the flap, any flow crossing the midline was more precarious than ipsilateral flow.

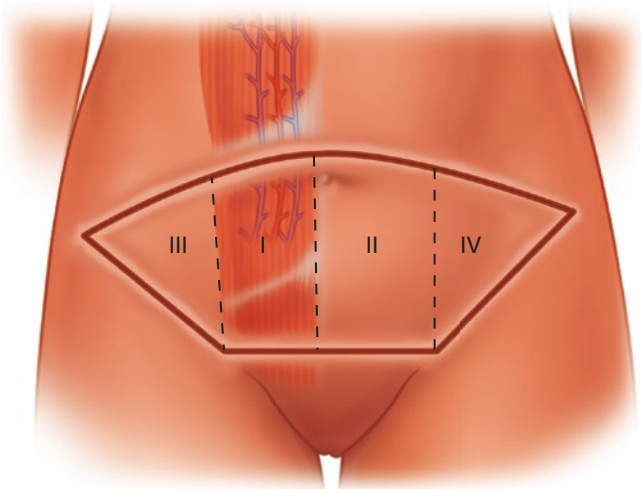

Fig. 16.3 Hartrampf's classification of TRAM perfusion zones: zone I, territory on the pedicle; zone II, territory crossing the midline adjacent to the pedicle; zone III, territory adjacent to the ipsilateral pedicle; and zone IV, territory adjacent to contralateral zone II

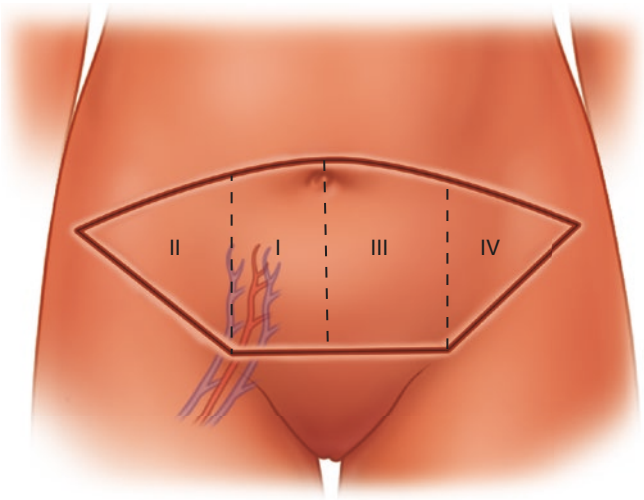

Fig. 16.4 Ninkovic's classification of perfusion zones for TRAM and DIEP free flap

Patient Selection

Patients who require a greater amount of tissue, either because of the poor quality of the skin remaining in the breast to be reconstructed or because of a higher-volume contralateral breast, and those who want more natural results are the ones that most benefit from the free TRAM flap. It is important to evaluate whether a patient has adequate donor area and to be aware of the necessity of postoperative rest in order to decrease the chance of complications. The patient's clinical condition should also be thoroughly evaluated since the procedure's surgical time is fairly lengthy. Risk factors such as hypertension, diabetes, smoking, and obesity are not contraindications to reconstruction but may influence the choice of surgical technique and predispose a patient to complications in the donor area. A patient must be examined for scars in places that may compromise the pedicle of the flap.

Preoperative Planning

The patient is placed in a seated position, and excess skin and subcutaneous tissue are evaluated through the pinch test with the patient lying down. A skin spindle that extends from the pubic crest inferiorly up to the navel superiorly and laterally to the anterior superior iliac spines is drawn on the lower abdomen; if a manual Doppler is available, perforator mapping can be performed in order to facilitate its intraoperative location (Fig. 16.5).

More specific examinations can be used to map perforators of the deep inferior epigastric artery. Doppler ultrasonography can aid in the mapping of perforators in addition to identifying and measuring the caliber of the pedicle. Computed tomographic angiography (CTA) provides a more accurate evaluation of flap vascularization. It is superior to the Doppler ultrasonography for the identification of perforators and can aid in the evaluation of the recipient vessels [15]. Magnetic resonance imaging (MRI) can also be performed in patients who do not want to be exposed to radiation [16]. The results of the examination usually present a high correlation with the intraoperative findings. Several studies show the reduction in operative times and complications when they are carried out preoperatively [17, 18].

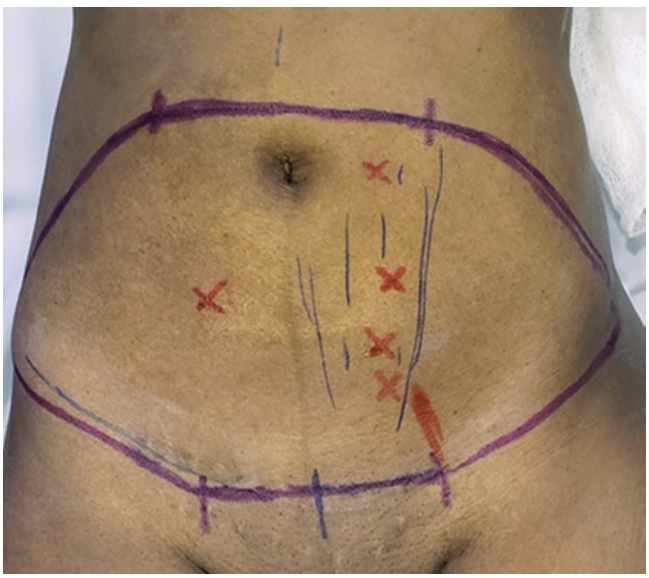

Fig. 16.5 Preoperative mapping of perforating vessels with a manual Doppler

Surgical Technique

The patient is placed in the supine position under general anesthesia. Exceptional care should be taken when positioning the patient in order to avoid neuropraxia. The dissection and identification of the recipient vessels in the thorax can then be performed. Usually the internal mammary vessels are found at the level of the third costal cartilage (Fig. 16.6). Internal mammary vessels provide a better match in terms of caliber to the deep inferior epigastric vessels and are more accessible than thoracodorsal vessels during autologous breast reconstruction procedures (Fig. 16.1b). Furthermore, using these vessels as the recipient vessels may make it possible to position the flap more medially.

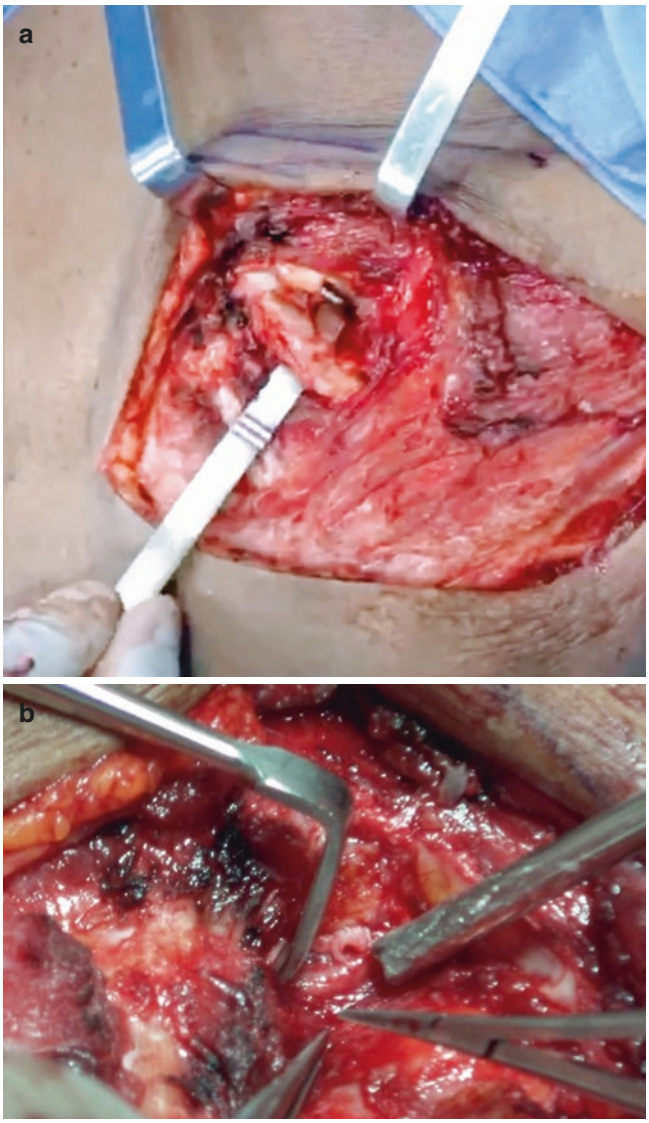

Fig. 16.6 (**a**) Exposure of the third costal cartilage by splitting the overlying pectoralis major muscle; (**b**) to gain adequate access to the internal mammary vessels, a medial segment of the ipsilateral third costal cartilage is excised

Preparation of the flap begins with an inferior incision in order to identify the superficial inferior epigastric vessels. If the superficial inferior epigastric artery (SIEA) is >1.5 mm in diameter and there is an adequate accompanying vein, we recommend proceeding with an SIEA flap. If the superficial inferior epigastric vessels are inadequate, detachment of the flap from lateral to medial is performed until the lateral border of the rectus abdominis muscle can be identified at which point a more careful dissection and identification of the perforating vessels should be done. An attempt to identify one or two large perforators in close proximity to one another should occur before proceeding with a DIEP flap. If there is no dominant perforator, a group of perforators should be selected; the anterior aponeurosis of the rectus abdominis is laterally opened preserving the lateral segment of the muscle, and the inferior epigastric artery and veins are dissected until their origin at the external iliac vessels (Fig. 16.7). Once this dissection is performed without injuring the pedicle, the remainder of the flap on the contralateral side is undermined, and the same careful dissection is performed just after the linea alba in order to preserve the maximum of the medial portion of the muscle and the fascia.

Using this technique, a small amount of the anterior rectus fascia and rectus abdominis muscle are used for the flap (muscle-sparing free TRAM flap). In order to minimize the chance of fat necrosis or partial or total flap loss, the free TRAM flap without muscle preservation should be chosen when there are several small-caliber perforators or when the patient has several risk factors. However, even in these cases, an attempt to save at least part of the lateral and medial segments of the anterior rectus fascia should be done. In the donor area, a polypropylene mesh for abdominal wall reinforcement in both the free TRAM and TRAM flap with preservation of muscle can be used (Video 16.1).

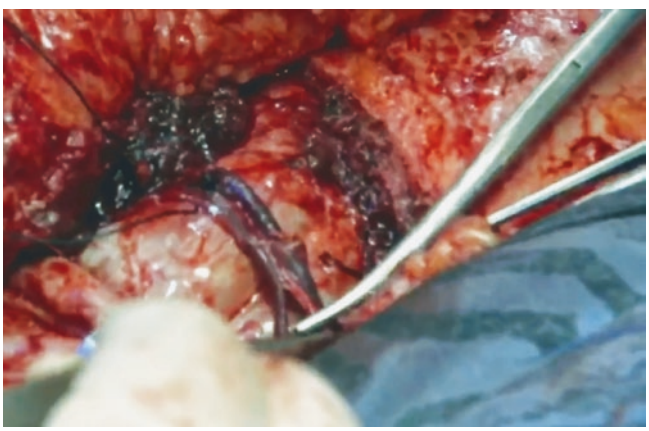

Fig. 16.7 The inferior epigastric artery and veins are dissected until their origin at the external iliac vessels

A video showing the preoperative marking, flap harvest, and preparation of recipient vessels is available as supplemental digital content.

Postoperative Care

Postoperative care involves both clinical care and surveillance of the free flap. It is important to keep the patient well hydrated postoperatively and perform the mechanical and pharmacological measures for prophylaxis of deep venous thrombosis. The dressing is made in such a way as to expose the central part of the flap for monitoring. The flap monitoring is done by a trained team, capable of identifying signs of arterial compromise as cold, pale flap, with temperature decrease without flap bleeding after needle puncture. Venous involvement usually presents with cyanotic flap and dark blood stasis after needle puncture. These clinical signs are evaluated every 2 hours in the first 24 h and every 4 h in the following 48 hours. If any of these signs are present, the patient must undergo anastomosis revision; the sooner the approach, the greater the chance of salvage of the flap. The length of hospital stay is at about 5 days.

Clinical Cases

Case 1

A 53-year-old female patient with a history of breast cancer in the right breast and total mastectomy with complete axillary lymph node dissection presented for delayed breast reconstruction. She also received chemotherapy and radiotherapy which produced extensive radiodermatitis. On physical examination, she had sufficient abdominal tissue for breast reconstruction with an abdominal flap. She underwent a free TRAM flap reconstruction with no major complications (Fig. 16.8).

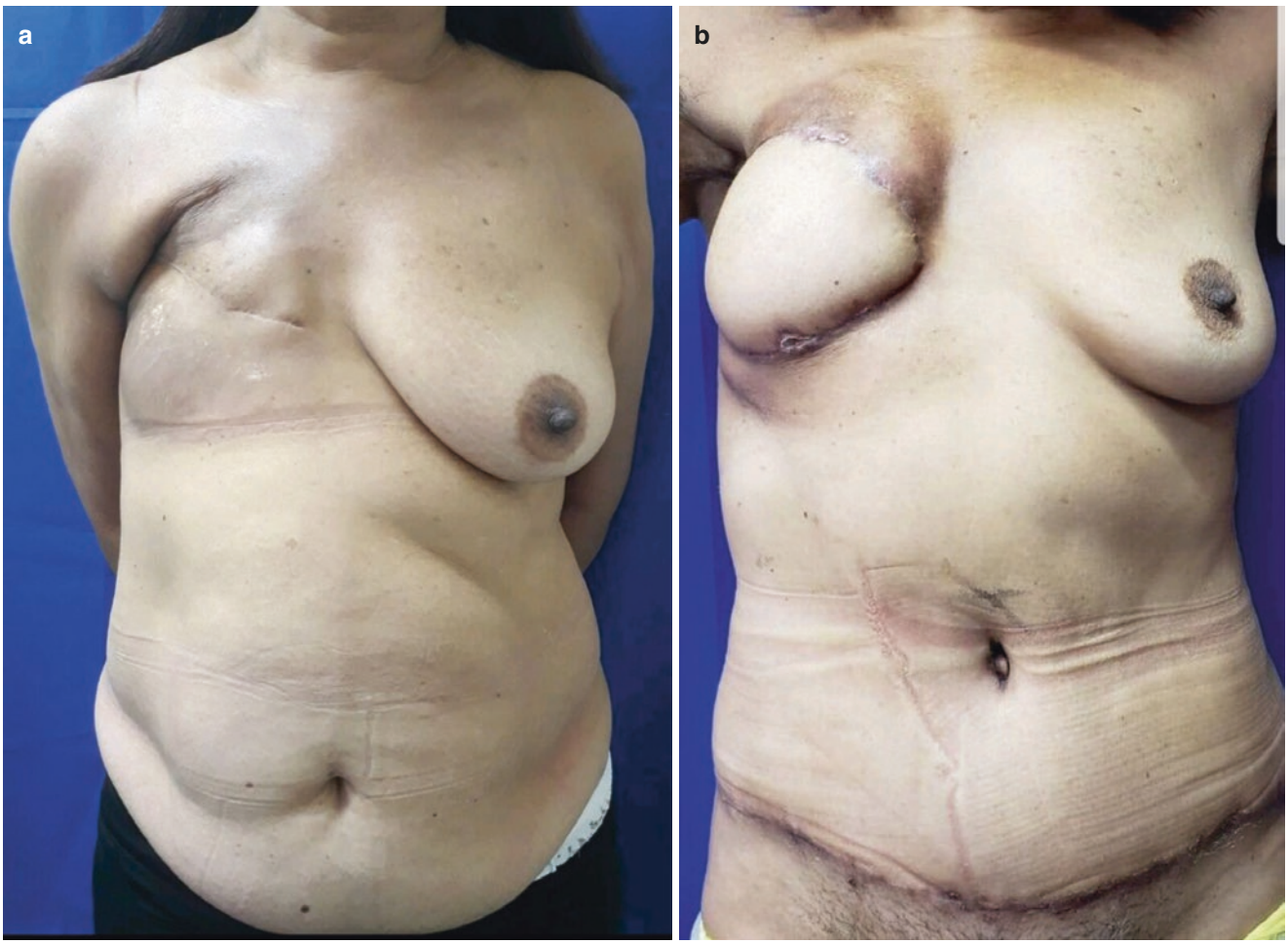

Fig. 16.8 (**a**) Preoperative frontal view and (**b**) postoperative frontal view at 45 days

Case 2

A 73-year-old female patient with a diagnosis of invasive ductal carcinoma in the right breast underwent mastectomy and immediate reconstruction with a tissue expander. After failed implant-based reconstruction, a delayed breast reconstruction with a free TRAM flap was performed with no major complications (Fig. 16.9).

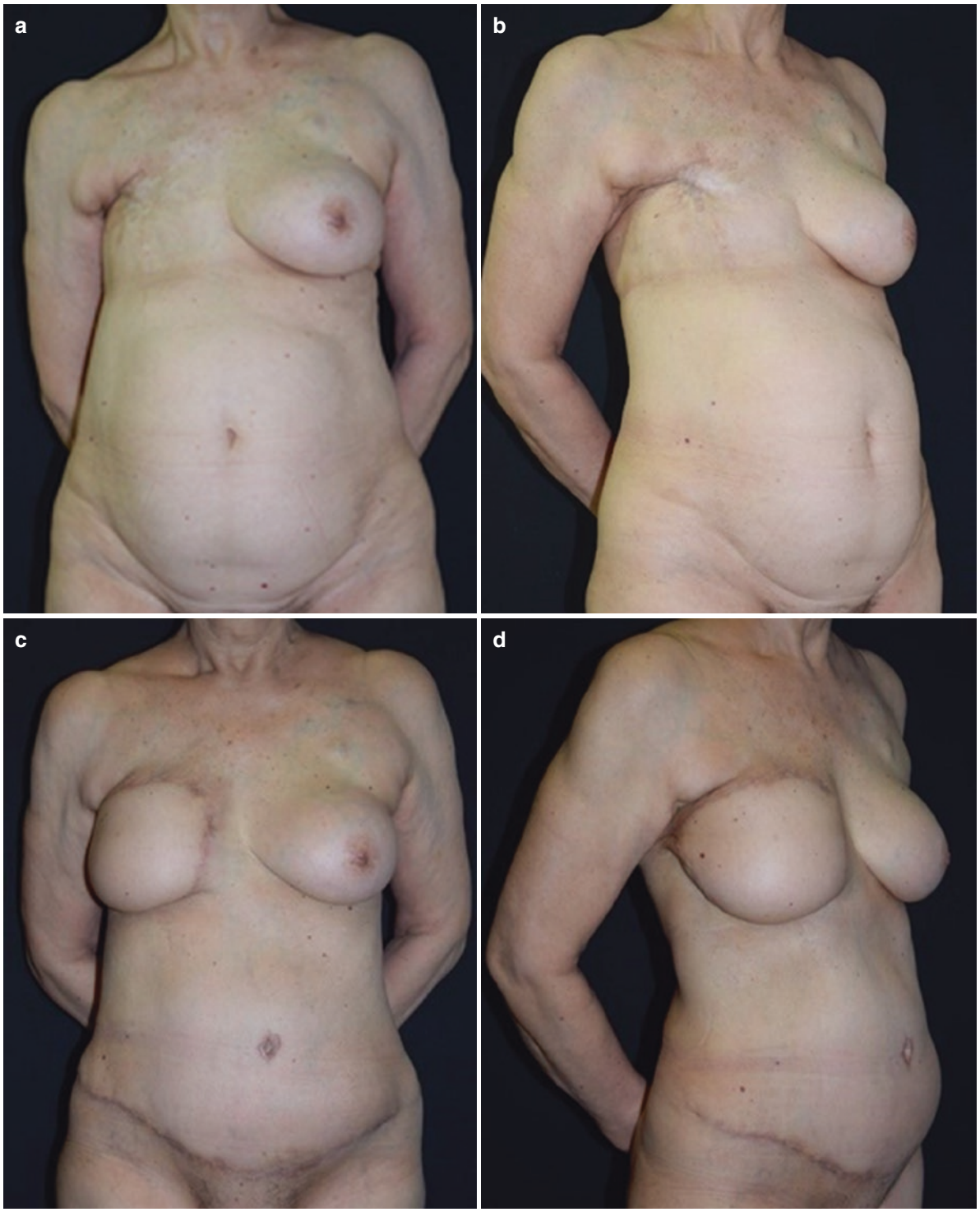

Fig. 16.9 (**a**) Preoperative frontal view, (**b**) preoperative oblique view, (**c**) and (**d**) postoperative frontal and oblique view at 3 months

Conclusions

The pedicled TRAM flap is an excellent option for breast reconstruction as it provides enough volume to create an aesthetically satisfying breast mound. With the advancement in microsurgical techniques, it is possible to perform the free TRAM flap that offers a safer vascularization than the pedicled flap. The evolution in the free TRAM flap technique allowed a decrease in donor-site morbidity with the muscle-sparing free TRAM flap and DIEP flap. Although the DIEP flap remains as the first choice in abdominal-based breast reconstruction, the free and the muscle-sparing TRAM flap have their own indications depending on intraoperative findings.

The free and muscle-sparing TRAM flaps have demonstrated to be highly reliable methods of autologous breast reconstruction in a broad spectrum of patients, including those considered at high risk for a pedicled TRAM flap reconstruction.

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Deep Inferior Epigastric Perforator Flap in Breast Reconstruction

17

Warren Mathew Rozen, Rafael Acosta, and Duncan Loi

Introduction

The deep inferior epigastric artery perforator (DIEP) flap was first described by Koshima and Soeda in 1989 [1], able to provide the volume of fat and overlying skin taken in the TRAM flap without the sacrifice of any rectus abdominis muscle. Its low donor site morbidity, combined with its reliability, has popularised the DIEP flap as the most common option for autologous breast reconstruction.

The DIEP flap is a perforator flap with an associated learning curve. Of the abdominal wall flaps used in breast reconstruction, it is associated with decreased rates of abdominal wall bulge or hernia [2] and is without the flap tunnelling required in the pedicled TRAM that can sometimes lead to epigastric bulge and an inferior aesthetic outcome. The flexibility and pliability of the flap tissue grant a superior degree of freedom for breast shaping to achieve an optimum aesthetic result. Compared to the muscle-sparing free TRAM, the close dissection of the pedicle required in the DIEP may decrease the risk of nerve injury resulting in abdominal wall muscle denervation and atrophy.

Key Points

- The DIEP flap provides a flexible, aesthetic breast reconstruction with low donor site morbidity.
- Abdominal wall anatomy and vasculature vary greatly between patients, and pre-operative imaging and planning is strongly recommended to optimise perforator selection and improve the intra-operative experience.
- Evaluation and assessment of the venous anatomy in addition to the arterial vasculature of the abdominal wall is being increasingly recognised as essential in the DIEP flap.
- Every effort should be made to preserve a superficial vein during dissection, with consideration for prophylactic second venous drainage.

Anatomy

The deep inferior epigastric artery originates in the majority of cases from the external iliac artery, just superior to the inguinal ligament, although it can often arise from a common trunk off the external iliac with the obturator artery or from the obturator artery itself.

It then courses superomedially, towards the lateral edge of the rectus sheath before approaching the deep aspect of the muscle. It travels a variable distance on the undersurface of the muscle before piercing the muscle, accompanied by paired venae comitantes. Distally the vessels anastomose with those of the superior epigastric artery and lower intercostal arteries.

Passing the arcuate line, the DIEA branches in three main patterns [3–5]. Type I describes a single inferior vessel (27–29%), with type II, a bifurcation of the vessel into medial and lateral branches that form medial and lateral row perforators, being the most common (57–84%). The type III pattern (14–16%) consists of a trifurcation of the inferior vessel.

An understanding of the perfusion of the abdomen is essential in the design and elevation of the DIEP flap. The revised Hartrampf zones describe the zones of perfusion provided by a unilateral DIEA, with zone I and II forming the ipsilateral hemiabdomen [6]. Zone 3, across from the midline, has adequate perfusion, whilst zone 4 is described to have poor to no perfusion.

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The individual arterial anatomy varies greatly between patients, and this has key clinical implications in the flap design and perforator selection. Between 2 cm cranial and 6 cm caudal to the umbilicus and between 1 and 6 cm lateral to the umbilicus, two to eight large perforators pierce either side of the anterior rectus fascia in the paraumbilical region [7]. Since the initial proposal and subsequent modifications of the model of zones of perfusion, further studies have revised the importance of considering the 'perforasomes' or perforator angiosomes of the individual selected perforator based on its size and location [8, 9]. The vascular territory of medial row perforators reliably crosses the midline, whereas the territory of lateral row perforators lies more solely within the ipsilateral hemiabdomen, with less reliable perfusion of tissue across the midline. Lateral row perforators also tend to be smaller but with a shorter intramuscular course, compared to medial row perforators.

The relationship of the segmental nerves to the perforators and vascular pedicle also requires consideration. Travelling from lateral to medial, mixed segmental nerves run either underneath or through the muscle towards the midline, splitting into motor and sensory branches. Whilst the sensory branches tend to run superficially into the subcutaneous tissue alongside the perforator and are sacrificed in the raising of a DIEP flap, the motor nerves often run superficial to the deep inferior epigastric vessels in an oblique fashion and should be preserved wherever possible. This may not be feasible if a flap is raised on two or more perforators in a row.

The abdomen is drained by both superficial and deep venous systems. The superficial system is dominant in the physiologic state, whereas in the DIEP flap the venous drainage is channelled through the deep system. The presence and quality of direct connections between the superficial and deep venous systems vary greatly across individuals [10, 11] and should therefore be assessed with pre-operative imaging. Schaverien et al. [11] found that on pre-operative MRA, medial row perforators were more likely to have direct connections between the venae comitantes and the superficial inferior epigastric vein compared to lateral row perforators (76% versus 57%). There usually are direct communicating veins across the midline [12, 13].

The superficial inferior epigastric artery lies above Scarpa's fascia, at the midpoint of the anterior superior iliac spine and the pubic symphysis. It is accompanied by its venae comitantes, but the superficial inferior epigastric vein is a separate vessel that is larger than the venae comitantes and can be up to several centimetres medial to the SIEA. If this is found to be particularly prominent on pre-operative imaging or intra-operatively, it may suggest that the smaller perforating veins of the deep venous drainage system are inadequate [14, 15].

Patient Selection

Autologous breast reconstruction may be clinically indicated due to previous radiotherapy, capsular contracture, poor skin quality or previous implant-related complications. Patients may also express a personal preference for autologous reconstruction or away from an implant-based reconstruction for a variety of reasons. In cases of unilateral reconstruction, the contralateral breast may require a balancing symmetrising procedure either concurrently or as a second-stage procedure.

Possible donor sites should be examined and their suitability assessed. Patients require sufficient abdominal tissue volume to be considered for a DIEP reconstruction. Individual patient factors and comorbidities will influence the outcome and modify the surgical risk profile, as with any operation, and patients therefore should be advised of their reconstruction options accordingly.

Previous instrumentation, trauma or surgery wall may alter the vascular anatomy of the abdominal wall or complicate perforator dissection. It is unclear to what degree previous abdominal surgery may influence donor site complications and wound healing or flap outcomes [16–18]. Previous abdominoplasty was considered an absolute contraindication to DIEP surgery due to the broad disruption and ligation of all central DIEA and SIEA perforators, with only peripheral perforators remaining. However, we have reported a successful DIEP case in a patient with previous abdominoplasty, where pre-operative CTA identified suitable-calibre perforators superior to the umbilicus [19]. Our experience has been corroborated by other case reports in the literature [20, 21], and therefore a DIEP procedure can be carefully considered in this patient population using pre-operative CTA findings. It should be noted that successful TRAM flaps have also been reported [22–24]. Previous liposuction is considered a relative contraindication, with mixed results in the literature [25–27]. Casey et al. [25] were able to significantly reduce the risks of fat necrosis and partial flap loss in patients with previous liposuction through the use of intra-operative indocyanine green laser angiography.

Obesity (>30 kg/m^2) has been associated for autologous breast reconstruction with greater rates of both flap and donor site complications. A meta-analysis by Lee et al. showed that in obese patients undergoing DIEP, MS-TRAM or SIEA flap reconstruction, there were a twofold increase in the risk of any flap loss and 1.5-fold increase in the risk of abdominal bulge or hernia as well as overall abdominal complications compared to non-obese patients [28]. However, obesity is also associated with poorer outcomes in implant-based reconstructions. In a series of 990 breast reconstructions performed on obese patients, Garvey et al. found that

immediate implant reconstructions had the highest failure rate, followed by delayed implant reconstructions, with free flap techniques being the most successful option in this patient population [29].

Smoking similarly is associated with poorer outcomes, particularly in regard to donor site wound healing. We recommend that any active smokers requesting elective, delayed reconstruction should stop smoking for at least 3 months prior to surgery. This can be confirmed with cotinine testing if desired. Whilst nicotine replacement therapy may help patients quit smoking and is certainly better than active smoking, nicotine is itself a vasoconstrictor and may still have an effect on tissue perfusion and so should be avoided depending on the patient's willpower and motivation.

Patients with pre-existing coagulopathies are also to be treated with care. Should microsurgical reconstruction proceed, maximal attention should be paid to thromboembolism prophylaxis in conjunction with the haematology team.

Pre-operative Planning, Imaging and Perforator Selection

Given the individual variability in flap volume requirements, abdominal wall vascular anatomy and tissue perfusion, perforator selection and assessment are vital in the design of the DIEP flap. In recent years there has also been a greater consideration for venous anatomy and its relationship with flap venous congestion. The advent of pre-operative imaging has allowed much of this planning to be done virtually, allowing for a safer intra-operative dissection which has translated to reduced operative time and improved overall flap outcomes [30–35]. This evidence is primarily with the use of pre-operative CTA, with a meta-analysis by Ohkuma et al. [33] showing an 87-minute reduction in operative time, as well as significantly fewer flap-related complications and reduced donor site morbidity with the use of pre-operative CTA.

From the pedicle to skin, the blood supply to the flap can be understood as having multiple segments: the deep inferior epigastric artery (DIEA) course deep to the rectus abdominis muscle, the intramuscular course of the DIEA, the intramuscular course of the DIEA perforator, the perifascial course of the perforator and the subcutaneous course of the perforator. The 'ideal' vascular pedicle can thus be described in terms of these segments [36]:

1. Large-calibre DIEA and vascular pedicle.
2. Large-calibre perforator (both artery and veins).
3. Central location within the flap.
4. Short intramuscular course.
5. Perforating veins communicate with the superficial venous network.
6. Broad subcutaneous branching, particularly into the flap.
7. Longer subfascial course.
8. Avoids tendinous intersections.

These factors are based upon maximising the ease and speed of operation and the clinical experience of complication in DIEP flap surgery. The size of the DIEA pedicle and perforator is intuitive, with regard to optimising perfusion to the flap. Centrality of the perforator similarly maximises the supply to the peripheral parts of the flap. A short intramuscular course has several benefits. In all cases, a short, longitudinal, intramuscular course is associated with ease and speed of dissection and the likelihood of less muscular branches requiring ligation. In the case of more than one perforator being included in the flap, a short transverse distance is associated with reduced dissection time and a reduced need for muscle and motor nerve sacrifice.

It is become increasingly apparent that many cases of diffuse venous congestion result from an intrinsic cause. This is thought to be due to the varying degrees of communication between the normally dominant superficial system and the deep venous system through which the DIEP primarily drains [10, 11, 14]. Using MRA, Schaverien et al. [11] demonstrated a strong relationship between diffuse venous congestion in DIEP flaps and the presence or absence of direct connections. Davis et al. [10] suggested that venous congestion was up to five times more likely in patients whose pre-operative CTA identified 'atypical' venous connections between the superficial and venous system, that is, connections that were narrow, tortuous or incomplete.

From experience, a broad subcutaneous segment and ramification of perforators into the flap improves flap vascularity and flap design. A long subfascial segment is sought, as this is associated with a reduced intramuscular course, and tendinous intersections were avoided, as these were associated with difficult dissections. Of all of these factors, these last three factors were considered the least important for perforator selection, although still worthy of consideration.

Various imaging modalities have been used to assist in perforator assessment and selection. Whilst intra-operative clinical assessment plays an important role, pre-operative imaging, in particular computed tomographic angiography (CTA), reliably confirms the presence of adequate perforators and reduces operative time by providing key information about perforator characteristics. Pre-operative imaging is a useful tool in patients who have had previous major abdominal surgery to determine if they are a suitable DIEP candidate, as well as to ascertain if an SIEA is present, as the abdominal wall vasculature may have been altered significantly.

Computed Tomographic Angiography (CTA)

CTA is a quick, non-invasive imaging modality that provides excellent anatomical detail and is performed in many centres as part of routine pre-operative workup. CTA is able to give accurate information about the number, calibre and location of perforators, demonstrating perforators as small as 0.3 mm in calibre (see Fig. 17.1). It is also able to depict the origin and intramuscular course of dominant perforators, and their location can be measured and mapped out on a grid centred on the umbilicus. This can then in turn be marked on the patient, providing a valuable guide in the operating theatre that is practical and easy to use.

Three-dimensional reconstructions are also commonly used to assist in pre-operative planning using CTA. These are achieved using computer software that performs multiplanar reconstructions. Volume-rendered technique (VRT) and maximum-intensity projection (MIP) reconstructions are widely used for this purpose and can be achieved with a wide variety of software programs from many software companies [37]. MIP reconstructions are optimal for demonstrating the DIEA pedicles and the intramuscular course of perforators. VRT reconstructions assign colour to data points which display a two-dimensional representation of the three-dimensional data set and are thus useful for representing the subcutaneous course of perforators and for generating perforator-location maps.

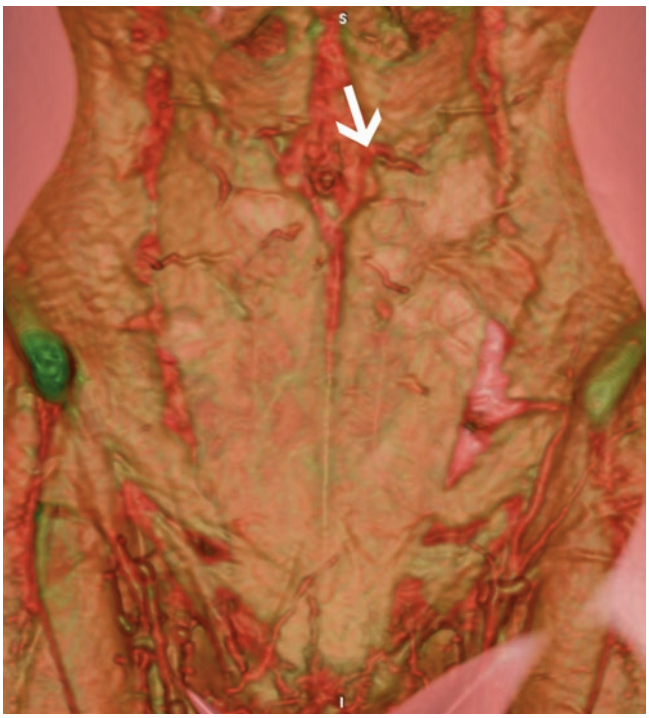


Fig. 17.1 Computed tomographic angiogram (CTA) of the abdominal wall vasculature, demonstrating a periumbilical perforator (white arrow), as well as the superficial inferior epigastric artery and veins

It should be noted that two different scanning protocols have been described [36]. The first is a time-delayed venous-phase scan, which is able to achieve maximal filling of both arterial perforators and veins. Whilst this allows appreciation of the venous anatomy, small perforating arteries and veins are unable to be reliability differentiated leading to potential confounders. This is similarly true for the SIEA, both due to confounding by the SIEVs and by some inadequacy in filling by the timing of the scan. The second protocol is a pure arterial-phase scan with no delay, which presumably provides greater accuracy for mapping of perforator arteries and the SIEA, but precludes any real assessment of the venous system.

The disadvantages of CTA are the use of intravenous contrast and associated risk of anaphylaxis and renal impairment, as well as the radiation exposure to the patient. The radiation dose has widely been discussed and found to be less than 6mSV when the scanning range is limited superiorly to the upper extent of the flap (between 2 and 4 cm above the umbilicus) and inferiorly to the origin of the DIEA and SIEA on the common femoral artery. This dose is considerably less than a standard abdominal CT and is equivalent to four abdominal plain films [38, 39].

Unidirectional Doppler and Two-Dimensional Duplex Doppler

The hand-held, unidirectional Doppler probe has been widely used in perforator mapping and is cheap and easy to use. Whilst it continues to be an adjunct to other methods, alone it is unable to provide the level of detail compared to other modalities. With low accuracy, high interobserver variability and the significant time associated with perforator mapping, it has limited value for pre-operative imaging for the DIEP.

Duplex Doppler imaging has shown a significant improvement on unidirectional Doppler and is able to determine dominant perforator location, size as well as flow. Whilst it is cheap and non-invasive, it is operator-dependent with high interobserver variability and does not provide the same level of anatomic detail and accuracy compared to CTA. It is still associated with high scanning times and has a significant degree of false positives and false negatives.

Magnetic Resonance Angiography (MRA)

MRA remains a continuing area of interest in the area of perforator mapping, with the initial advantage of avoiding the radiation exposure associated with CTA, whilst still providing accurate localisation and high-quality imaging of perforators. MRA is considered to have lower spatial resolution compared to CTA, but it can still reliably detect 1-mm-sized perforators and has higher contrast resolution which may

allow more accurate visualisation of the intramuscular course of perforators [40]. MRA also provides clear delineation of the superficial venous system even during peak arterial enhancement of perforators.

However, there are a number of drawbacks with using MRA for routine pre-operative perforator mapping. There is a lengthy examination time involved of up to 40 min, which may be difficult for patients with claustrophobia and anxiety, or those unable to lie still. MRA is less accessible and contraindicated in patients with non-MRI-compatible implants or metallic foreign bodies, and similarly to CTA, it is contraindicated in patients with severe renal impairment.

The value of MRA and its impact on clinical outcomes are yet to be determined. In the future, with further advancements in technology and accessibility, MRA may become a widely adopted imaging modality for pre-operative mapping.

Surgical Technique

Pre-operative Marking

Pre-operative marking is done in the holding room, with the patient in standing position. Curtains are drawn for privacy. Standard anatomical landmarks for the chest are drawn, including the inframammary fold, breast meridian, midline of the chest and xiphisternum, the borders of the breast base and anterior axillary line. Markings for contralateral symmetrising procedures should be made if required and reassessed intra-operatively.

For the abdomen, a fusiform ellipse is drawn extending to each anterior superior iliac spine. The upper incision extends just superior to the umbilicus, with the inferior incision extending along the suprapubic crease. These markings can be adjusted based on the laxity of the tissue and amount of tissue available, and efforts should be made to centre the flap over the selected perforator.

Intra-operative Technique

Like with any free flap, the operative technique comprises of three main elements – flap raise and closure of the donor site, exposure and preparation of recipient vessels and microsurgery and flap inset. Ideally, two surgical teams operating in tandem will be able to reduce operating time by working on these different components simultaneously where possible.

Flap Raise and Donor Site Closure

The marked elliptical incision is made to the level of the fascia. When making the inferior incision, the superficial system should be carefully explored. If the superficial epigastric vein is found to be of large calibre, more than 1.5 mm, it should be preserved as a possible second venous drainage. In some cases, a primary second venous drainage can be performed prospectively, for example, if only small perforating veins and a large SIEV are seen on pre-operative imaging. An incision around the umbilicus and umbilical stalk is also made. In bilateral reconstruction, an incision can be made down the midline.

Suprafascial dissection then begins from the flanks, working medially. The skin and subcutaneous tissue are separated from the external oblique fascia with the use of diathermy. Once approaching the lateral border of the rectus abdominis, more care is taken as perforators are identified (see Fig. 17.2). Pre-operative imaging and perforator selection can help to speed up this process, as division of lateral perforators will allow better access medially. Dissection can proceed from all directions to improve visualisation of perforators. The assistant should be providing gentle traction to assist with dissection. If the calibre of an individual perforator is small, one or more perforators in the same vertical row can be dissected and included in the flap. A good-sized perforator will have a palpable or visibly pulsating artery and will have a vein >1 mm in diameter where it is entering the flap [41].

When beginning dissection around the perforator, the abdominal wall should be paralysed. This is imperative as any movement of the muscles from coughing or stimulation by diathermy may damage or avulse the perforator. Using scissors, the rectus fascia is incised. With careful dissection and lifting up of the fascia, the fascia is incised 2 cm superiorly and several centimetres inferiorly, oriented obliquely towards the origin of the DIEA. The perforator may travel for a variable distance adherent to the deep surface of the

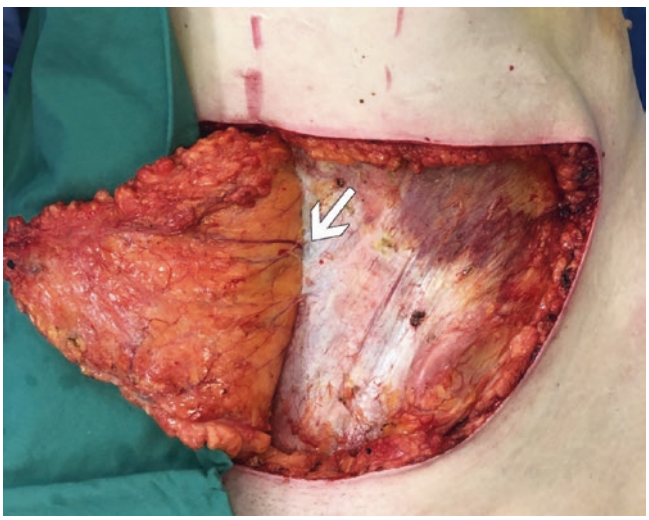


Fig. 17.2 Intra-operative photograph during DIEP flap harvest, identifying the perforator seen on pre-operative CTA imaging, at the level of perforation of the anterior rectus sheath (white arrow)

fascia, so care must be taken when incising the fascia until it is seen to dive intramuscularly. Clear exposure is key in order to identify and carefully clip all small branches. Clips should be placed 1–2 mm away from the main perforator to give space for a second clip if required. Inadvertent avulsion of these branches may damage the perforator or cause it to spasm and cause bleeding which obscures vision.

Once the perforator begins its intramuscular course, the overlying and underlying muscle fibres are cauterised with bipolar forceps or scissors to continue following the perforator. If more than one perforator is being included in the flap, all intervening tissue will need to be dissected and divided until they are seen to form into a single vessel. Sensory nerve branches run superficially within the subcutaneous fat and can be safely ligated. Motor nerve branches may be identified running through or underneath the muscle and should be preserved unless they are running between two perforators. Any time there is resistance to dissection of the pedicle, or the pedicle appears tethered adjacent muscle fibres, a small muscular branch or nerve will be encountered. On encountering any larger branches, if there is any uncertainty about which is the main DIEA branch and which is the perforator, clipping branches should be held until the anatomy is better visualised. Dissection continues inferiorly, with sequential division of the rectus fascia, overlying muscle fibres, and control of small muscular branches, until adequate pedicle length and calibre are attained. This may be at the origin of the perforator on the major branch of the DIEA, or it may require further dissection to the main DIEA. If further dissection is required, consider limiting the inferior extent of fascial incision that is made through the use of retraction underneath the muscle. Incidence of post-operative lower abdominal bulge is multifactorial but is primarily due to the disruption of the anterior rectus sheath [42].

It is important to stop to observe the flap for perfusion, capillary refill and bleeding at critical points. Other perforators which have been preserved up to this point may be clamped to ensure adequacy of the raised pedicle. If the flap does not appear be well perfused, additional perforators along the same vertical row or conversion to an MS-TRAM flap should be considered. In the case of venous congestion, the connected deep venous system may not be sufficient to supply the raised flap. If present and intact, the SIEV or large superficial vein can then be used as venous super-drainage [43]. Once perfusion is confirmed, the remainder of the flap can be raised with ligation of remaining perforators.

The flap extent/dimensions are based therefore on pre-operative perforator angiosome mapping on pre-operative imaging (see Figs. 17.3 and 17.4), as well as on intra-operative observation of perfusion.

In a bilateral case, the other side can then be raised. The raised flap should be secured back in position with skin staples, with a staple on the skin to mark out the location of pedicle. Once the recipient site and vessels have been prepared, the pedicle can be divided. The vessels can be marked with a skin marker along one side to assist with orientation of the flap. The flap is turned over with the pedicle laid carefully on the undersurface, ensuring there is no twisting or rotation of the pedicle. The flap is then weighed, with the ischaemia time noted. Once the flap has been transferred to the recipient site, it should be stapled to the surrounding skin for stability. A moist pack is used to prevent desiccation during microsurgery.

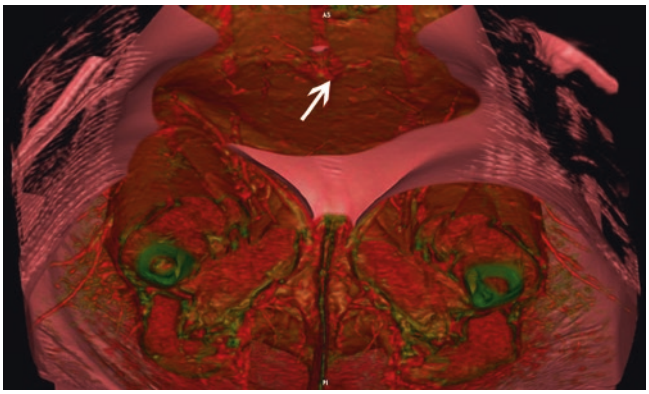


Fig. 17.3 Computed tomographic angiogram (CTA) of the abdominal wall vasculature, demonstrating a periumbilical perforator in its three-dimensional subcutaneous course, enabling mapping of its perforator angiosome/perforasome (white arrow)

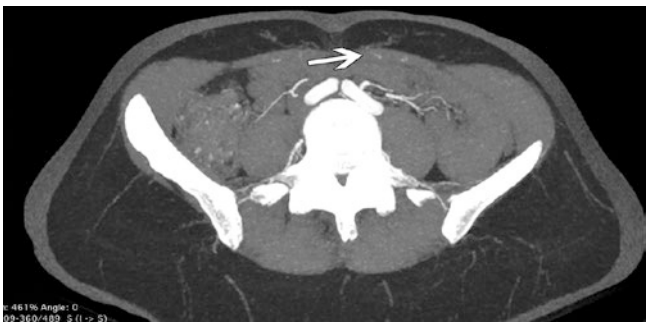


Fig. 17.4 Computed tomographic angiogram (CTA) of the abdominal wall vasculature, demonstrating a periumbilical perforator in its three-dimensional subcutaneous intramuscular course, enabling mapping of its perforator angiosome/perforasome (white arrow), and the course through rectus abdominus to the deep inferior epigastric artery (DIEA) pedicle

Donor Site Closure

Closure of the donor site proceeds in a stepwise fashion. First the rectus fascia is closed using a monofilament absorbable or non-absorbable suture, first with a row of interrupted figure-8 knots, followed by a second reinforcing running suture. In the case of the DIEP flap, the primary closure of

the fascia should be achievable in a tension-free manner. In some situations, either a biologic or synthetic mesh can be necessary as an inlay graft to achieve tension-free closure [44]. Once the fascial defect is closed, plication of the remaining fascia may be required to improve contour [45]. This is achieved through the similar use of interrupted figure-8 sutures. In unilateral reconstructions, plication of the contralateral abdomen may assist in centralising the umbilicus and even out the anterior abdominal wall. In bilateral reconstructions, midline plication will help prevent an upper abdominal bulge.

The operating table will need to be put in a flexed position to aid closure of the skin. A drain on either side of the patient is placed through separate stab incisions. The position of the umbilicus should be marked on the abdominal wall so it can be easily brought up through the abdominoplasty flap. Scarpa's fascia is closed with Vicryl suture, followed by interrupted buried dermal sutures and a running subcuticular suture, carefully addressing any dog ears at the lateral aspects of the wound.

The use of progressive tension sutures using unidirectional barbed sutures in the closure of the DIEP donor site has been proposed [46–48], following favourable results seen in the literature for abdominoplasty, to reduce seroma formation and eliminate the need for abdominal drains. In two small series of DIEP flaps, Liang et al. [46] found that progressive tension with running barbed sutures reduced drain output volumes, whereas Nagarkar et al. [47] chose to forgo drains using this technique without adverse outcome.

Breaking the table may not always be necessary, and avoiding this can help to ensure reliable closure. On-table tissue expansion techniques can be performed if direct closure will be particularly tight, and we have used a technique utilising K-wires and the principles of mechanical creep to achieve this [49]. In this technique, K-wires are woven longitudinally along the dermal edges of either side of the wound, and the wound is slowly closed and held in that position for 20 min through the serial and sequential application of open towel clips.

Recipient Site and Vessel Preparation

In immediate reconstruction, the mastectomy site should first be irrigated and inspected for skin viability and haemostasis. Overdissection of the pocket, which may occur laterally, inferiorly or medially, should be corrected with internal tacking sutures to restore the inframammary fold and natural breast footprint.

In delayed reconstruction, the mastectomy scar should be fully excised to allow for an even appearance on flap inset. The mastectomy flaps should be raised, with the undersurface of the flaps scored to assist with pliability and mobility of the tissue.

The internal mammary vessels have become the preferred choice for recipient vessels over the thoracodorsal vessels. Using the thoracodorsal vessels requires a longer pedicle or risking lateral positioning of the flap and lateral fullness, whereas the internal mammary vessels are centrally positioned in a way that is more flexible during flap inset and breast shaping and allows easy access for both the surgeon and assistant during microsurgery [50]. The internal mammary vessels have a more favourable size match, and venous drainage is aided by negative intrathoracic pressure. Previous axillary surgery and radiotherapy are more likely to cause scarring or perivascular fibrosis to the thoracodorsal vessels in the case of delayed reconstruction, and they are more prone to spasm. Using the thoracodorsal vessels also prevents the use of the latissimus dorsi flap as a secondary salvage procedure.

The disadvantages of the internal mammary vessels compared to the thoracodorsal vessels include precluding their use in coronary artery bypass surgery, the removal of rib cartilage required and the lengthier time and dissection required.

When accessing the internal mammary vessels, the third rib cartilage is usually removed to improve exposure. The patient should be examined in the standing position preoperatively to ensure that removing the chosen cartilage will not be visible as a chest contour deformity. The main vessels are most commonly used, though the perforators can be used if they are of sufficient calibre. The artery size is reliably between 2.5 and 2.8 mm at the third to fifth intercostal spaces [51]. The venous anatomy however is more variable. The left-sided veins tend to be smaller than the right and, in 70% of patients, exist as two paired veins which unite to form a single vein at various levels [51, 52]. In 68% of cases they are united at the upper border of the third rib. At the level of the second intercostal space, the vessels are larger and the vein will be more likely to exist as a single larger vessel compared to the third or fourth space. Even so, using one of the smaller paired veins is usually adequate. Otherwise the thoracodorsal vessels can be used, with the cephalic vein and external jugular vein being other alternatives.

The exposure gained by removing one segment of intercostal cartilage will vary from patient to patient. There may be adequate exposure by only removing intercostal muscles of an intercostal space without removal of any cartilage, but nibbling of the lower border of the rib above and upper border of the rib below may also be required.

The third costal cartilage is palpated, and the pectoralis major muscle is divided along its fibres with diathermy from the sternocostal junction laterally along the rib to a length of approximately 4 cm. This will expose the anterior perichondrium. An 'H' incision is made and the perichondrium is elevated superiorly and inferiorly off the cartilage, developing the plane under the perichondrium as much as safely possible. A heavy bone nibbler is then applied, working laterally

initially to keep away from the vessels, whilst keeping the posterior perichondrium intact. The periosteal elevator is used to continue developing this subperichondrial plane to allow the remainder of the cartilage to be removed without issue.

Next, the intercostal muscle and posterior perichondrium are elevated and excised. At the lateral extent, the perichondrium is incised. Immediately deep to the perichondrium is a thin layer of subcutaneous fat, through which the internal mammary vessels will be visible medially. The perichondrium is then carefully elevated using blunt dissection, using bipolar at low setting to control any vessels. If there is only one vein, it is usually medial to the artery. The vessels should now be on view, and the surrounding intercostal muscle should be divided with bipolar forceps to expose the length of the vessels. The vessels do need to be gently freed and mobilised from the fatty layer underneath, with keen awareness that the pleural membrane lies immediately deep to this layer. Lymphatics run through this layer and lymph nodes may be encountered. Side branches of the main vessels should be carefully controlled with clips. If the vessels are too small or damaged from previous radiotherapy, the option of removing an adjacent costal cartilage should be entertained before looking at other sites for recipient vessels. The vessels are to be irrigated with a vasodilator solution and covered with a moist gauze in the interim until the flap is ready for anastomosis.

Microvascular Anastomosis and Shaping of the Breast

Prior to anastomosis, the flap must be oriented to reduce any chance of kinking or twisting the pedicle. In the shaping of the breast, the breast footprint, breast conus and skin envelope are all taken into consideration [53]. Most commonly the flap is rotated 180 degrees prior to anastomosis and inset. This gives easy access to the superficial inferior epigastric vein if required and places the thicker portion of the flap from the mid-abdomen in the inferior pole of the breast.

Once microsurgery is complete, perfusion is assessed and bleeding from the edges of the flap is observed. The flap is placed underneath the mastectomy flaps, and flap volume, position and shaping are confirmed. The skin paddle can then be determined and the flap deepithelialised. A drain is placed at the outer inferior aspect of the pocket away from the pedicle. A final check for haemostasis is performed before proceeding to flap inset with interrupted and subcuticular dermal sutures.

The shaping of the breast mound is a key factor in achieving an aesthetic outcome. Ultimately the skill of manipulating the flap into a three-dimensional structure, with the optimum shape and projection for each individual patient, comes with experience. A small number of techniques have been described to assist with this learning process. Blondeel et al. implement a ‘three-suture’ technique, where Scarpa’s fascia is secured to the pectoralis fascia in the superolateral edge of the footprint, followed by a second suture to hold the lateral edge of the flap to the lateral inframammary fold under tension and a third suture placed medially to form a smooth medial cleavage [53]. Nahabedian et al. describe a similar technique for bilateral reconstructions, but in unilateral constructions, it rolls or folds the flap to provide projection [54]. We utilise the St. Andrews’ coning technique [55], where rounds of dissolvable sutures are placed on the upturned flap to shape the breast prior to anastomosis. A 3D-printed mirror image created from 3D photography of the contralateral side assists in the guidance of these coning sutures. A commonly quoted ‘rule of thumb’ is to use a similar volume of tissue and to medialise the flap. Gravity, tissue quality and time will contribute significantly to the final shape of the breast.

Technical Variations

Rib Preservation

Several large series of successful internal mammary exposure through a rib-sparing or rib preservation technique have been published in the literature [56–60]. The aim of this is to reduce post-operative pain and complications such as visible chest wall deformity and injury to intercostal vessels and nerves that may result during removal of the costal cartilage.

This approach uses the second, third or fourth intercostal space, whichever is wider or provides easier access and exposure to the internal mammary vessels. Kim et al. found that after selecting the largest of the intercostal spaces, mean intercostal space width was 18 mm [57], whereas in the series by Rosich-Medina et al., the mean was 21 mm with a range of 9–29 mm [59]. The pectoralis is split in a V-shaped fashion that allows it to be swept up and sutured to the rib above. The intercostals are divided at their point of insertion to the costal cartilage approximately 3–4 cm lateral to the sternal border, progressing medially to raise a laterally based flap of intercostal muscle to reveal the intercostal fascia and internal mammary vessels. If further exposure is required, an adjacent cartilage can be partially removed. Darcy et al. [56] describe using a swab to protect and push the vessels gently backwards to then remove the posterior perichondrium whilst leaving the anterior surface of the costal cartilage intact in order to further increase the length of exposure. In their series of 463 patients, they were able to safely achieve

adequate exposure and never required excision of a complete section of costal cartilage [56].

Sheath-Sparing Techniques

In dissecting the perforator to its origin at the DIEA, a longitudinal incision is usually made in the anterior rectus sheath to access the DIEA pedicle. A number of techniques have been investigated to limit the incision of rectus sheath required in order to reduce donor site morbidity and incidence of hernia or abdominal bulge.

A limited rectus sheath incision technique has been used in select patients whose pre-operative imaging showed large periumbilical perforators with an extended segment of DIEA without any musculocutaneous perforators [61]. In this technique, a limited incision is made to access the perforator, with a second incision made to access to DIEA pedicle, made in the line of the external oblique fibres, thereby limiting the length of incision required in the anterior rectus sheath.

An endoscopic approach to the DIEA pedicle has also been described, though successful clinical cases have been reported only recently for the DIEP flap. Hivelin et al. [62] successfully performed a delayed DIEP reconstruction utilising laparoscopic dissection of the pre-peritoneal plane, requiring a single 5-cm fascial incision. Experimental use of the da Vinci robot has showed robotically assisted DIEP flap harvest to be possible. Gundlapalli et al. [63] performed a robotically assisted DIEP flap harvest, using the da Vinci robot to assist in an intra-abdominal dissection of the pedicle, and were able to limit fascial incision to 1.5 cm.

Decisions as to these approaches are often also based on pre-operative imaging of the DIEA pedicle (see Fig. 17.5),

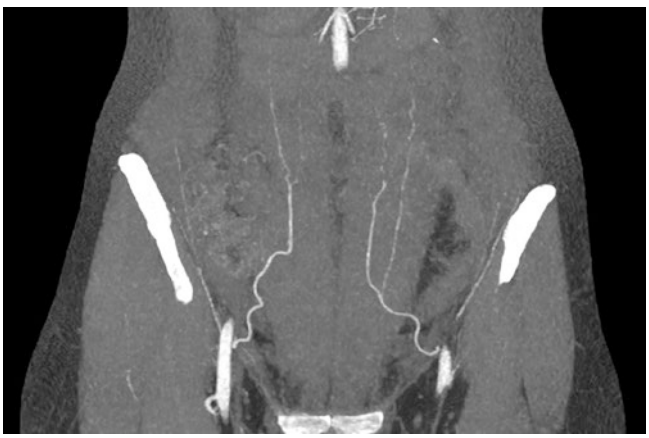


Fig. 17.5 Computed tomographic angiogram (CTA) of the abdominal wall vasculature, demonstrating the deep inferior epigastric artery (DIEA) pedicle

which can demonstrate major DIEA branches and relations of the DIEA to the surrounding soft tissues.

The Stacked DIEP

Zones I to III are generally reliably perfused in the DIEP flap. If there is insufficient abdominal tissue volume provided from a single DIEP flap, a DIEP from each hemiabdomen can be raised and 'stacked' in a unilateral reconstruction. Two sets of microvascular anastomoses are required. For the artery, end-to-end anastomosis can be made with the proximal and distal end of the transected internal mammary artery. The distal end will be perfused retrograde by the costomarginal artery [64]. Alternatively, one deep inferior epigastric artery can be connected end-to-end to the internal mammary and the second deep inferior epigastric artery connected end-to-side to the pedicle of the first. For the vein, paired venae comitantes of the internal mammary can be used if present. Other venous recipient vessels are discussed in the following section.

Extended Tissue Harvest (the 'Extended' DIEP)

Extended tissue harvest has been proposed as a technique to increase the volume of the harvested DIEP flap in cases where there may be insufficient volume in the standard DIEP flap design and raise, or where additional volume may reduce the need for contralateral reduction or second-stage fat grafting. Shafighi and Ramakrishnan [65] were able to extend their flap volume by recruiting subscarpal fat above the umbilicus. Upon incising Scarpa's fascia at the upper border of the flap, dissection proceeded cranially immediately below the fascia to include as much subscarpal fat tissue as possible, in a bevelling fashion for up to 6–8 cm. This extra tissue increased the total flap volume by 10–15% in a series of ten patients. The authors of this study found that the extra tissue was often helpful in recreating upper pole fullness and did not seem to have increased risk of fat necrosis.

Secondary Venous Drainage

Diffuse venous congestion in the DIEP flap can still occur despite patency of the DIEV anastomosis due to the intrinsic venous anatomy of the flap and dominance of the superficial venous system. Whilst the use of the SIEV has been traditionally described as a 'lifeboat' in salvage procedures, some surgeons have advocated use of the SIEV or a prominent superficial vein as a second venous drainage either routinely

[66, 67] or prophylactically when the deep venous system is suspected to be inadequate either on pre-operative imaging or intra-operatively.

Various recipient vessels for secondary outflow have been described. Many techniques have been described using the basilic vein [68], intercostal branch of the internal mammary vein [69] or intercostal vein [43], thoracodorsal vein [43], lateral thoracic vein [43] or external jugular vein [70]. We have found cephalic vein harvest for this purpose to be quick, easy and reliable [66]. For this technique, the deltopectoral groove is identified and marked, and this line is extended out onto the arm as the cranial-most limit of the incision. The anterior axillary skin crease is identified where the crease meets the deltopectoral groove, and an incision is made caudally from the marked line for 2–4 cm. Dissection occurs in the cranial part of the incision until the fat pad between the deltoid and pectoralis major is seen. The deltopectoral fascia is opened and the cephalic vein exposed.

Blunt dissection is performed with a finger to expose the path of the vein laterally along the arm. The vein is harvested medially, with division of any side branches, and usually followed until it dives towards the subclavian vein. The dissection is then continued laterally as far as possible as can be reached with long scissors and forceps. If further length is required, then serial stab incisions along the arm can be performed to follow the vein. The vein is then clamped and divided and is tunnelled subcutaneously to the chest wall.

The retrograde limb of the internal mammary vein has been used as a recipient vessel for secondary venous drainage [71–74], though its reliability remains controversial. In a series of 74 patients, La Padula et al. [72] performed double venous anastomoses in 36 patients using the retrograde limb of the IMV. In this group there were no incidences of venous exploration requiring takeback, in contrast to their single venous anastomosis control group. The IMV was previously thought to be valveless. However, Mackey et al. [75] in a cadaveric study showed 44% of cases had valves on at least one side. Thus, the retrograde limb of the IMV is unlikely to be reliable as a sole recipient vessel.

Intra-operative Fluorescent Angiography

Fluorescent angiography is a dynamic imaging modality that enables accurate assessment of blood flow and tissue perfusion through the fluorescence of intravenous dye, most commonly indocyanine green (ICG). It has been used in ophthalmology and other specialties for several decades, but over the last 10 years has seen use in areas of plastic surgery, particularly breast reconstruction. It has minimal value in pre-operative mapping as it is only able to assess tissues up to 1 cm deep [76]. However, it has been shown to accurately correlate areas of ICG-indicated hypoperfusion with areas of post-operative flap necrosis in TRAM and DIEP flaps intra-operatively [77, 78]. This allows either adjustment of the flap pedicle or anastomosis or guided excision of at-risk areas which are likely to declare itself post-operatively. At this point, evidence correlating with fluorescent angiography with clinical flap outcomes is non-confirmatory, but this may change with higher-powered studies and rigorous study design.

Optimising Efficiency

As the DIEP flap has evolved into a safe, reliable and routine method for autologous breast reconstruction, attention has turned to optimising efficiency of not only flap harvest but all steps of the procedure. Reducing the operative time not only has benefit for the patient but has significant cost-benefits in a public health system.

Well described are the routine use of a two-team approach, venous coupler and pre-operative CT angiography. Pre-operative imaging allows the course of surgical dissection to be anticipated and reduces decision-making intra-operatively [30–35]. The perforator vessel that is of the largest calibre and most central to the flap can be determined pre-operatively and aimed for immediately during dissection. A common pitfall is to preserve more lateral perforators which tethers the flap laterally, limits the rate and range of medial dissection of the flap and increases the risk of damage to the poorly visualised medial perforators.

A process mapping approach can be used to identify inefficiencies and improve operative flow [79]. For example, in our experience, the use of the intra-operative oesophageal Doppler monitor for haemodynamic monitor is effective and safe [80] and obviates the need for the insertion of a central or arterial line, which may take up to 20 min compared to the 2 min taken for the siting of an oesophageal Doppler probe via the port on a laryngeal mask. Ensuring a two-team approach is a simple way to improve efficiency as there are multiple steps in the operation that can be performed concurrently. Flap shaping and deepithelialisation can be performed whilst awaiting recipient vessel preparation, by temporarily insetting the flap in the mastectomy defect to determine the required flap volume and shape and size of required skin paddle. With optimisation of resources and efficiency, two DIEP cases can be routinely completed within daytime hours in a single operating theatre [81].

Post-operative Care and Flap Monitoring

Flap monitoring in the immediate post-operative period remains critical in order to swiftly identify any signs of flap compromise. Clinical flap assessment remains the standard for routine post-operative flap monitoring, with some experienced groups demonstrating salvage rates of 70–80% in compromised free flaps [82–85]. Timely detection of flap compromise and subsequent exploration in the operating theatre are likely to significantly improve the rate of salvage [86–89]. The no-reflow phenomenon, described in 1978 [90], confirmed the relationship between the duration of ischaemia and its reversibility, confining successful flap salvage to a critical window of only a few hours post the onset of microvascular thrombosis and tissue ischaemia.

This has led to a number of different monitoring techniques being developed and studied to improve early detection and therefore management of free flap compromise. However, with overall low incidence of flap compromise and takeback, as well as the variability in both the implementation of these techniques and the measurement of clinical outcomes in the literature, substantive evidence for the majority of techniques is lacking [91]. The effectiveness of any method in improving salvage rate and overall flap failure rates must also be balanced by its practicality. Creech and Miller laid down essential criteria for free flap monitoring, dictating that the ideal technique should be harmless, accurate, inexpensive, easy to use and interpret, rapid, repeatable, reliable, recordable and rapidly responsive [92].

The implantable Doppler probe is the technique that has been most extensively used and studied in the literature as an alternative or adjunct to traditional clinical monitoring [93–100]. It is, in our experience, a clinically valuable technique for either routine use or use in select patients. First introduced by Swartz in 1988 [101], the Cook-Swartz probe consists of a 5-mm silicone cuff containing a 20-MHz piezoelectric crystal. The cuff is secured around the venous pedicle with microclips, sutures or fibrin sealant and detects blood flow through the pedicle. The probe exits the skin as a thin wire through the surgical wound and is taped or sutured to the patient's skin to prevent accidental dislodgement. The wire connects to an external box which emits a sound to indicate blood flow in the pedicle. Once monitoring is no longer necessary, the electrode can be pulled free from the cuff with a tension of 50 g. Initial studies placed the probe around the arterial anastomosis, but subsequent studies found that the probe was more sensitive when placed on the venous pedicle [101]. The arterial Doppler is only able to detect venous occlusion after a period of 3–4 h, whereas the venous Doppler detects both venous and arterial occlusion immediately [101].

Two separate meta-analyses were performed in 2016 by Han [102] and Chang [103] to compare the implantable Doppler probe and clinical assessment in post-operative flap monitoring, which included 1995 patients across five studies and 3252 flaps across six studies, respectively. They both concluded that the implantable Doppler group had a significantly greater flap salvage rate and decreased flap failure rate. One drawback of the implantable Doppler probe is a higher rate of false positives, ranging 0–17% [102, 103], thus requiring an unnecessary return to theatre. False positives were associated with probe dislodgement, fibrin coating or device malfunction and thought to be primarily due to the learning curve associated with the placement of the probe around the pedicle.

A small number of comparative series comparing clinical flap monitoring with other techniques show promise. These include microdialysis [98, 104], which provides real-time measurements of flap metabolism and therefore ischaemia; fluorimetry [105], which can monitor elimination and perfusion of fluorescein or indocyanine green in the flap following intravenous infusion; and near-infrared spectroscopy [106, 107], which uses a non-invasive oximeter probe to measure haemoglobin saturation and tissue oxygenation at the capillary level. In a retrospective series of 1050 free flaps for breast reconstruction, Koolen et al. [106] found the adjunct use of near-infrared spectroscopy (T.Ox tissue oximeter by ViOptix) to significantly improve salvage rate and reduce total flap loss. In the near-infrared spectroscopy group comprising 670 flaps and 29 re-explorations for flap compromise, the salvage rate was 96.6% compared to 57.7% in the group that received clinical monitoring alone.

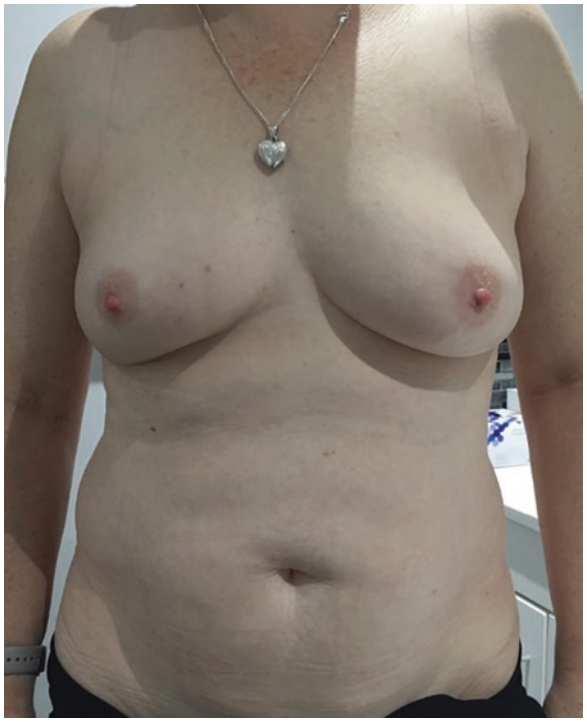
With regard to the standard post-operative course, patients should be fitted with an abdominal binder and encouraged to mobilise or sit out in a chair on day 1. Venous thromboembolism chemoprophylaxis should be given, along with regular simple analgesia and breakthrough oral opiates. The urinary catheter is removed once the patient is mobilising. A soft bra can be worn by the patient from day 2. The patient is discharged on day 5 of an uneventful hospital stay. Drains are kept in situ until their outputs are less than 30 ml/day.

Clinical Cases

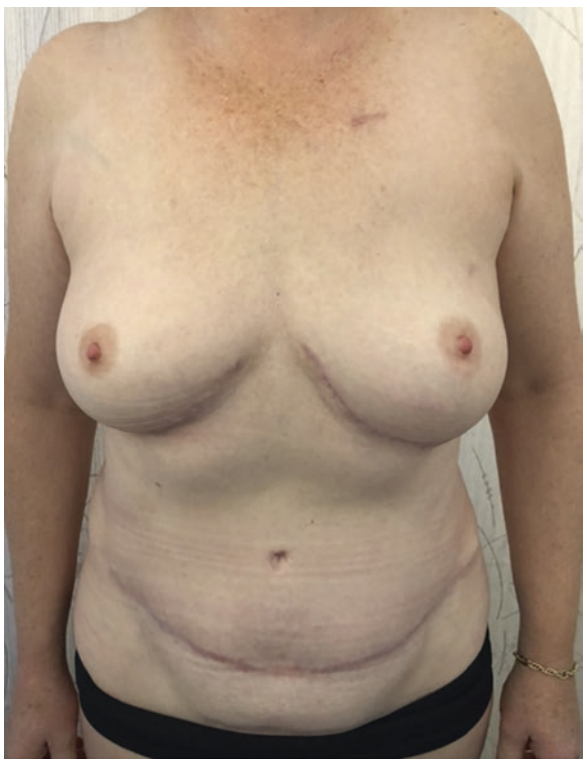
Case 1

The first example demonstrates a woman with bilateral early breast cancer, planned for bilateral, skin and nipple

sparing mastectomies and immediate breast reconstruction with DIEP flaps, with no plan for adjuvant radiotherapy.

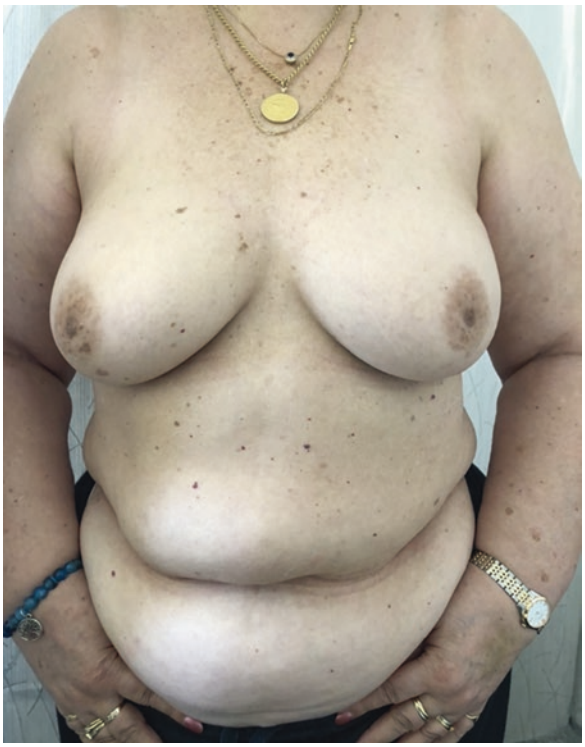


She was planned for an 'envelope' mastectomy, with an inframammary approach to the mastectomy, and no superior chest wall scars at all. Skin paddles were placed within the inframammary folds for monitoring, and the internal mammary vessels used as recipient vessels. The skin paddles were excised secondarily.

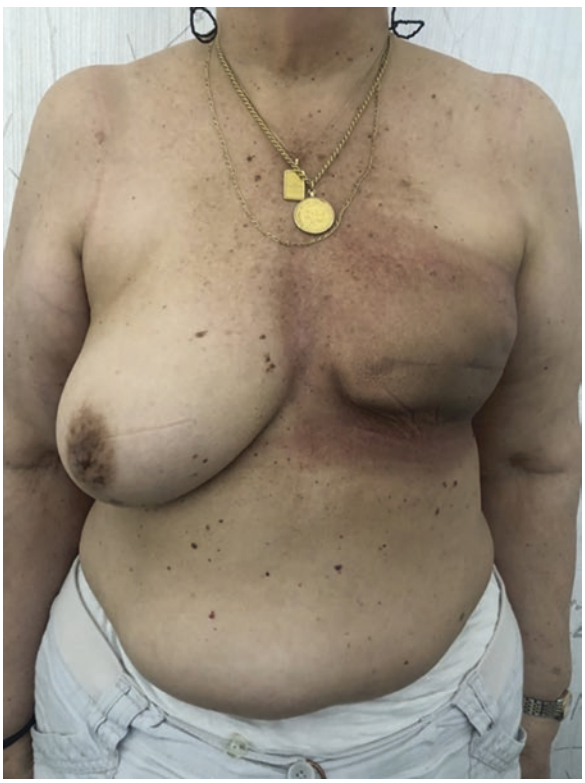


Case 2

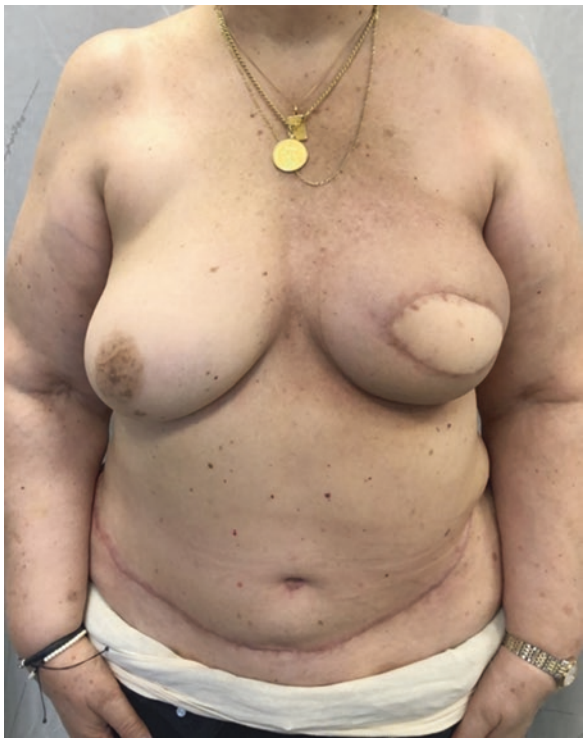
This case demonstrates a woman with locally advanced breast cancer, planned for mastectomy, and a delayed unilateral breast reconstruction after adjuvant radiotherapy.



A tissue expander was placed at the time of mastectomy to maximise preservation of the native skin envelope, and was maintained in-situ through adjuvant radiotherapy.



She ultimately underwent a delayed unilateral breast reconstruction with a DIEP flap.



Conclusion

The DIEP flap provides a reliable and aesthetic breast reconstruction whilst minimising donor morbidity. Pre-operative imaging and various intraoperative techniques allow the experienced surgeon flexibility to manoeuvre and troubleshoot unfavourable perforator anatomy or unexpected anatomical variants.

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18 Breast Reconstruction with the Neurotized Deep Inferior Epigastric Perforator Flap

Andres Rodriguez-Lorenzo, Tianyi Liu, and Maria Mani

Introduction

Abdominal-based free flap for autologous breast reconstruction has become the gold standard in experienced microsurgical centers. While an insensate flap, the DIEP free flaps have been noted to gain some spontaneous degree of sensation over time; however, the recovery remains unpredictable and varies among studies in the literature.

The technique of neurotization of abdominal free flaps for breast reconstruction was described more than 20 years ago [1, 2]. However, this technique has gained new popularity in recent years in an effort to enhance sensation and quality of life in autologous breast reconstruction [3–5]. It has been a matter of debate and research if nerve coaptation in abdominal free flaps would increase the sensory outcomes in comparison with nonneurotized flaps. It has been reported that due to the progressive spontaneous sensory recovery observed in non-innervated flaps, the time spent to do nerve dissection and coaptation could be spared [6]. When quantitatively comparing sensory return of innervated versus non-innervated DIEP flaps, Blondeel et al. [2] found only an improvement in the sensation of the central (nipple-areolar) segment in innervated flaps, while Yak et al. [7] showed a significant improvement in the sensation of both the innervated flap and mastectomy skin. The heterogenicity of published data makes it difficult to assess and compare results between non-neurotized and neurotized DIEP [8]. However, as shown by a systematic review of the literature performed by Beugels et al. [9] that included 1177 breast reconstructions and 32 studies, the quality of sensation in innervated flaps was superior, started earlier, and gradually improved overtime in comparison to non-innervated flaps.

Breast numbness is a recognized problem in some patients after mastectomy and breast reconstruction especially in the early postoperative period which may cause secondary complications such as thermal or pressure injuries to the breast [10, 11]. Several publications reported thermal injuries in non-sensate flaps [12], with an incidence of 0.7% of thermal injuries in a clinical series of 600 DIEPs which occurred between 2 and 18 months postoperatively.

Herein we describe the surgical technique, anatomical considerations, and patient selection using neurotized DIEP flaps for breast reconstruction.

Anatomy

The main technical difference between an innervated and non-innervated DIEP is the inclusion of a nerve in the flap harvesting and selection of a recipient nerve along with the vessels in the recipient site. Selection of recipient and donor nerves is relevant to maximize sensory recovery in the innervated DIEP reconstruction [13] (Fig. 18.1).

Selection of Branches of Intercostal Nerves from T10 to T12 to Be Included in the Flap

The appropriate selection of the perforating neurosomes has been emphasized for optimum sensory recovery [13]. An anatomical and electrophysiological study by Yap et al. [7] describes the course of the motor and cutaneous branches of the intercostal nerves that provide segmental innervation to the anterior abdominal wall. Lower intercostal nerves seem to enter the rectus muscle at its lateral border, while the T12 intercostal nerve enters beneath the

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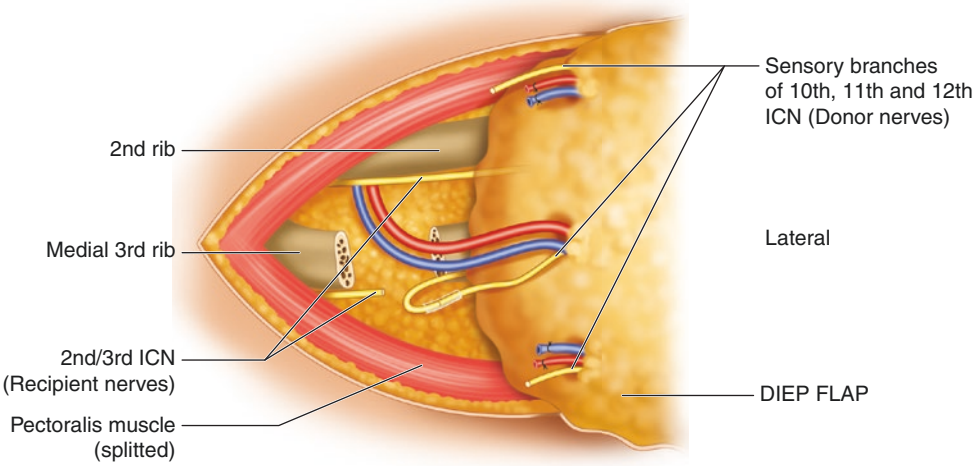

Fig. 18.1 Illustration showing the donor and recipient nerves commonly used in breast reconstruction with the innervated DIEP

anterior rectus sheath superficial to the muscle. The main trunk of the intercostal nerves gives off intramuscular motor nerve branches to the rectus abdominis muscle. The cutaneous branches divide from the main trunk where they join the medial or lateral row perforator vessels. It is advocated to harvest the cutaneous nerve at this branching point with either the medial or lateral row perforators to preserve the motor function to muscle [7]. Alternatively, the cutaneous nerve associated with the most inferior and lateral perforator vessel can be dissected and harvested at the level of the fascia in T10 to T12 nerves. To allow for primary tensionless nerve repair, a long intercostal nerve of up to 10–12 cm can be harvested including both sensory and motor components by lateral dissection [13]. A nerve autograft or allograft may be necessary for nerve coaptation in case a shorter nerve is dissected [5].

Recipient Site: Sensory Branches of the Third to Fifth Intercostal Nerves

The sensory innervation of the breast originates from medial and lateral cutaneous branches of the third to fifth intercostal nerves. Recipient nerve selection depends on the availability of the nerves postmastectomy [14]. Isenberg et al. [15] reported superior sensory return to breast flaps with coaptation to the lateral branch of the fourth intercostal nerve which consequently has become the standard recipient nerve. This has a diameter of 2 mm and can be located laterally to the pectoralis minor and traveling under the thoracodorsal vessels. The anterior branch of the third intercostal nerve can be found in the third intercostal space adjacent to the sternum during internal mammary vessel dissection to be used as recipient nerve [5].

Patient Selection, Preoperative Planning, Patient Preparation, and Postoperative Care

Both immediate and delayed breast reconstruction patients are candidates for sensate DIEP free flap reconstruction if the patient qualifies for autologous microvascular reconstruction. General requirement at our institution for breast reconstruction is nicotine free 6 weeks preoperatively, BMI less than 30 (relative indication), and no comorbidity that contraindicates long general anesthesia. The indication of neurotized DIEP is currently based on surgeon preference as there is still no strong evidence to offer neurotized DIEP as the standard of care in autologous breast reconstruction. We perform CT angiography preoperatively to map the abdominal perforators and standard preparation as described elsewhere [16], and the surgery is performed using a two-team approach [17].

The patients are mobilized from day 1 postoperatively and discharged on day 4. The postoperative care follows the same routines as non-neurotized DIEP.

Surgical Technique

(a) Flap Harvest. As in standard DIEP flap harvest, the dissection starts by identifying the superficial epigastric vessels (SIEV) which may serve as a life boat for venous outflow. The dissection is then carried out from lateral to medial to identify the perforators vessels and nerves. Several branches of the tenth to twelfth intercostal nerves can be encountered during the dissection as they arise parallel to vascular perforators from the lateral and medial row. One of the nerves is included in the flap and ideally running parallel to the main vascular perforator to allow for direct coaptation at the recipient site. The selected nerve is referred with a vessel loop and dissected laterally in the subfascial plane to increase the nerve length, which allows for direct coaptation. The perforator is then dissected in a standard fashion toward the source vessel (Figs. 18.2 and 18.3).

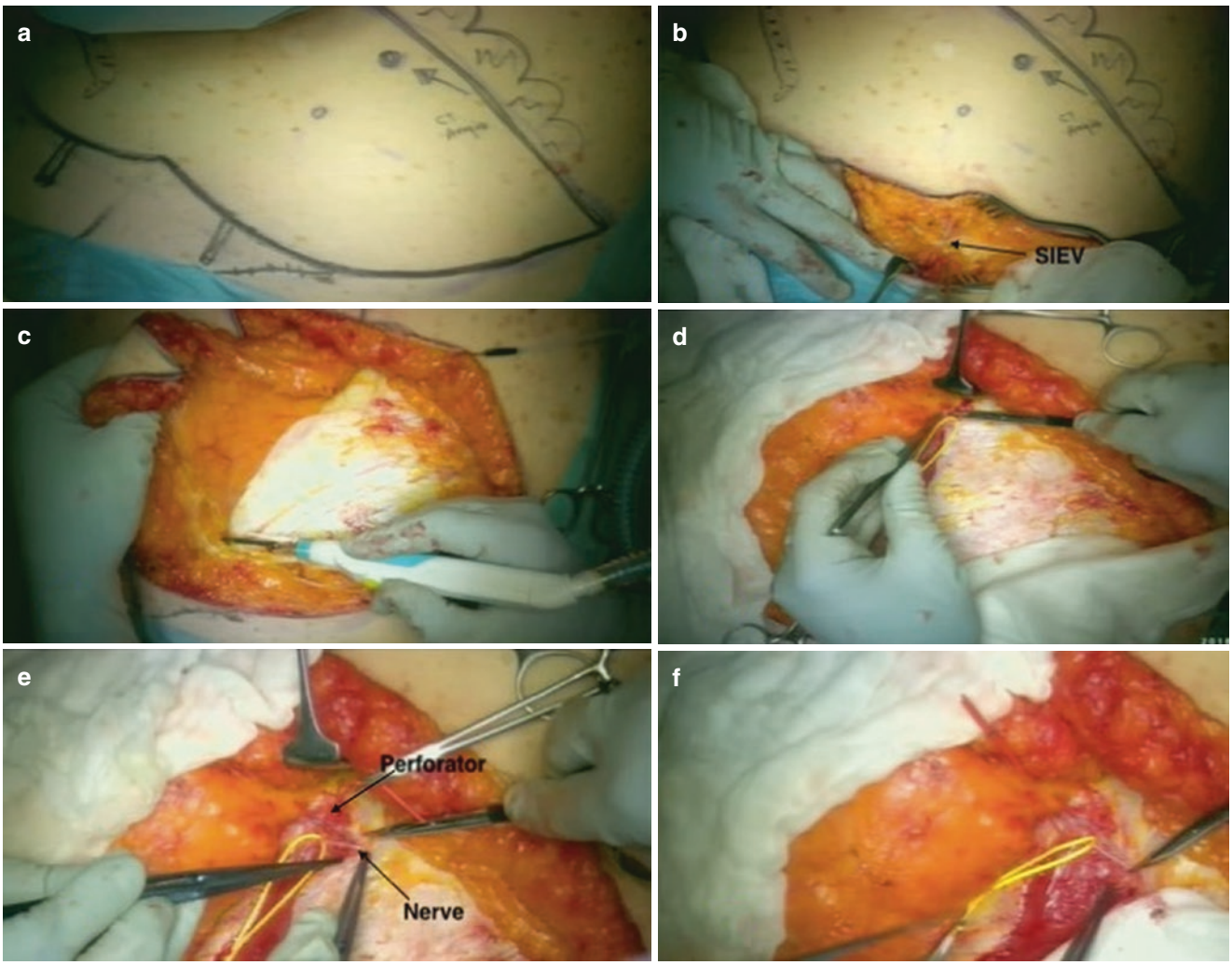

Fig. 18.2 Flap harvesting sequence of the innervated DIEP. (**a**) Flap design including marking of dominant perforator seen in CT angiography; (**b**) dissection of SIEV; (**c**) lateral to medial standard dissection searching for the perforator and nerves; (**d**) identification and reference of sensory nerve with yellow vessel loop; (**e**) identification of vascular perforator and reference with a red vessel loop; (**f**) subfascial lateral dissection of the nerve

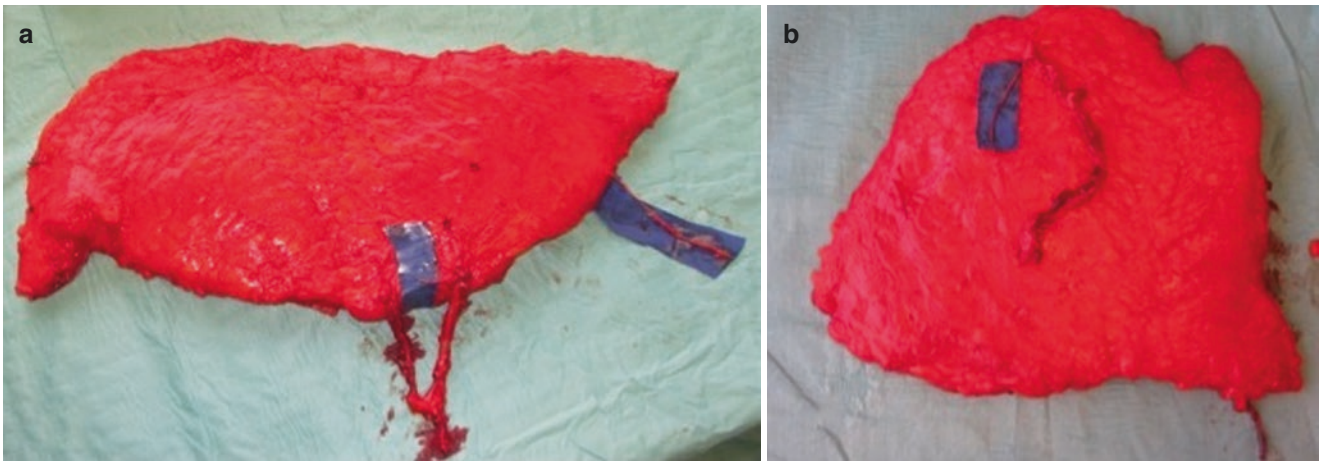

Fig. 18.3 Two examples of harvested flap showing the vascular pedicle and the nerve with a blue background. (**a**) Flap harvested with two nerves, one short nerve parallel to vascular perforator and one long nerve lateral. (**b**) Flap harvested with one nerve parallel to vascular perforator

(b) Recipient Site: The internal mammary vessels are harvested in the second or third intercostal space after the breast pocket is performed. The sensory branch of the intercostal nerves is seen under the upper rib of the space, transected, and dissected laterally to allow coaptation with the nerve from the flap. The internal mammary artery and vein (IMA and IMV) are dissected and prepared for anastomosis to the pedicle (Fig. 18.4).

(c) Flap Positioning: Several combinations can be performed, but we favor the use of contralateral hemiabdomen flaps rotated 180 degrees to allow the easier coaptation of the nerve to the intercostal nerve dissected in the intercostal space (Fig. 18.5).

(d) Vascular and Nerve Repair: Microvascular anastomosis is performed first (artery with 9/0 nylon and vein with a coupler device), and then the nerve is coapted with 9/0 nylon and fibrin glue (Fig. 18.6).

(e) Flap insetting, breast shaping, and donor site closure are standards prescribed.

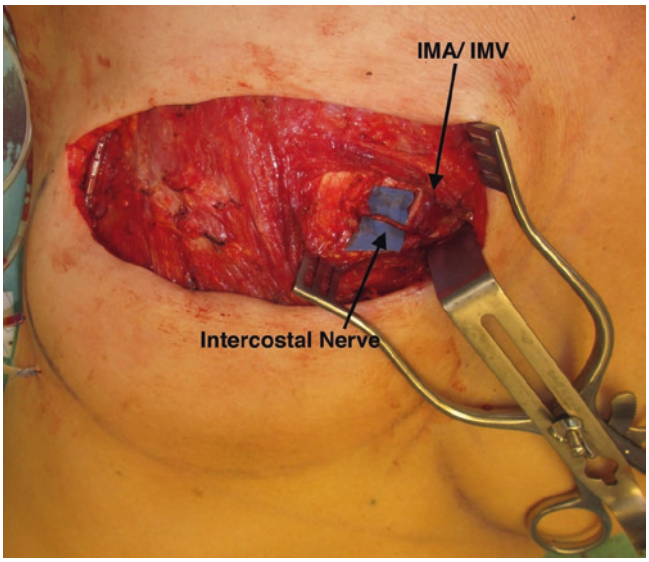

Fig. 18.4 Recipient site after breast pocket is prepared, the internal mammary artery and vein dissected (IMA/IMV) and the donor intercostal nerve

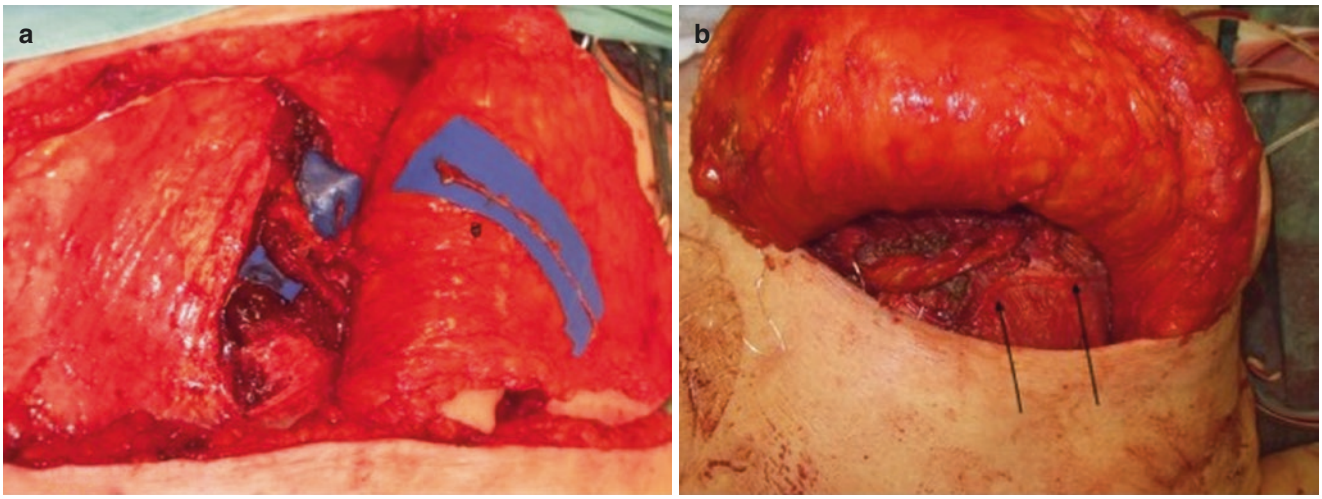

Fig. 18.5 Example of flap insetting after vascular anastomosis. (**a**) The nerves prepared are to be connected; (**b**) the arrows show the nerves after repair

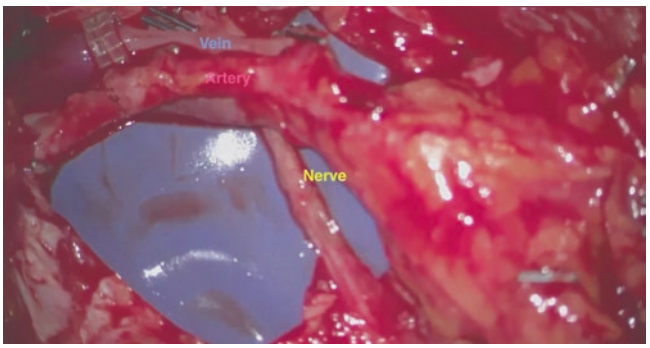

Fig. 18.6 Microscopic view of vascular and nerve anastomoses

Technical Variations

The main technical variations for neurotizing DIEPs are the possibility to perform direct nerve coaptation versus interposition of a nerve autograft or an allograft. To be able to perform direct nerve coaptation, subfascial lateral dissection of the sensory branch of the intercostal nerves needs to be performed in contrast with a less extensive dissection when the strategy is to use nerve grafts. There are currently no prospective studies that show any differences in sensory outcomes or donor site comorbidities between these methods.

Clinical Case

A 59-year-old woman with right side breast cancer was previously treated with mastectomy followed by chemotherapy and radiotherapy (Fig. 18.7). Delayed breast reconstruction with a neurotized DIEP was performed 3 years later followed by contralateral breast reduction and nipple reconstruction. At 1-year follow-up, the patient recovered light sensation of the whole skin paddle of the flap (red dots), more intense in the medial aspect (Fig. 18.8).

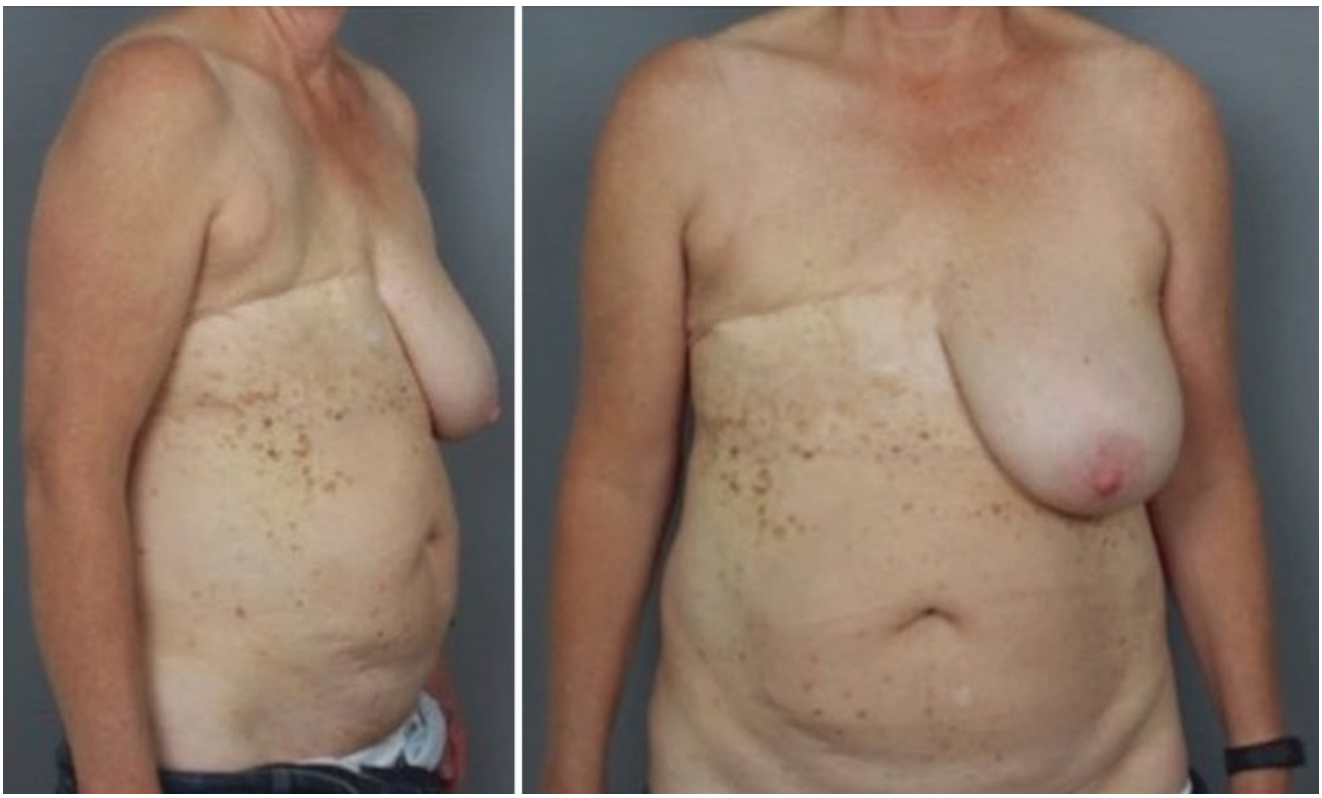

Fig. 18.7 Preoperative photos of clinical case of breast reconstruction with innervated DIEP

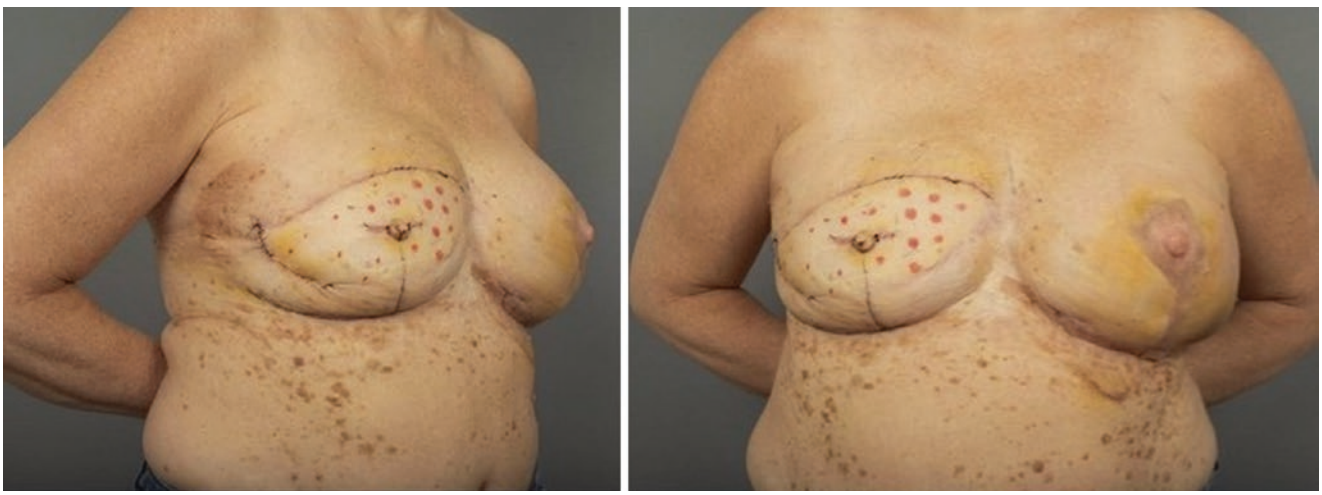

Fig. 18.8 One-year follow-up after breast reconstruction with innervated DIEP and secondary procedures with contralateral breast reduction and nipple reconstruction with sensory recovery of the skin flap (marked with red dots)

Conclusions

Neurotization of DIEP flaps in breast reconstruction should be considered in autologous breast reconstruction. The heterogenicity of the data shown in the literature still does not provide strong evidence of its benefit in comparison with non-innervated DIEP long term; however, studies suggest that sensory recovery can be achieved early. Selection of recipient and donor nerves may play a role in the final outcomes and quality of recovery as it influences the potential neurosome distribution of the flap as well as the possibility of direct nerve coaptation.

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Breast Reconstruction with Simultaneous Lymphatic Transfers

19

Warren Mathew Rozen, Harmeet K. Bhullar, David J. Hunter-Smith, and Rafael Acosta

Introduction

Lymphoedema of the upper extremity is a distressing consequence of breast cancer treatment. It describes an accumulation of protein-rich fluid in the interstitial space due to an imbalance between lymphatic production and drainage [1].

The damage and destruction to the lymphatic system of the upper extremity can be caused by radiation therapy, surgical management and local destruction by the tumour. Lymphoedema post mastectomy and sentinel node biopsy can occur in 3–23% of patients and 30–47% of patients post mastectomy and axillary node dissection [2]. Radiation therapy post mastectomy has also been shown to cause lymphoedema with a rate of 58–65% [2]. Therefore, the reconstructive surgeon must consider the surgical management of lymphoedema when planning for breast reconstruction post mastectomy.

The signs and symptoms of lymphoedema include [1, 3]:

- Sensation of heaviness and discomfort.
- Pitting or non-pitting oedema.
- Skin thickening and fibrosis.
- Lymphorrhoea: weeping and oozing of clear to light yellow fluid.
- Peau d'orange: pitted or dimpled texture of the affected skin.
- Elephantiasis nostras verrucosa: the skin develops a warty, hyperkeratotic or 'cobblestoned' appearance.

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Lymphoedema can also cause psychological distress to breast cancer survivors by acting as a consistent reminder of previous disease and attract unwanted attention from others [4].

Patients with lymphoedema are susceptible to a number of complications. Recurrent soft tissue infections such as erysipelas and cellulitis from group A streptococcus can occur. Each episode of soft tissue infection further damages the lymphatic system, exacerbating the patient's condition. Cutaneous ulcerations are common and difficult to manage. In rare cases, cutaneous angiosarcoma, a rare and aggressive tumour, can develop.

The current gold standard of treatment is complete decongestive therapy (CDT) administered by a certified lymphoedema therapist. It is comprised of an initial reductive phase and a maintenance phase [5]:

- Initial reductive phase: daily manual lymph drainage, multilayer, short-stretch compression bandaging, therapeutic exercise, skin care, education in self-management and elastic compression for 3–8 weeks.
- Maintenance phase: self-lymph drainage, exercise, skin care and compression garments or bandages.

Surgical management should be considered when conservative measures have failed. Surgery is indicated when there is insufficient lymphoedema reduction, recurrent episodes of infection, decreasing limb function and the patient's desire to pursue surgery. The surgical options for lymphoedema management include ablative and physiologic operations [5].

Ablative operations include debulking procedures and liposuction. Debulking procedures are simple to perform and reduce the size of the lymphoedematous extremities; however, they result in extensive scars and are associated with significant morbidity for the patient.

Liposuction involves aspiration of subcutaneous fat via a small metallic cannula attached to a suction device. It is effective at reducing the volume of hypertrophic adipose tissue; however, it has the potential of damaging the residual lymphatic vessels.

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Physiologic operations include lymphaticovenous anastomosis (LVA), lymphaticolymphatic bypass and vascularised lymph node transfer (VLNT). Lymphaticovenous anastomosis is a surgical technique that aims to bypass the obstruction to lymphatic flow by creating a direct route for lymphatic fluid to drain into the venous system. While lymphaticolymphatic bypass involves harvesting healthy lymphatic vessels from a donor site which are then used as a composite graft to bypass the damaged or destroyed lymphatic vessels.

In the 1970s, free lymph node transfer with a vascular anastomosis was performed by Shesol et al. in rats [6]. These vascularised lymph nodes survived completely and preserved their original histologic structures. Then in 1982, the first human VLNT was performed by Clodius et al. in a patient with lower leg lymphoedema [7]. A pedicled groin flap with inguinal lymph nodes was harvested from the contralateral inguinal region and transferred to the lymphoedematous limb. The surgery was successful, and they noted a reduction in volume of the affected limb. The first VLNT utilised for upper extremity lymphoedema post breast cancer treatment was described by Becker et al. in 1991 [8].

Lymph node transfer involves harvesting a vascularised lymph node with its associated vessels and transferring it to a recipient site. The aim of this procedure is to create new lymphatic channels to aid drainage of the recipient site. For upper extremity lymphoedema, two or three lymph nodes are harvested from the groin and transplanted into the upper extremity.

The current literature has proposed several theories to explain how VLNT could improve lymphoedema [9]:

- When performing VLNT, the lymphatic vessel anastomoses are expected to form spontaneously as the microsurgical anastomoses are only between vascular structures. Spontaneous anastomoses of the lymphatic vessels occur via a 'lymphangiogenetic' mechanism, whereby lymphatic vessel angiogenesis arises due to the production of vascular endothelial growth factor C (VEGF-C) by the transplanted lymph node flap. These new lymphatic vessels then form connections with the surrounding lymphatics of the affected limb thereby allowing drainage of accumulated lymph.
- The transplanted lymph node flap acts as a pump, actively siphoning lymph fluid into the systemic circulation via the flap's venous drainage system. Lymph nodes act as an interface between the lymphatic and venous system to aid drainage of lymph into the venous system.
- Release of scar tissue in the affected limb will aid more effective drainage by any native marginally functioning lymph channels. Replacement of scar tissue with non-irradiated soft tissue (lymph node flap) can act as an interposition lymphatic graft. The flap's lymphatic channels can connect to the limb's lymphatic channels which are unaffected by surgery and radiation to enable flow of lymph.

In addition to improving lymphoedema, VLNT has the potential benefit of reducing recurrent soft tissue infections. The lymphatic channels of the affected limb present antigens to the lymph node flap which is able to mount an immune response thereby reducing the incidence of soft tissue infections [9].

Vascularised lymph node transfer has been shown to have better long-term outcomes in the likelihood of patients discontinuing compression garments when compared to LVA. The remainder of this chapter will focus on breast reconstruction with simultaneous vascularised lymph node transfer commonly known as the dual reconstruction flap. The dual reconstruction flap involves harvest of an extended abdominal island flap including a lymph node flap from the groin.

Anatomy

The vascularised groin lymph node (VGLN) flap forms one part of the dual reconstruction flap for breast reconstruction in patients suffering from upper limb lymphoedema. The VGLN flap is based on either the superficial circumflex iliac artery/vein (SCIA/V) or sometimes the superficial inferior epigastric artery/vein (SIEA/V). In an anatomical study of the vascular supply of the superficial inguinal lymph nodes, Cheng et al. conducted ten groin dissections on five embalmed cadavers [10]. The superficial inguinal nodes had two clusters: [1] superior column with a mean of 3.4 ± 0.3 nodes supplied by the SCIA and [2] medial column with 2.8 ± 1.5 nodes supplied by a small medial branch of the common femoral vessels. This medial branch was consistently present and was of sufficient calibre for microvascular anastomosis. The SCIA length and diameter were 2.5 cm and 1.5 mm while the medial branch was 1.9 cm and 1 mm, respectively. Rozen et al. conducted computed tomography angiography (CTA) scans on 500 hemi-abdomens and found that the SIEA was present in 94% of cases [11]. Of those without an SIEA, 11 were absent bilaterally and 10 absent unilaterally. The SIEA had a mean diameter of 0.6 mm and was >1.5 mm in 24% of cases.

Zhang et al. demonstrated the distribution of lymph nodes in the groin using multidetector row CTA (MDCTA) [12]. The confluence of SCIV with the great saphenous vein (GSV) was used as a midpoint and the groin was divided into four sections: quadrant I superior lateral, quadrant II superior medial, quadrant III inferior lateral and quadrant IV inferior medial (Fig. 19.1).

Zhang et al. found that out of 104 MDCTA images, quadrant I has the highest number of lymph nodes and is largely supplied by the SCIA. The distribution of lymph nodes within the groin as found by Zhang et al. is depicted in Table 19.1.

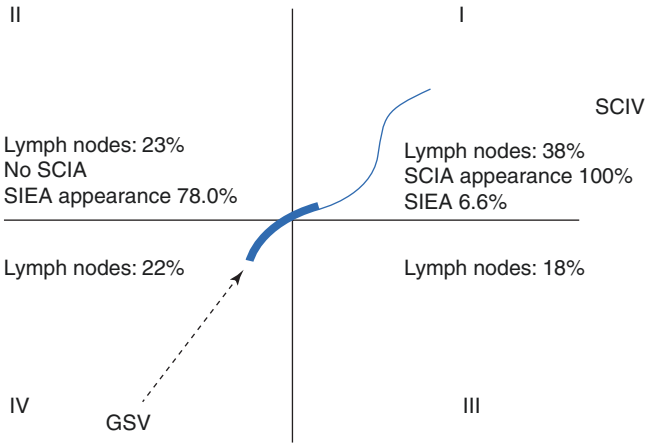

Fig. 19.1 Diagram illustrating the four quadrants of the groin: superior lateral (I), superior medial (II), inferior lateral (III) and inferior medial (IV). The midpoint is designated by the confluence of the superficial circumflex iliac vein (SCIV) and great saphenous vein (GSV). SCIA: superficial circumflex iliac artery, SIEA: superficial inferior epigastric artery. (Adapted from Zhang et al.[42])

Table 19.1 Mean number of lymph nodes in quadrants I–IV in the groin region

Quadrant	Mean number of lymph nodes ($N = 104$)
I	3.3 ± 1.6
II	2.0 ± 1.2
III	1.5 ± 1.3
IV	1.9 ± 1.4

Adapted from Zhang et al. [42]

An understanding of the lymphatic anatomy of the lower limb and groin is crucial in avoiding iatrogenic lymphoedema of the lower extremity. The lymph nodes within the groin can be divided into deep and superficial groups. The superficial lymph node basin drains the lower abdomen, while the deep lymph node basin drains the lower extremity [13].

Scaglioni and Suami mapped the lymphatic anatomy of the lower extremity on five human cadavers using indocyanine green (ICG) angiography [14]. They found that lymphatic vessels originating within the lower leg converge in the medial thigh and then run towards the inguinal region. These lymphatic vessels formed a medial bundle running parallel to the great saphenous vein connecting to two or three sentinel lymph nodes in the distal part of the inguinal triangle. The distal two sentinel nodes were considered to be the dominant nodes draining the lower limb and were consistently located on both sides of the great saphenous vein. Lymphatic vessels in the lateral thigh did not connect to the two dominant lymph nodes and instead converged on lymph nodes located in the lateral part of the inguinal triangle. The lymphatic vessels of the lower abdomen converged towards lymph nodes located in the upper part of the inguinal triangle (Fig. 19.2). The abdominal group lymph nodes received their blood supply from either the SCIA or SIEA. Dayan et al. utilised magnetic resonance angiography (MRA) to map out the lymph nodes supplied by the SCIA [15]. These lymph nodes are consistently located at or just below the inguinal ligament but above the level of the groin crease. Both Saaristo and Dayan recommend avoiding harvest of lymph nodes medial to the SIEV and below the groin crease [15, 16] to reduce the risk of accidental harvest or injury to the deep lymph nodes.

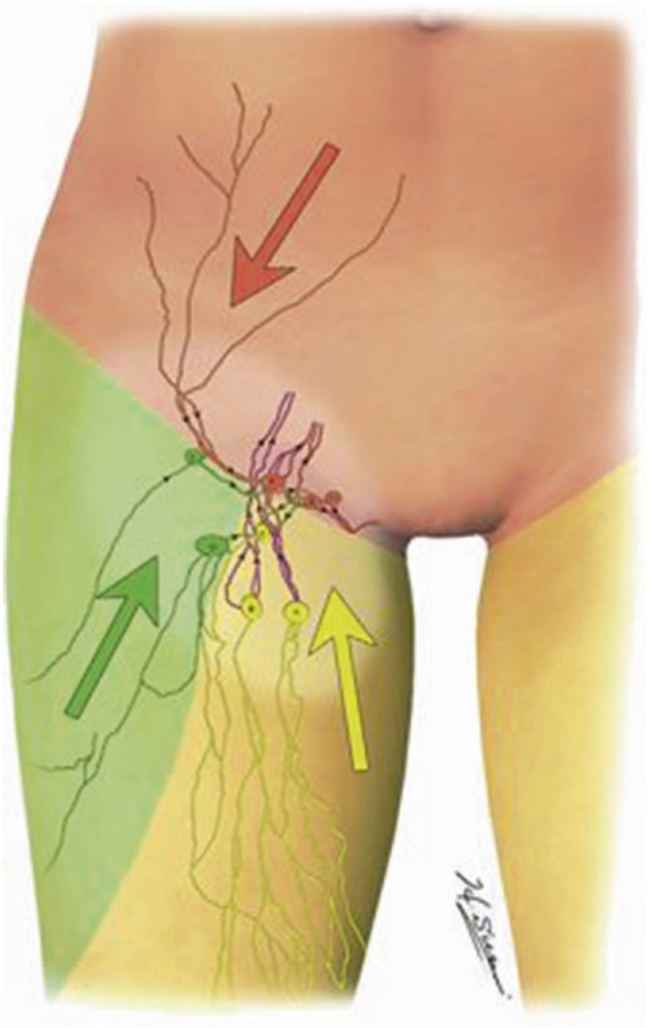

Fig. 19.2 The three different distribution patterns of lymphatic drainage within the groin. Orange indicates the lower abdomen, green indicates the lateral thigh and yellow indicates the medial thigh. (Reproduced from Scaglioni and Suami [14])

Patient Selection

Lymph node transfer is indicated in Stage II and III lymphoedema as per the International Society of Lymphology. Lymphoedema can be classified into five stages as per Campisi et al. (Table 19.2) [5, 17].

Table 19.2 Five different stages of lymphoedema with increasing severity

Staging of lymphoedema		% volume increase
Stage	Characteristics	
Stage I	(a) Sub-clinical disease with impaired lymph transport (demonstrated by lymphoscintigraphy) but no evidence of oedema	0–20%
	(b) Mild lymphoedema, totally resolves with limb elevation	
Stage II	Persistent lymphoedema: partially resolves with limb elevation	21–40%
Stage III	Persistent, progressive lymphoedema: lymphostatic skin changes and suppressed lymph transport capacity with worsening disability	41–60%
Stage IV	Fibrotic lymphoedema with column limb	>61%
Stage V	Elephantiasis: severe limb deformation, scleroindurative pachydermatitis and lymphostatic warts	>61%

The surgeon must first assess the extent and severity of the patient's lymphoedema before contemplating VLNT. The comparison between the affected and unaffected side and between the pre-operative and post-operative status is one objective method at evaluating management outcomes. A primary longitudinal measure to evaluate lymphoedema includes the volume differential [5]. It is calculated as:

$$\frac{(\text{Affected limb volume} - \text{Unaffected limb volume})}{\text{Unaffected limb volume}} \times 100 = \text{VD}(\%)$$

To evaluate the volume differential reduction post-operatively [5]:

$$\frac{\text{Preop VD} - \text{Postop VD}}{\text{Preop VD}} \times 100 = \text{VDR}(\%)$$

The above formula does not account for a change in weight of the patient. Therefore, instead the weight-adjusted formula can be used.

Weight-adjusted formula (WAC) [5]:

$$\frac{\text{A2} \times \text{W1} - 1}{\text{A1W2}} = \text{WAC}$$

A1 = pre-operative arm volume
A2 = post-operative arm volume
W1 = pre-operative weight
W2 = post-operative weight

The was is also useful in patients with bilateral lymphoedema from bilateral breast surgery or radiotherapy.

The degree of lymphatic dysfunction in the affected limb is then assessed by a combination of indocyanine green (ICG) lymphography, lymphoscintigram and magnetic resonance (MR) lymphogram [18, 19] (Table 19.3).

Table 19.3 Available imaging options for assessment of lymphoedema in the affected limb

Imaging technique	Indications
Lymphoscintigraphy	Assessment of length of time radiotracer takes to reach axilla, assessment of lymphatic anatomy
Injection of a radiotracer into the first and second webspace of the hand	Assessment of backflow through valves
	Useful in 'reverse mapping'
Magnetic resonance lymphangiography (MRL)	Rapid visualisation of lymph flow disturbance
	Assessment of viability and functionality of lymph nodes
Indocyanine green (ICG) lymphography	Identification of lymphatic vessel anatomy
	Pre-operative planning
	Intra-operative guidance

Once the degree of lymphatic dysfunction is established, the following algorithm by Masia et al. can be employed to determine the most appropriate surgical option [20]:

- No evidence of a functioning lymphatic system → ablative operation.
- Evidence of a functioning lymphatic system with impaired flow within the axilla → VLNT.
- Evidence of a functioning lymphatic system with no impairment in lymphatic flow → LVA.
- Evidence of a functioning lymphatic system with impaired flow within the axilla and requiring breast reconstruction → dual reconstruction flap.

Therefore, VLNT should be considered in patients with grade II or III lymphoedema and evidence of a functional residual lymphatic system with impaired flow at the axillary area.

Pre-operative Planning

Pre-operative imaging has become the mainstay in microsurgical planning of free tissue transfers. Perforator mapping for the abdominally based flap can be performed via a variety of imaging modalities including ultrasound, CTA and MRA [21]. Pre-operative imaging of the donor site for the VGLN flap is essential to assess the vascular anatomy and reduce the risk of iatrogenic donor lymphoedema.

Ultrasound

Doppler ultrasound is used widely in the pre-operative planning stage of free tissue transfers to localise the desired per-

forating vessels to aid marking of the patient. However, it falls short due to its inability to accurately locate the perforators exiting the fascia or in providing the anatomical course of the desired perforator [22]. Duplex ultrasonography allows for evaluation of lymph node quantity in the desired donor site and the diameter of the SCIA/V [23]. However, it can be difficult to visualise arterial and venous diameter depending on patient factors [23]. The drawback of ultrasound is its inability to produce images in a format that can be easily viewed by the surgeon.

Computed Tomography Angiography (CTA)

Pre-operative CTA can help demonstrate the location and number of lymph nodes from the donor site. Computed tomography angiography has become the standard of care for planning an abdominally based flap and enables the surgeon to review the lymph nodes within the groin simultaneously. Superficial lymph nodes within the groin can be localised for harvest and the side with more lymph nodes can be chosen for transfer [24]. Pre-operative CTA can also determine the vascular supply of the superficial lymph nodes as they can be supplied by either the superficial circumflex iliac artery, superficial inferior epigastric artery or a medial branch of the femoral artery [10]. However, while CTA is advantageous in mapping perforator anatomy and lymph node location and number, it contrasts with the negative effects of ionising radiation exposure, potential for contrast-induced allergy and nephrotoxicity [22].

Magnetic Resonance Angiography (MRA)

Pre-operative MRA provides information on both the perforator anatomy required for harvest of the abdominally based flap and also the location and number of lymph nodes at the donor site. Magnetic resonance angiography has been shown to be useful in determining the exact location of lymph nodes supplied by the SCIA [15]. There is no exposure to radiation with MRA; however, it is rife with many contraindications including metal implants, cardiac pacemaker and claustrophobia [22].

Flap Design

Nguyen et al. described the following algorithmic approach for the dual reconstruction flap considering prior midline incision and recipient vessel location [25]. They described three potential options when performing a dual reconstruction flap:

- Hemi-abdominal flap: for patients undergoing bilateral reconstruction or with a prior midline incision. Both the abdominal free flap (AFP) and VLNT are designed ipsilaterally on the hemi-abdominal flap. The deep inferior epigastric vessels are anastomosed to the internal mammary vessels while the VLNT vessels are anastomosed to the thoracodorsal branches.
- Contralateral VLNT: for patients undergoing only unilateral reconstruction without a prior midline incision. The AFP is designed ipsilateral and the VLNT contralateral to the mastectomy defect. Utilising this technique allows rotation of the flap to access the internal mammary vessels and places the VLNT in the axilla.
- Ipsilateral VLNT: for patients undergoing unilateral reconstruction with damage to the superficial vascular system of the abdominal wall from a Caesarian section. The VLNT is designed ipsilaterally while the AFP is contralateral to the mastectomy site. The flap can be rotated in this instance for anastomoses to the internal mammary artery however it may be limited by pedicle length. The VLNT is orientated in the axilla and anastomosed to one of the branches of the thoracodorsal vessels if required.

Patient Preparation

Pre-operative marking for the dual reconstruction flap is performed both in the standing and supine positions as commonly performed for the DIEP flap alone [26]. The abdominally based flap is centred over the identified perforators from the CTA and its boundaries marked from the anterior superior iliac spines laterally and umbilicus medially and superiorly [26]. The inferior skin incision is slightly lower than the standard suprapubic crease in the abdominally based flap to allow for simultaneous harvest of lymph nodes from the groin [27]. A Doppler probe is used to mark on the skin the locations of the perforators to be utilised in the abdominally based flap and VGLN flap.

Reverse Lymphatic Mapping

An essential component of patient preparation in the dual reconstruction flap includes performing reverse lymphatic mapping as it provides an intra-operative map of lymphatic drainage specific to the patient, guiding safe lymph node harvest. Dayan et al. described a modification of the axillary reverse mapping (ARM) technique to avoid harvest of groin lymph nodes responsible for draining the donor limb [28]. The steps described are summarised as follows:

1. 0.2 mL of technetium sulphur colloid is injected into the first and second webspace of the foot on the donor side 2 h prior to the operation.
2. In the operating room, a gamma probe is used to locate the lymph nodes with technetium uptake and these sites were marked on the skin to indicate avoidance intra-operatively.
3. 0.2 mL of ICG is then injected intradermally at four locations along a parallel line, 5 cm above the inguinal ligament.
4. The SPY device is then used to mark the location of lymph nodes which drain the lower abdominal wall.
5. Intra-operatively: a combination of the SPY device and gamma probe is used to delineate lymph nodes which only drain the lower abdominal wall, and these are included in the dual reconstruction flap. Lymph nodes identified by the gamma probe are avoided.

Alternatively, isosulfan blue can be injected into the first and second webspace of the donor limb foot instead of ICG [29].

Surgical Technique

The dual reconstruction technique is beneficial as the patient does not require two separate operations. Saaristo et al. first described an abdominally based flap (either deep inferior epigastric perforator flap or muscle sparing transverse rectus abdominus musculocutaneous flap) with a simultaneous SCIA lymph node flap in nine patients in 2012 [30].

A two-team approach is required for simultaneous raising of the dual reconstruction flap and preparation of recipient vessels.

Harvest of the Dual Reconstruction Flap

The following describes the technique for raising the dual reconstruction flap, as detailed in multiple studies [27, 29–32]. The skin incision is made slightly lower than the standard abdominally based flap incision and continued further towards the lateral margin of the femoral artery if required. Dissection is performed to the level of the cribriform fascia denoted by superficial veins. In some instances, a superficial vein crosses diagonally, which aids in identifying the plane and the lymph nodes located between the muscular aponeurosis and superficial fascia [27]. The desired lymphatic vessels and nodes to incorporate within the flap will also be highlighted by either the use of isosulfan blue or ICG dependent on the reverse lymphatic mapping technique employed. The superficial circumflex iliac vessels are identified and isolated. The lymph node flap is elevated laterally to medially to the level of the muscular aponeurosis following the superficial circumflex iliac vessels. The superficial inferior epigastric vessels are then identified and isolated as they can also be used for anastomosis within the chest or axilla. A combination of anatomical knowledge to contain dissection within the inguinal ligament inferiorly, the muscular aponeurosis deeply and the cribriform fascial superficially and reverse lymphatic mapping will reduce the risk of accidental harvest of the deep nodes.

The abdominally based flap is then elevated as per standard procedure with lymph node flap connected to its inferior portion. Once harvested, the abdominally based flap is reshaped to reconstruct the mastectomy site.

Preparation of Recipient Vessels

The axilla is exposed to damage during breast cancer treatment secondary to sentinel node biopsy, axillary dissection and radiation therapy. Therefore, performing microvascular anastamosis at the axilla requires thorough preparation of the site via adhesiolysis and removal of scar tissue. Performing this step will enable flow of lymph through native marginally functioning lymph channels in addition to preventing compression of the pedicle and transplanted lymph nodes once anastomosis is complete. The following describes the many different recipient vessels available within the axilla and chest for microvascular anastomosis in the dual reconstruction flap.

Circumflex Scapular Vessels

Becker et al. described using the posterior circumflex scapular vessels for microvascular anastomosis in 2006 [8]. An axillary incision of the affected limb is made, followed by dissection and adhesiolysis of the fibrotic muscular and burned tissue from previous radiotherapy and surgery. Lantieri et al. determined in their series of 40 consecutive cases that the easiest method to identify the circumflex scapula vessels is to find it distally within the triangular space (bordered by subscapularis superiorly, teres major inferiorly and the long head of triceps laterally) [33]. The groove between teres major and subscapularis can be dissected bluntly superiorly until the branches for teres major are encountered. These collateral branches can be clamped and ligated at its distal part. The posterior circumflex scapula vessel can then be utilised for microvascular anastomosis.

Thoracodorsal Vessels

The thoracodorsal vessels can be utilised as recipient vessels as they provide an adequate size match for the dual reconstruction flap. However, these vessels may have been divided or damaged during axillary node dissection. The technique for isolation of the thoracodorsal vessels described by Serletti et al. in 1999 begins with placing the patient supine with the arm abducted to 90° on an arm board [34]. The mastectomy scar is extended to the mid-axillary line and a lateral flap of skin is raised at the level of the fifth rib. The flap is elevated posteriorly to expose the lateral border of latissimus dorsi and dissection is carried out from lateral to medial allowing identification of the most distal portions of the thoracodorsal vessels as they enter the muscle. Dissection continues from distal to proximal to enable the full extent of the vessels to be available for microvascular anastomosis. The circumflex scapular vessels are left in continuity and the thoracodorsal vessels are divided just proximal to the serratus vessels.

Internal Mammary Vessels

The internal mammary is the preferred recipient vessel for breast reconstruction with an abdominally based flap. However, the lymph node flap must lie within the axilla and therefore a long pedicle is required for anastomosis at the anterior chest wall. Hamdi et al. described an algorithm for utilising the internal mammary perforators instead of the main vessel itself to avoid removal of the rib [35]. The internal mammary perforators can be encountered above the pectoralis major muscle at the level of the second or third intercostal space. If the vessel diameter is inadequate, the pectoralis major muscle can be split and the perforators followed until their exit through the intercostal muscles. Finally, if the perforators are still too small or absent, the fourth rib is removed to access the internal mammary vessels. These vessels are then prepared for microvascular anastomosis.

Technical Variations

Slight variations in technique published over the years have improved the harvest of the dual reconstruction flap. To reduce the risk of seroma formation in the groin donor site, Dancey et al. leave an additional cuff of fat on the superior abdominal flap to obliterate the volume defect of the VLNT donor site [36].

Nguyen et al. propose that the VGLN flap is perfused by the abdominally based flap and therefore arterial anastomosis is not required, especially if an adequately sized SCIA or SIEA is not present [25]. However, they do recommend venous anastomosis as the VGLN flap is located in a peripheral perfusion zone of the deep inferior epigastric artery (DIEA) and is at risk of venous congestion.

With the development of three-dimensional (3D) technology, the dual reconstruction flap can now be pre-operatively planned using CTA. Hummelink et al. developed a 3D image of the DIEA and groin lymph nodes from a patient's CTA and projected the image over the abdomen [37]. This image was later traced onto the abdomen with a marker pen. A Patent Blue injection was administered intradermally in the lower abdomen to aid identification of the superficial groin lymph nodes. Both Patent Blue and the traced vascular and lymphatic anatomy of the patient were utilised to locate the superficial groin lymph nodes to incorporate within the flap.

Post-operative Care

Post-operatively, a manual drainage regimen daily from day 1 for a total of 3 months can be performed [8]. Manual drainage can then be performed twice a week for the following 3 months and finally discontinued. Elastic compression dressings are avoided to prevent external compression of the transplanted nodes.

Post-operatively, the patient should be assessed clinically with either the volume differential or weight-adjusted calculation. The severity and incidence of cellulitis and reduction in signs and symptoms of lymphoedema should also be noted. Duplex ultrasound and CT can be performed at 6 months to determine the number of lymph nodes that survived transfer and the patency and diameter of the recipient vessels.

Becker et al. demonstrated that that VLNT significantly improved Stage I and Stage II lymphoedema in 40% of patients who underwent the procedure [27]. While for Stage III lymphoedema, 95% of patients experienced some improvement and 98% remained infection free. Stage III patients were recommended by Becker et al. to continue CDT post-operatively to maintain improvement in lymphoedema. Several studies have also demonstrated improvement in lymphoedema post VGLN flap. Cheng et al. reported a significantly greater decrease in arm circumference with VGLN flap (40.4%) compared to CDT (8.3%) [10]. A review by Scaglioni et al. found that 70.4% of 138 patients that underwent VGLN flap reported that the procedure benefitted their lymphoedema treatment [38].

Surgeons should consider progressive venous outflow stenosis from scarring if there is limited improvement post-

VLNT [39]. Revision surgeries are considered at least 1 year post-operatively to remove scar tissue and revise the venous anastomosis. During this time, the flap can be debulked and de-epithelialised to improve the cosmetic result. At the 1-year mark, lymphoscintigraphy should also be performed to assess if lymphatic flow has improved.

The major limitation of VLNT is the potential for iatrogenic secondary lymphoedema at the donor site. A recent review of donor site lymphoedema post VGLN flap demonstrated a rate of 1.6% [40]. To reduce this complication, reverse mapping should be employed in all cases to identify and protect lymph nodes that drain the donor site extremity.

Patients undergoing VLNT are also at risk of developing lymphocele and delayed wound healing [41]. Becker et al. recommend the use of a drain tube at the donor site for 24–48 h post-operatively and local compression to reduce its occurrence [27]. The use of microsurgical clips on lymphatic vessels supplying the donor flap is crucial to reducing this complication. Saaristo et al. found that the dual reconstruction group required abdominal suction drainage for an average of 4.6 days (range 3–6) compared to 3.6 days (range 2–7) in the breast reconstruction-only group [30]. The risk of seroma formation in the abdomen or axilla post-operatively in the dual reconstruction group was also slightly higher when compared to the breast reconstruction only group. Abdominal wound healing was delayed in two out of the nine (22%) lymphoedema patients and six out of the 78 (8%) patients without lymphoedema.

Clinical Case

Figure 19.3 highlights the pre-operative planning for lymphatic transfer with a combined DIEP or SIEA flap with a CTA. The CTA highlights perforators of the deep system (DIEA) and the superficial system (SIEA and SIEV), and the relationship of inguinal lymphatics and nodes to these vessels. The size and location of lymph nodes in relation to these vessels can aid incision and dissection planning.

After incision planning with aid of the CTA, the SIEA and SIEV are identified, and their relationship to inguinal lymph nodes (see Fig. 19.4). These nodes can then be used for harvest as a stand-alone lymph node flap based on either the SIEA/SIEV or the DIEA/DIEV, with no cutaneous component, or can be harvested in conjunction with a DIEP or SIEA flap, where a combined fasciocutaneous flap and lymphatic transfer is sought.

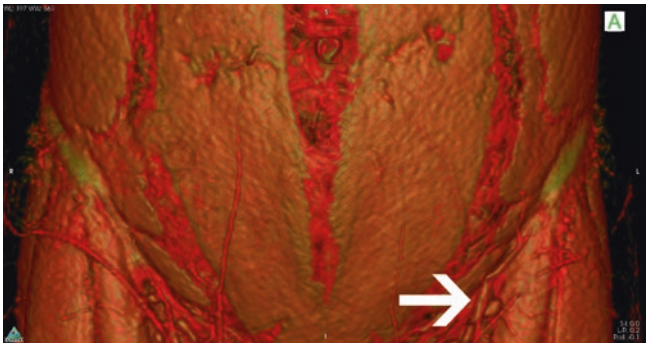

Fig. 19.3 Computed tomographic angiogram in the pre-operative planning for lymphatic transfer with a combined DIEP or SIEA flap. The CTA highlights the relationship of inguinal lymphatics to the DIEA, DIEV, SIEA and SIEV

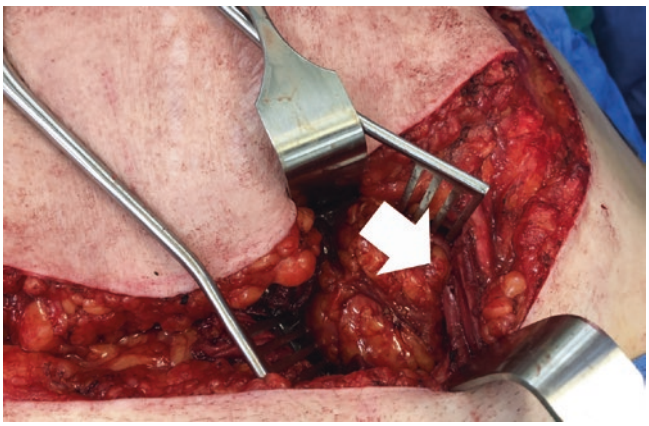

Fig. 19.4 Clinical intra-operative photograph demonstrating inguinal lymph nodes being harvested with the SIEA and SIEV as a free lymph node transfer

Reverse lymphatic mapping, using the techniques described above, with the use of indocyanine green and lymphoscintigraphy has been used to reduce the risk of donor site lymphoedema in vascularised lymph node transfer from inguinal and axillary lymph nodes. The intra-operative photograph in Fig. 19.5 highlights this technique, for use with inguinal node transfer as part of a DIEP flap. In this case, technetium is injected into the foot for drainage of lymph nodes that drain the lower leg. Lymphoscintigraphy and gamma probe identification of these nodes allow them to be avoided during harvest. While these nodes are avoided, indocyanine green is injected into the lower abdomen to identify those inguinal lymph nodes that can be safely harvested.

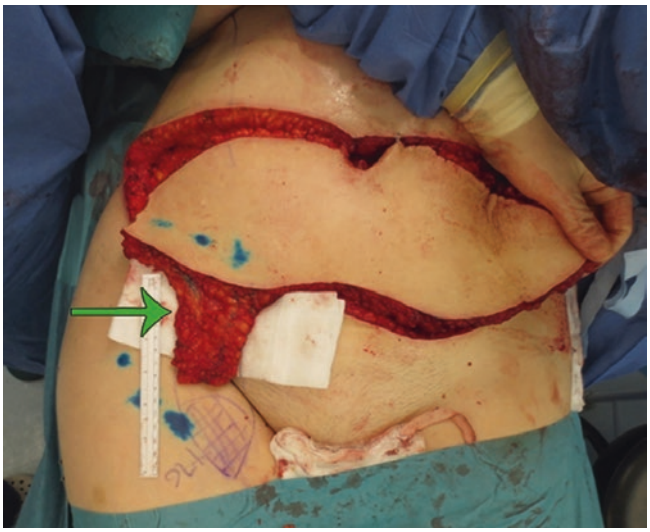

Fig. 19.5 Reverse mapping technique, with deep limb-draining lymphatics demonstrated on lymphoscintigraphy illustrated over medial thigh with blue pen, and superficial lateral nodes selected for transfer harvested (arrow). (Reproduced from Chowdhry et al. [18])

Conclusions

Lymphatic transfer in breast reconstruction is a comprehensive approach to the management of a breast cancer patient with lymphoedema requiring mastectomy reconstruction. The procedure reflects an extension of the abdominally based flap providing significant improvement to lymphoedema of the affected limb. The groin lymph node flap component is supplied by either the SCIA or SIEA and incorporates an average of three lymph nodes per flap. The superficial lymph nodes are incorporated within the flap and their location is confirmed by a combination of ultrasound, CTA, MRA and reverse lymphatic mapping. Post-operatively, the patient undergoes a manual lymphatic drainage regimen and is monitored for improvement in lymphoedema. The VGLN has a high rate of reduction in lymphoedema of the affected limb and a low rate of iatrogenic lymphoedema of the donor limb.

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Superficial Inferior Epigastric Artery Flap in Breast Reconstruction

20

Edward I. Chang

Introduction

The abdominal donor site is the most popular donor site for autologous breast reconstruction. With the initial description by Hartrampf, the transverse rectus abdominus myocutaneous (TRAM) flap became the workhorse flap that could provide sufficient skin as well as volume in order to reconstruct an aesthetic breast [1–4]. Initially described as a pedicle flap based on the superior epigastric vessels, the TRAM remains one of the most commonly used flaps to this day. With the increasing comfort in microsurgery, plastic and reconstructive surgeons began using the deep inferior epigastric vessels as the pedicle for a free flap in breast reconstruction and were able to achieve high success rates. [5–8]. However, the first free tissue transfers performed using the abdominal donor site for breast reconstruction were also full muscle TRAM flaps. As with pedicle TRAM flaps, the sacrifice of the entire rectus abdominus muscle was associated with high donor site morbidity including bulges and hernias that required additional operations to repair [9–13]. However, proponents of the pedicle TRAM and full muscle TRAM have found the placement of mesh at the time of flap harvest significantly reduces the rate of donor site complications from harvesting the entire rectus abdominus muscle [14–16].

As the field of microsurgery progressed and with the increasing comfort with free tissue transfer, perforator flaps also gained popularity where flaps consisting of only skin and subcutaneous fat could be harvested without sacrifice of the muscle. Perforators arising from the main deep inferior epigastric vessels could be carefully dissected through the muscle that provided adequate perfusion of the overlying tissue again without compromising the postoperative functional dynamics of the muscle [17]. With this notion, the deep inferior epigastric perforator (DIEP) soon became the flap of choice for many reconstructive plastic surgeons for breast reconstruction. Some have resorted to a hybrid, or so-called muscle-sparing TRAM flap where only a portion of the muscle is taken with the flap while preserving some of the rectus abdominus muscle to maintain some component of abdominal wall function and integrity [18, 19] The overwhelming majority of studies have not demonstrated significant differences between abdominal donor site morbidity between a DIEP and muscle-sparing TRAM flap [20–22].

However, in some patients, the anatomy allows for harvest of an abdominal flap that not only preserves the entire muscle, but also avoids any fascial incisions entirely. Patients who have a dominant superficial system where the superficial epigastric artery and vein are of sufficient caliber and can perfuse the entire infraumbilical perforasome are potential candidates for a superficial inferior epigastric artery (SIEA) flap where the abdominal flap is perfused via the superficial system.

Anatomy

The superficial inferior epigastric artery (SIEA) arises from the femoral artery below the inguinal ligament while the superficial inferior epigastric vein (SIEV) most often drains into the femoral vein or the greater saphenous vein. In some circumstances, the superficial circumflex iliac vein converges with the SIEV before draining into the femoral vein. The vascular anatomy of the superficial system can be quite variable and in certain circumstances can be quite diminutive or absent altogether. Prior to committing to harvest of an SIEA flap, the artery and vein should be carefully dissected to confirm a sufficient length and caliber of the vessels. The perforators from the deep inferior epigastric vessels should

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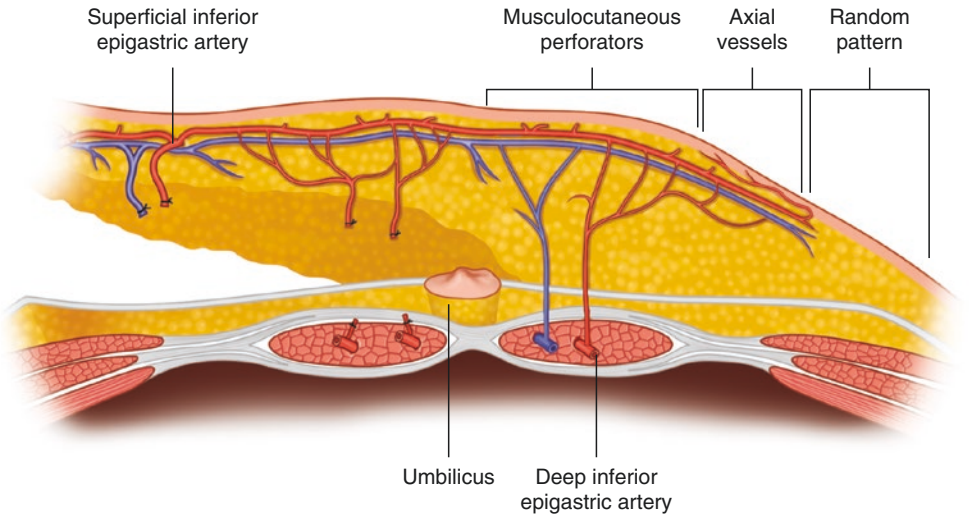

Fig. 20.1 The superficial inferior epigastric vessels lie in the subcutaneous tissue above Scarpa's fascia where they are isolated and then progress deep through the fascia toward the takeoff from the femoral vessels. The deep inferior epigastric vessels lie deep to the rectus abdominis muscle and send perforators through the muscle to nourish and perfuse the subcutaneous tissue and overlying skin

be preserved until the superficial vessels are found to be adequate for free tissue transfer (Fig. 20.1). Perfusion of the abdominal tissue is also critical in determining the suitability of the SIEA flap as the superficial system may not perfuse tissue across the midline. It is important to note that the external diameter of the SIEA is considerably smaller than the internal diameter and lumen of the artery. This is an important consideration knowing the internal mammary artery is typically a larger caliber artery, typically 2–2.5 mm in diameter, and can create an unfavorable size mismatch [23, 24]. Another important consideration is the pedicle for the SIEA flap is considerably shorter compared to a DIEP flap which may increase the difficulty during the microvascular anastomosis.

Patient Selection

As with any patient undergoing surgery, the preoperative evaluation should include a thorough history and physical. For patients undergoing autologous free flap breast reconstruction, it is also important to consider other factors which should be obtained in the routine history such as history of prior radiation and when the radiation was completed. If patients will require radiation, it is generally recommended that radiation be completed first prior to reconstruction as the radiation can affect the final cosmetic result of the reconstruction. Further, patients with a strong family history should have genetic testing for any deleterious BRCA mutations or other chromosomal aberrations that may warrant a contralateral prophylactic mastectomy. Since the abdominal donor site can typically only be used once, if patients are opting for a contralateral mastectomy, then both breasts should be reconstructed simultaneously in order to achieve the most optimal symmetry and potentially avoid another operation for the patient. Any history of venous thromboembolic events should also be documented, and any patient with a number of unplanned miscarriages or spontaneous abortions should raise concerns for an undocumented hypercoagulable condition. Aside from any genetic predisposition for thrombotic events, a patient's medication list should also be reviewed. In general, cessation of agents like tamoxifen and other antiestrogen and hormonal agents is recommended because of the potential increased risks of blood clots.

On physical examination, patients should have ample soft tissue in the inframumbilical region to serve as a donor site allowing for primary closure of the abdominal incision without tension. Careful attention should be paid toward any prior scars and corroborated with a thorough history of prior surgeries which may have injured either the superficial or deep inferior epigastric vessels. In particular, a Caesarian section through a low Pfannenstiel incision may have divided or ligated the superficial system precluding their use as a pedicle for free tissue transfer. In some circumstances, prior C-sections have even injured the deep inferior epigastric vessels. Inadvertent placement of trocars during laparoscopic operations has also been associated with injuries to the pedicle, and therefore any prior surgery should heighten a microsurgeon's awareness for potentially increased difficulties with flap harvest and dissection. In these circumstances, preoperative imaging may be warranted. Whether one chooses

to obtain a preoperative computed tomography angiogram (CTA) as a matter of routine practice is at the surgeon's discretion and will be discussed in the following section.

Preoperative Planning

The use of computer tomography angiogram (CTA) has predominantly replaced traditional angiograms for evaluation of the vascular anatomy as they are readily obtainable, do not require the technical expertise of a vascular surgeon or interventional radiologist, minimize the contrast dye load and the potential nephrotoxic effects of the contrast, and can provide resolution equivalent or superior to traditional angiograms. An added benefit of the CTA is the ability to perform three-dimensional reconstructions of the images providing a more precise depiction of the vascular anatomy that can aid in flap design and perforator dissection, leading to shorter overall operative times. However, the CTA does not offer any information regarding the perforasomes supplied by the perforators and cannot predict the perfusion pattern of the flap. Other imaging studies, most commonly indocyanine green (ICG) angiography, are needed in order to more accurately assess the perfusion to the flap. While there are certainly communications and "choke vessels" between the superficial system on the right and left side, most would agree that the superficial inferior vessels are only sufficient to support a hemiabdomen, and it is rare that there will be sufficient perfusion across the midline from the ipsilateral pedicle to the contralateral side. This is an important consideration when reconstructing breasts of large volume or when more than a hemiabdomen is needed to reconstruct a unilateral mastectomy defect.

The CTA will provide information on the superficial system just as it provides information on the deep inferior epigastric vessels. Based on the angiogram, one is able to assess both the superficial inferior epigastric artery and the vein [25, 26]. If a large caliber superficial artery and vein are visualized, this may indicate that the patient would be a reasonable candidate for an SIEA flap. If only a large SIEV is identified, this may suggest that there is a component of superficial dominance, and may motivate the surgeon to perform a second venous anastomosis to drain the superficial system. However, if large perforators arising from the deep system are also visualized, the reconstructive microsurgeon will need to decide which pedicle is safer.

Despite the information gained from preoperative imaging, the reconstructive surgeon should always be cautioned to explore and visualize the perforators and superficial vessels before sacrificing either pedicle and committing to one flap or the other. The superficial inferior epigastric vessels can be quite variable and are notorious for a much smaller caliber artery than the deep inferior epigastric artery. If the dissection of the superficial inferior epigastric artery provides a suitable sized vessel, again the decision to use the SIEA is at the discretion of the microsurgeon.

Surgical Technique

The SIEA flap is harvested in an identical fashion as the DIEP or muscle-sparing TRAM flap. Typically, the inferior incision is made first, and dissection should proceed cautiously through the subcutaneous flap to identify the superficial inferior epigastric vessels. The vein is typically lateral to the artery, and the artery may have its own vena comitantes associated with it which can also serve as the flap vein although they are typically smaller in caliber than the superficial inferior epigastric vein. The superficial inferior epigastric vessels can be dissected to their takeoff as proximally as possible in order to maximize the length and caliber of the vessels. There are often a number of small branches arising from both the superficial inferior epigastric artery and the vein which should be controlled with clips or carefully with cautery paying attention to avoid thermal damage to the main vessels (Video 20.1).

While one can choose to ligate all the perforators arising from the deep system immediately, the safer approach is to dissect and isolate the perforators arising from the deep inferior epigastric vessels [27]. If no large, dominant perforators are identified, the superficial system may represent the dominant blood supply to the flap. If large perforators are encountered, one can place Acland clamps to control the perforators and then reevaluate the perfusion of the flap. In circumstances when large perforators exist, consideration for perfusion assessment using indocyanine green angiography may be useful in determining whether the deep inferior epigastric or the superficial inferior epigastric vessels are superior. Once the decision is made to proceed with the SIEA flap, all perforators are ligated and the flap elevation is completed.

Donor site closure is considerably simpler as no fascial repair is needed. In the setting of diastasis, one can choose to plicate the fascia similar to an abdominoplasty. The donor site should then be closed in layers over closed suction drains, and the umbilicus is matured and inset based on surgeon preference.

The microvascular anastomosis should be completed with care as with any microsurgical operation. However, the superficial inferior epigastric artery tends to be more prone to spasm and can have a noticeable size mismatch with the internal mammary artery [28–30]. If a sizable internal mammary perforator is identified, the size match of the internal mammary artery perforator is often much closer to the superficial inferior epigastric artery. Issues with the smaller caliber superficial inferior epigastric artery as well as the tendency for spasm are likely factors associated with an increased risk of total flap loss with SIEA flaps compared to DIEP or muscle-sparing TRAM flaps [31, 32]. However, despite the increased risks of complications, SIEA flaps can be performed successfully, but should be considered with caution [33, 34].

Postoperative Care

Postoperative management for an SIEA flap is no different than a DIEP flap in terms of the recipient site. At the author's institution, the protocol is hourly flap checks (color, temperature, capillary refill, handheld Doppler, and turgor) for the first 48 h. After the first 48 h, the flap checks are advanced to every 2 h for the next 48 h and then to every 4 h until discharge. Patients are admitted to the ward rather than the intensive care unit (ICU). Patients are mobilized on postoperative day 1 to a chair and started on venous thromboembolism (VTE) prophylaxis. The Foley catheter is removed on postoperative day 2, and patients are evaluated by our physical therapists to assist with mobilization and ambulation. Patients are discharged on postoperative day 4 or 5 depending on the patient's progress.

Closed suction drains are removed when they are less than 25 cc a day for 2 consecutive days. Patients are typically advised to refrain from heavy lifting or strenuous activity for 2 months in the setting when the fascia is incised during harvest of the deep inferior epigastric vessels. However, when the fascia is not violated as in the SIEA flap, abdominal precautions are not necessary since the fascia is not violated.

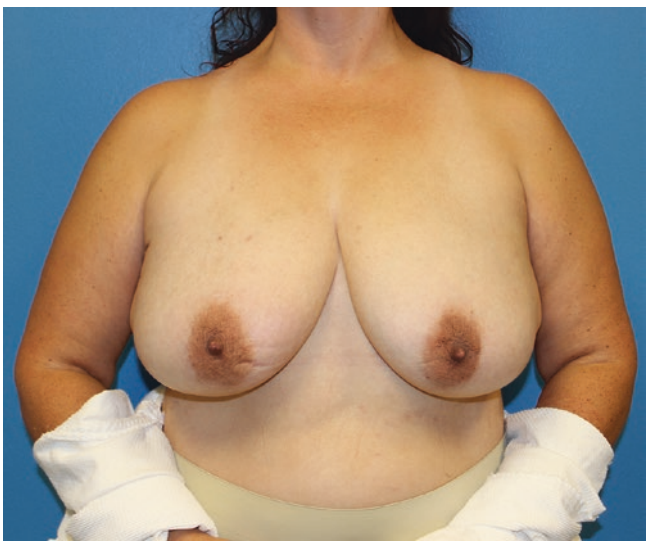

Fig. 20.2 Preoperative photo of a patient undergoing bilateral skin-sparing mastectomies and autologous abdominal free flap breast reconstruction

Clinical Cases

Patient is a 54-year-old woman who was found to have ductal carcinoma in situ of the right breast and presented for immediate breast reconstruction (Fig. 20.2). The patient opted to have a contralateral prophylactic mastectomy and opted to proceed with reconstruction using autologous tissue. The patient was counseled on the use of the deep inferior epigastric vessels for her free flaps, but she was also explained the possibility of using the superficial system. Upon dissection, we found that the right superficial inferior epigastric vessels were of sufficiently large caliber to harvest an SIEA flap (Fig. 20.3). The superficial inferior epigastric vessels were dissected as proximally as possible to maximize the length and caliber of the vessels, and the patient had an uncomplicated hospital stay and had a healthy viable reconstruction (Fig. 20.4).

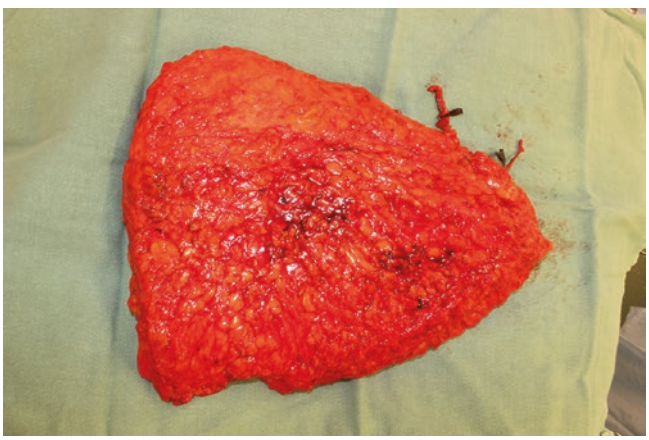

Fig. 20.3 Intraoperative photo of SIEA flap

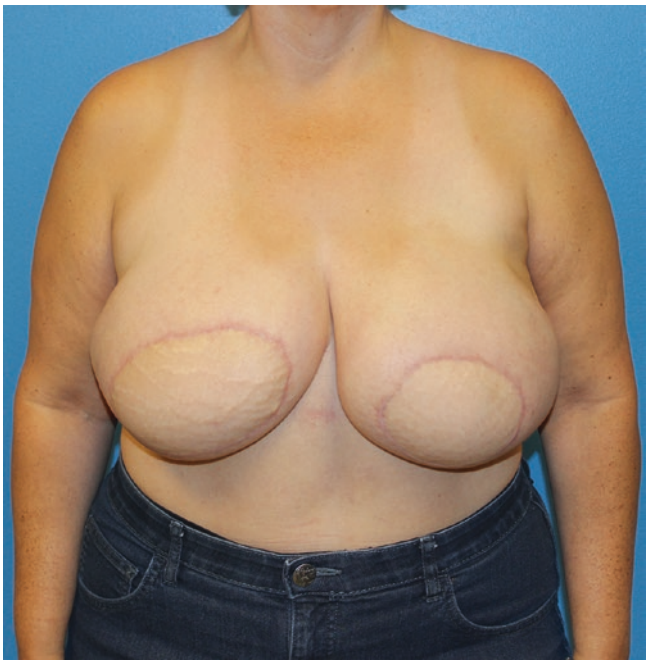

Fig. 20.4 Postoperative photo following reconstruction without compromised flap perfusion, partial flap loss, and no palpable fat necrosis. The SIEA flap was used to reconstruct the left breast, and a DIEP flap was used to reconstruct the right breast

Conclusions

The superficial inferior epigastric artery (SIEA) flap is an excellent option for autologous breast reconstruction if the vessels are sizable and adequate to perfuse the flap. However, while the harvest is simpler to some degree, caution should be used when deciding on whether to perform an SIEA flap versus a DIEP flap as the SIEA pedicle is smaller, more prone to vasospasm, and associated with increased flap loss rates.

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Breast Reconstruction with the Laparoscopically Harvested Omental Free Flap

21

Tert C. van Alphen, Gerrit D. Slooter, Maarten R. Fechner, and Coralien L. Broekhuysen

Introduction

Abdominal flaps are still the most commonly used flap in autologous breast reconstruction today. Autologous fat transfer (AFT) is another reconstruction that is popular currently. These techniques are not always possible due to the woman's characteristics, body shape, and previous abdominal operation(s). Patients may decline surgery that has risks of stark scarring or donor site morbidity.

Currently, there are many uses of the omental flap in abdominal thoracic surgery, such as massive sternotomy infection/wounds and reconstructive surgery after trauma or oncologic resection. The omentum appeared to be an attractive alternative to fill an empty skin envelope in breast reconstruction, but the risk of donor site morbidity from the pedicled flap (hernia, volvulus, etc.) was a major limitation. With the advent of laparoscopically harvested omentum, most of the drawbacks are avoided and we have used the omentum in select cases with excellent results. These surgeries are not yet widespread to our knowledge.

In 1880, Senn described the pedicled omental flap for the first time while using it to protect a suture line of an intestinal anastomosis [1]. In breast reconstruction, Kirikuta was the first to use the omentum as a pedicled flap in 1963 [2]. While the development of microvascular surgery progressed, free tissue transfer became popular. In 1993, Saltz et al. described the use of laparoscopy to harvest omental flaps [3], but breast reconstructions were not described. In 2006, Zaha et al. described the first significant case series of 40 cases, where the omentum was used for immediate breast reconstruction but from these only four were laparoscopically harvested [4]. Breast reconstruction using laparoscopically harvested omental free flap (LHOFF) can be an excellent option, provided there is a sufficient skin envelope and omentum.

Anatomy

"The omentum" in breast reconstruction/LHOFF refers to the greater omentum. The greater omentum is also called the omentum majus, gastrocolic omentum, or epiploon. It is a free-hanging mesenteric tissue apron in the abdominal cavity. It is attached to the greater gastric curvature and descends to the symphysis. It is a double sheet of peritoneum, folded on itself so that it has four layers. The omentum is composed of a connective tissue framework and consists of arteries, veins, lymphatics, and fat pads. The arterial vascularization of the omentum consists of a double blood supply from the left and right gastroepiploic arteries. The left artery obtains blood from the lineal artery and the right by the gastroduodenal artery. Both are branches of the celiac trunk. The right gastroepiploic artery is, most of the time, the stronger and slightly larger artery of the two. Either can be used to make a microvascular anastomosis. Both gastroepiploic arteries branch off gastric and epiploic arteries. The venous blood drainage of the omentum runs parallel to the arteries and empties into the portal system. The dimensions of the omentum vary from 5.5 to 14 inches (14–36 cm) in length and from 8 to 18 inches (20–46 cm) in width. The relationship between the weight of the patient and the weight of the omentum is unpredictable, and it cannot be accurately estimated with noninvasive techniques (e.g., echo, CT, MRI) [5, 6].

Patient Selection

Breast reconstruction using an LHOFF is indicated in selected cases [7].

In our clinic, LHOFF autologous breast reconstruction is indicated in the following group of patients:

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H. F. Mayer (ed.), *Breast Reconstruction*, https://doi.org/10.1007/978-3-030-34603-4_21

- A patient needing a unilateral reconstruction
- Patient's choice to have a solely autologous reconstruction, with a preference of minimal additional scarring
- A lean patient with low breast volume, where it was not technically possible or desirable to use an abdominal-based flap, other perforator flaps (like buttocks or upper leg region), or AFT
- A patient with an intact and sufficient skin envelope
- A patient having sufficient omentum volume (as seen in diagnostic laparoscopy)

Preoperative Planning and Patient Preparation

The relationship between the patient's characteristic (height and weight) and the volume of the omentum is unpredictable, and the volume of the omentum cannot be accurately estimated with noninvasive techniques (e.g., echo or MRI) [5, 6]. A diagnostic laparoscopy is therefore advised prior to the reconstruction. During the diagnostic laparoscopy, the volume of the omentum is estimated, and conflicting abdominal pathology (e.g., omental malignant nodules, abdominal adhesions) can be evaluated.

A sufficient skin envelope is required for successful LHOFF. If this was uncertain at the time of mastectomy, we usually performed a two-stage procedure. The initial stage included a subpectoral tissue expander (TE), which also preserves the pocket while awaiting definitive pathology reports. In the second stage, we performed the LHOFF breast reconstruction. In all other cases, an immediate reconstruction was done.

It is extremely important to mark on the pocket, prior to surgery, to show where filling is necessary to get the best postoperative outcome. We advise our patients to stop smoking for at least 6 weeks prior to surgery.

Surgical Technique

We use the technique as described in an earlier paper in Microsurgery [7].

Thirty minutes prior to the operation, we administer Kefzol (Cefazolin) antibiotics (2 g IV).

The plastic surgery and the general surgery teams are operating simultaneously.

The omentum is harvested laparoscopically by the general surgeon. The Veress needle is inserted at Palmer's point, and the abdominal cavity is inflated with CO_2 until intra-abdominal pressure is 10 mmHg. We use three trocars in the French position, 12 mm for a 30-degree fiber optic camera and two 5-mm trocars. The surgeon is positioned between the patient's legs for a comfortable position to dissect the omentum from the bowel and stomach. The branches of the gastric vessels to the stomach are sealed using Harmonic Scalpel (Ethicon Endosurgery, Cincinnati, Ohio). The origin of both the artery and vein of the right gastroepiploic (GE) vessels is identified. To limit ischemia time, shortly after the preparation of the recipient site by the plastic surgeon, the vessels are clipped (the artery and vein are clearly identified, marked) separately and transected to limit ischemia time. Using an endobag, the free omentum is then extracted through a 4 cm Pfannenstiel incision at the superior edge of the mons pubis (See Fig. 21.1). After suturing the fascia, all wounds are closed intracutaneously.

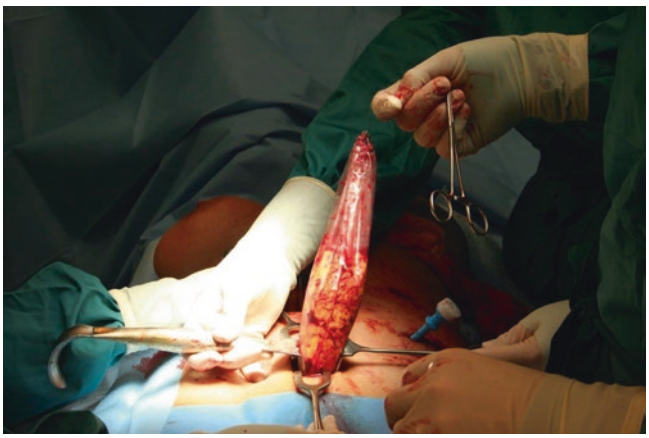

Fig. 21.1 Using an endobag, the greater omentum is extracted through a 4 cm Pfannenstiel incision at the superior edge of mons pubis. (With courtesy and permission of van Alphen et al. [7]. Wiley)

Simultaneously, the plastic surgeon's team prepares the mammary area above the muscle pectoralis major to prevent muscle animation of the pectoralis major. It is important to remove all the fibrotic tissue of the chest wall to create the softest result and to maintain full range of motion in the shoulder. After the pocket is created, the internal mammary vessels at the level of the fourth rib are dissected as the recipient site. We place the free omentum in the pocket to measure the size of the omentum. If there is too much volume, the omentum can be shaped. The gastroepiploic artery is anastomosed to the internal mammary artery in an end-to-end manner. Due to the amount of fat in the omentum, the vessels tend to draw back in the fat and are therefore less easy to identify and handle. This is the reason why the general surgeon is asked to mark the artery (one clip) and vein (two clips) clearly and the vessels are mobilized longer than in other flaps. You can

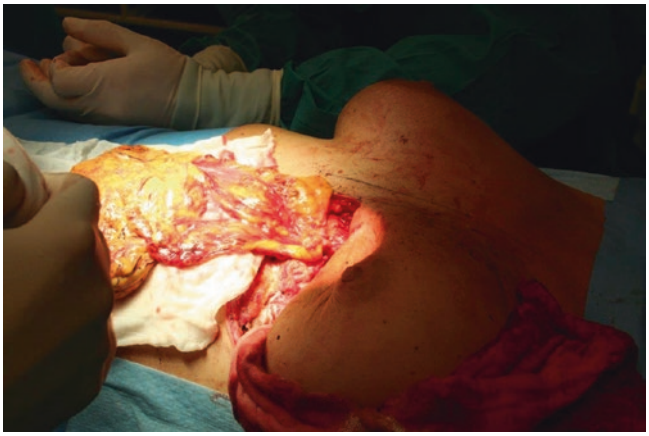

Fig. 21.2 LHOFF after the anastomosis is completed. (Gastroepiploic artery to the internal mammary artery in an end-to-end fashion and the vein in an end-to-end fashion using flow coupler device). (With courtesy and permission of van Alphen et al. [7]. Wiley)

use the left or right gastroepiploic (GE) vessels for anastomosis, but often the right vessel is stronger and has a slightly larger caliber (See Fig. 21.2). A possible mismatch (in many cases, the GE artery is slightly wider) can be solved by using an oblique section from the smaller artery. The accompanying veins are anastomosed using a coupler device (even a mismatch of 2–3 sizes after cutting the vein, measured by the coupler measuring device, is acceptable here.) The omentum is then carefully fixed in place in the pocket, using six cranial monofilament 3.0 sutures. (The omentum tends to sag downward since it consists of a lot of fatty tissue which can slip.) One suction drain is placed in the anterior axillary line. The subcutaneous layer and skin are closed using a Monocryl 4.0 and Vicryl Rapide 4.0.

Note: Since the general surgeon sealed the gastroepiploic vessels using clips and cut them with diathermy, we shorten the vessels by 0.25 inch or 0.5 cm to minimize any complications with the anastomoses from thermal damage.

Note: The gastroepiploic vessels have a thicker adventitia than, for instance, the deep inferior epigastric artery perforator flap (DIEP) vessels, so carefully dissecting and cleaning the vessels prior to anastomosing prevent any interposition.

Technical Variations

Our preference is to create the pocket above the muscle pectoralis major, provided the skin envelope is thick and sufficient, to limit the change of animation while contracting the muscle. If additional volume is needed during the reconstruction, an implant can be placed under the omentum or in a dual-plane method subpectoral. In a second procedure, lipofilling can be used to increase the volume or to augment the thickness of the skin flap if any irregularities in thickness occurred.

Table 21.1 Advantages and limitations of using LHOFF

Advantages	Limitations
Minimal donor site morbidity and scarring with the use of laparoscopic harvesting	Sufficient skin envelope is required
Very soft tissue resembling the natural feeling of a nonreconstructed breast	Volume may be insufficient to reconstruct a whole breast
Easily adaptable	Pre-op prediction of the volume is not possible with noninvasive techniques (echo, MRI, CT). Diagnostic laparoscopy is advised to predict the volume
Long pedicle	Iatrogenic abdominal injuries can occur during the diagnostics laparoscopy
Minimal blood loss when harvesting the flap	Reconstructed breast can be firm in the first few months after surgery
No volume loss occurs to the flap after radiotherapy	Unilateral use only
The flap can be used to cover a silicone implant	
Fast recovery within 2–3 weeks and discharge in 2–3 days.	

Depending on the surgeon's preference, the thoracodorsal vessels can also be used as recipient vessels. We prefer the internal mammary vessels for the anastomosis since they facilitate easy anastomosing of LHOFF and we have extensive experience with the internal mammary vessels from DIEP reconstructions. We also believe that by using the internal mammary vessels, it is easier to limit the pocket laterally and that less sagging or ptosis of the omentum toward the lateral border will occur. Another benefit is that you can still use a LD reconstruction as a rescue procedure because the thoracodorsal vessels have been preserved.

You can perform LHOFF as primary or delayed reconstruction. When planning a delayed reconstruction, we advise placing a tissue expander during the primary stage, to create or preserve the skin envelope. If the volume of the omentum is insufficient, the omentum can be used to cover an implant, but this negates the autologous aspect of the reconstruction (Table 21.1).

Postoperative Care

- Evaluation of flap: The free omental flap is postoperatively monitored using a handheld Doppler ultrasound device to monitor in- and outflow. (Every hour for the first 24 hours, after that every 4 hours) When performing the operation for the first time, we used to use a flow monitoring coupler device for monitoring the venous outflow. Although the little cable of the device is very supple, kinking of the venous vessels proved a high risk due to the soft vessels of the omentum. A normal handheld Doppler ultrasound device can be easily used to monitor in- and outflow.
- Drain: Vacuum drain for 4 days or until production <30 cc in 24 hours.

  Note: Drain production can be significantly more than DIEP reconstruction. 50–100 cc clear or serosanguineous production is normal in the first 4–5 days. We advise leaving the drain in for 4 days and that the patient had been mobilized sufficiently.
- Antibiotics: Kefzol (Cefazolin), 1 g IV every 8 hours for 72 hours.
- Thrombosis prophylaxis: Leg pumps are used routinely. Prophylactic Fragmin (dalteparin) is administered during hospitalization. At discharge, the patient is given acetylsalicylic acid (Ascal) 80 mg every day for 1 month in total. Early mobilization during hospitalization is advised.

Complications

Since the arterial vascularization of the omentum consists of a double blood supply from the left and right gastroepiploic artery, it is well vascularized and reliable. The microsurgeon can choose the best vessels to use for the anastomosis, and the artery and vein can be easily lengthened to make the anastomosis easier. We advise performing a diagnostic laparoscopy prior to the reconstruction to estimate the volume and inspect the omentum and the abdomen. Literature showed that LHOFF is a safe flap with low complication rate [8].

Complications related to the amputation of the breast are skinflap necroses, since LHOFF is "buried" in a skin envelope. We now use a handheld Doppler ultrasound device for monitoring in- and outflow in the vessels to prevent flap necrosis.

Abdominal intervention-related complications are abdominal hernia ileus and visceral injury, although the complication rate of these abdominal complications is minimal when using the laparoscopic harvesting technique. Further general complications of surgery include: hematoma, wound infection, seroma, deep venous thrombosis, and pulmonary embolism.

Clinical Cases

A 61-year-old woman underwent mastectomy and secondary breast reconstruction with LHOFF. Breast size lift 75A. BMI 23.9.

The LHOFF was indicated because of the following reasons: The choice to have a solely autologous reconstruction, with a preference of minimal additional scarring. A patient needing a unilateral reconstruction. Technically not possible to use an abdominal flap or latisumuss dorsi. A patient with an intact and sufficient skin envelope. And sufficient momentum volume was seen with the diagnostic laparoscopy. See Fig. 21.3 for preoperative result (pre-LHOFF reconstruction but after tissue expansion) TE in situ. See Fig. 21.4 for *postoperative results after LHOFF at 6 months.*

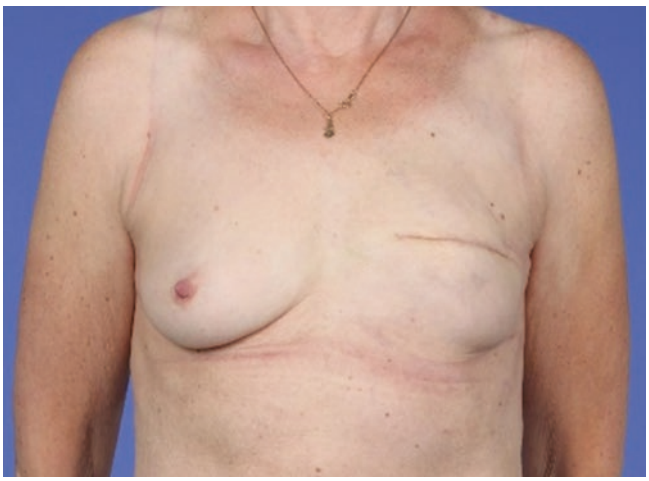

Fig. 21.3 Preoperative result (pre-LHOFF reconstruction but after tissue expansion) tissue expander in situ

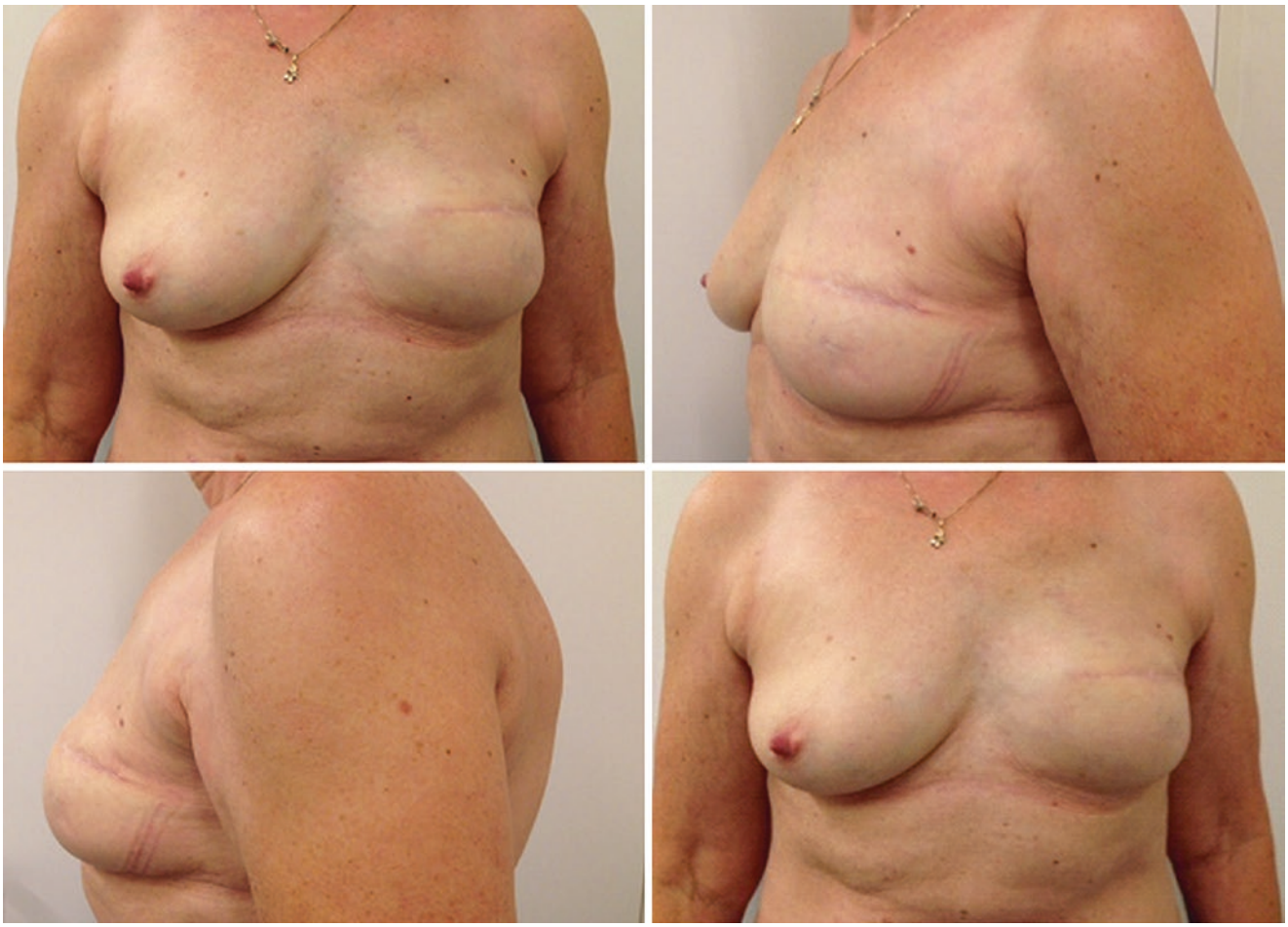

Fig. 21.4 Postoperative results at 6 months are shown. (With courtesy and permission of van Alphen et al. [7]. Wiley)

Conclusions

Autologous breast reconstruction using a laparoscopically harvested omental free flap (LHOFF) can be an excellent option in select cases. It is a safe flap with minimal donor site morbidity and scarring with the use of laparoscopic harvesting. The aesthetic results are excellent with minimal scarring, good volume, and very soft tissue resembling the natural feeling of a nonreconstructed breast, which is highly appreciated by the patients.

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Lumbar Artery Perforator Flap for Breast Reconstruction

22

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Introduction

The lumbar artery perforator (LAP) free flap is an excellent alternative in autologous breast reconstruction for those patients who are not eligible for the deep inferior epigastric artery perforator (DIEAP) flap, which is still considered the gold standard. Musculocutaneous and adipofascial flaps from the lumbar region have been described since the 1970s; also known as 'reversed latissimus dorsi flaps', they were used as pedicled flaps for low lumbar soft tissue defects and decubitus ulcers [1, 2].

The lumbar artery perforator flap was first described in the literature by Kroll and Rosenfield in 1988 as a new type of flap based on unnamed perforators arising near the midline of the lower back region for the coverage of lumbosacral defects, thus reducing the donor-site morbidity associated with traditional musculocutaneous flaps [3]. In 1999, Kato reported a cadaveric and clinical study about the vascular territory of lumbar artery perforators, therefore validating the use of this vessel in harvesting LAP island flaps and free flaps in this region [4]. Since then, several studies had described the anatomy of LAP flap based on perforators [5–11]. This flap can be used as a pedicled flap to reconstruct soft tissue defects in the lumbosacral region including the closure of myelomeningocele, decubitus ulcers or exposed spine. As a free flap, the LAP flap is a possible option for use in autologous breast reconstruction. For the first time in 2003, De Weerd and colleagues published a case report describing a free LAP flap as a possibility for autologous breast reconstruction [12]. To date, a few case series of LAP flaps for breast reconstruction have been reported [10, 13, 14]. For this purpose, LAP flap may be a satisfactory option, providing a large amount of fat tissue harvested from the so-called love handles in the lumbar and flank regions. The lumbar region offers a better quality of fat, softer and pliable as compared to the gluteal region, thus making flap shaping easier. Even though the resulting donor-site scar is often too high to be hidden by standard underwear, it is usually well accepted in favour of the pleasing flank contouring [10]. For these reasons in our practice, the LAP flap is a reliable second choice for breast reconstruction, despite flap dissection being more challenging and time-consuming compared to other alternatives. The LAP flap can be also used as a sensate flap by harvesting the nervi clunium superiores and anastomosing the sensory nerve of the flap to the fourth intercostal nerve [13].

Anatomy

The four pairs of lumbar arteries (LAs) arise from either side of the abdominal aorta, and they travel behind the psoas major muscle. The upper three lumbar arteries run laterally and backwards between the quadratus lumborum muscle and the erector spinae musculature, whilst the lowest set of arteries normally run anterior to the quadratus lumborum muscle [4, 5, 9]. The arteries then give perforators that pierce the thoracolumbar fascia just lateral to the erector spinae muscle and supply the skin and the subcutaneous tissue in this region. The course of LAs is variable; however perforator vessels arising from the first pair of LAs were more likely to be musculocutaneous, whereas perforators arising from the fourth LAs were more likely to have a septocutaneous course, emerging between the erector spinae muscle and quadratus lomborum. Kato investigated in a cadaveric study the vascular anatomy and skin territory of lumbar arteries in 11 cadavers using fluorescein injection. He described that the skin territory supplied by a single lumbar artery extended from the posterior midline to the lateral border of the ipsilateral rectus sheath and at least 10 cm above the anterosuperior iliac spine. Kato also concluded that the fourth LA was superior to others as it had the largest size of perforator and it was the most reliably present [4]. The superiority of the fourth LA

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has been confirmed by following studies showing larger calibre of L4 perforators (mean 2.3 mm, range 1.3–4.5 mm) and septocutaneous course in 65% of the cases of L4 perforators, whereas the L1 artery showed a musculocutaneous course in 67.5% of specimens and a smaller calibre (mean 1.2, range 0.4–2–2 mm) [7]. The author published in 2016 an anatomical study using multidetector computed tomographic scan in 20 patients and described that L1 and L2 perforators were less common than L3 and L4 perforators, whilst the fourth lumbar artery was the most reliable for having perforators [10]. This is also confirmed in a recent study by Sommeling et al. who found that the dominant perforators usually originate from the lumbar arteries at the level of the third or fourth vertebra [11]. This data support the commonly accepted fact that the lower lumbar vessel gives off more and slightly larger perforators. Cadaveric and imaging studies revealed a mean number of 6 ± 2 lumbar artery perforators per patient [5, 6] but the size, position and course of the lumbar perforators can be somewhat variable. The author found a mean diameter of a lumbar vessel perforator (artery and vein) of 2.8 ± 0.3 comparable to the results described by Offman (2.1 ± 0.5 mm) [5, 10]. Sometimes (20% of dominant perforators) the vessel diameter at the level of the transverse process was smaller than at the transition through the fascia into the subcutaneous tissue. This may happen because once the vessel has left the muscle, a surrounding counterpressure falls away and the vessel assumes a slightly larger diameter [10]. The mean point of perforation of the lumbar fascia by the lumbar vessel perforator lay 7.22 cm (range 5–9 cm) from the midline [4]. The following studies showed similar results; the author measured 6.9 cm ± 0.62 cm of distance from the midline and the emerging point through the fascia [10], whereas Sommeling found that the 85% of dominant LAPs entered the skin at 7–10 cm lateral to the midline (mean, left 8.6 cm, right 8.2 cm) [11]. The pedicle length showed high variability and has been described a tendency to have a shorter pedicled from L1 to L4 [7]. The mean pedicle length is described to vary between about 5 and 7 cm [5, 10, 13]. Therefore, the pedicle of the LAP is rather short compared to the superior gluteal artery perforator (SGAP) flap or the profunda artery perforator (PAP) flap that have an average pedicle length of 7.8 cm and 9.9 cm, respectively [13, 15].

Patient Selection

As mentioned above, the DIEAP flap is the gold standard in autologous breast reconstruction [16]. The LAP flap can be a good alternative in patients who are not suitable for a DIEAP flap breast reconstruction because of unavailable abdominal donor site: insufficient abdominal tissue, previous abdominoplasty or excessive abdominal scar. Other candidates for LAP flap breast reconstructions are patients who already underwent a failed DIEAP flap or who developed a secondary tumour in contralateral breast after DIEAP flap [10]. The LAP flap is also indicated in BRCA-positive young women who want immediate reconstruction after preventive mastectomy and who lack abdominal bulk for bilateral reconstruction [13]. These indications are mainly the same as for the SGAP flap, the inferior gluteal artery perforator (IGAP) flap, the transverse myocutaneous gracilis (TMG) flap or the PAP flap. Gluteal fat has a firm texture, which can make breast shaping more difficult. Furthermore, a contralateral buttock lift could be necessary to correct the asymmetry caused by the distortion of the buttock contour. On the other hand, the TMG and PAP flaps provide only a limited amount of soft tissue and additional procedures as fat grafting or implants may often be needed to obtain enough volume. The scar location close to the genital area may also cause discomfort to the patient. The LAP flap is best suited for patients who have significant subcutaneous fat in the lumbar and flank region, where the harvest of a significant amount of tissue is possible without creating a contour deformity. However, contralateral liposuction may be required in unilateral cases. The resulting donor-site scar is often too high to be hidden with typical underwear. This may limit indication in young women or in patients not willing to have a visible scar [10].

Preoperative Planning and Patient Preparation

Preoperative evaluation should include the same workup as for any other free flap autologous breast reconstruction technique. Physical examination should include inspection of the skin of the lumbar region for scarring or previous incision sites and general tissue bulk is examined with a pinch test.

Given the variability of perforator size, course and length, all patients should undergo a preoperative computed tomographic angiography (CTA) of the lumbar and thoracic regions. This enables the surgeon to evaluate the branching pattern and course of the perforator (septocutaneous or musculocutaneous), thus identifying the most appropriate perforator, and also to assess the patency of the internal mammary (IM) recipient vessels [7]. The perforators are marked by the radiologist using a grid system in which the midline along the spinal process represents the *Y*-axis whilst the *X*-axis is a horizontal line connecting the highest points on both iliac crests. The dominant perforator is marked and confirmed by a unidirectional Doppler. In general, an ipsilateral LAP flap is planned but bilateral cases are always performed in two stages with a minimum of 3 months between operations.

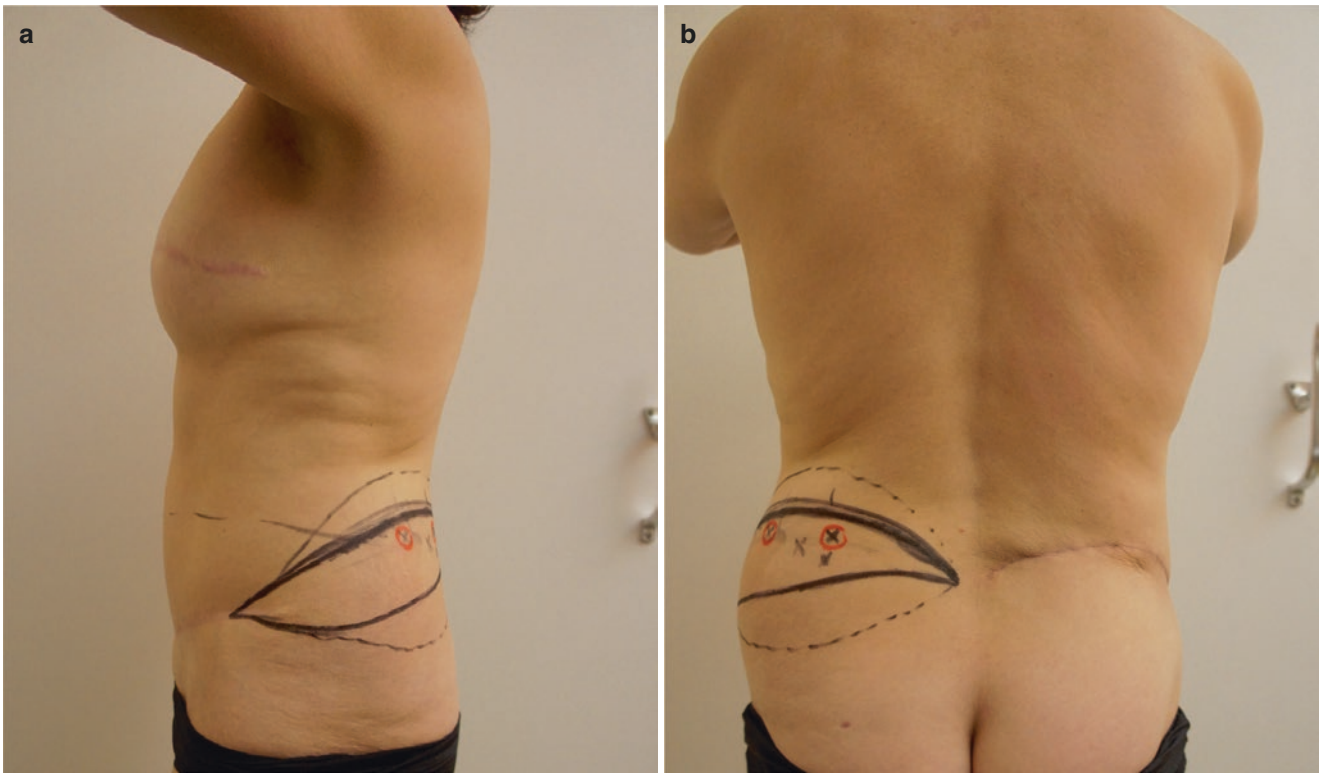

Fig. 22.1 (**a**, **b**) Preoperative skin markings. The perforators were marked according to the CT scan findings and confirmed by unidirectional Doppler. A fusiform skin island is drawn over the perforators obliquely above the iliac crest pointing towards the anterior superior spine. The size of the flap is judged using the pinch test. The flap's design is extended to reach the previous abdominoplasty scar

The patient is marked in a standing position (Fig. 22.1a, b). The posterior midline and iliac crest are marked initially and then the dominant LAP is identified and confirmed by unidirectional Doppler. A fusiform skin island is drawn over the perforators slightly obliquely above the iliac crest pointing towards the anterior superior spine to resemble an upper buttock lift scar. The drawings should not pass the posterior midline, and they are designed to eventually meet up with an abdominoplasty scar laterally. The size of the flap is judged using the pinch test. Nevertheless, the skin island should be kept as small as possible to avoid problems with donor-site closure; a skin island of 8–10 cm can be easily closed primarily. In the last few years, a more anterior design of the flap was introduced in order to reduce the incidence of seroma by preserving the lymphatic drainage over the thick deep fascia over the paraspinal muscle [10].

Surgical Technique

The flap can be harvested either in a prone position or in a lateral decubitus position. Attention is paid to the protection of all pressure points and placement of an arm roll is mandatory for patients positioned in the lateral decubitus (Fig. 22.2).

If the patient lies in lateral decubitus position, the flap is most easily harvested from the back towards the abdomen with the surgeon standing at the posterior side of the patient (posterior approach). The anterior approach is also used when the perforator is more laterally located. It allows a two-team approach for the simultaneous preparation of the mastectomy site and for the harvesting of a deep inferior epigastric interpositional graft if necessary.

In case of prone decubitus, the operation starts with the patient in supine decubitus whilst the mastectomy site is prepared, the recipient vessels are dissected and a deep inferior epigastric pedicle interpositional graft is harvested. Subsequently, the patient is turned to a prone position for flap dissection. The flap is harvested from the lateral to the medial with the surgeon standing at the ipsilateral side. Whilst anastomosis of the interpositional graft is performed, a second team closes the donor site and repositions the patient in a supine position for revascularization and shaping of the flap [10, 13].

After incising the skin and subcutaneous tissue, the thoracolumbar fascia is opened medially over the erector spinae

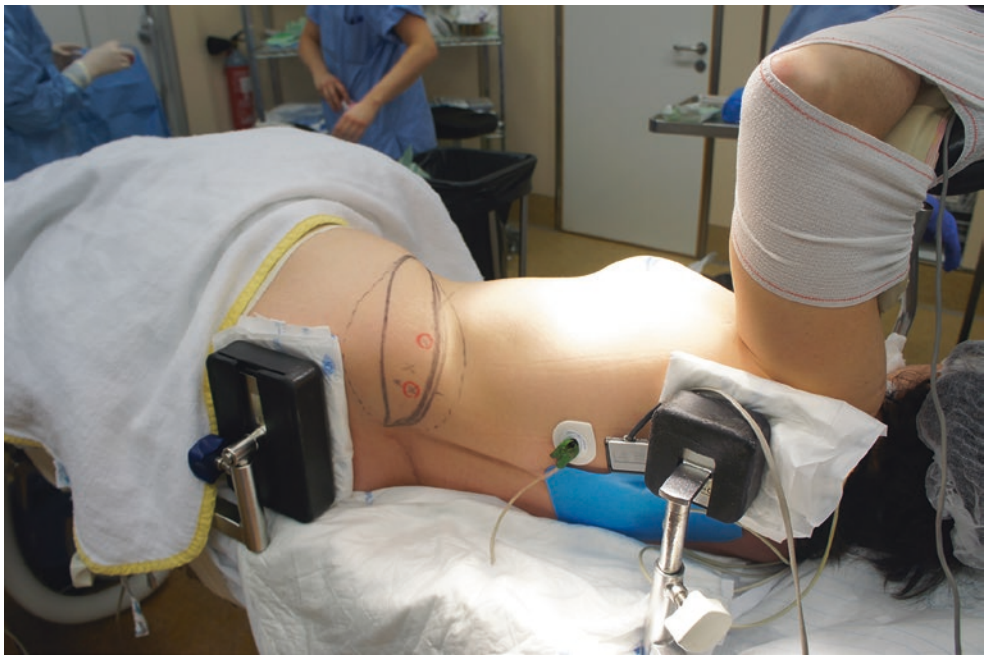

Fig. 22.2 Patient positioning. The patient is positioned on lateral decubitus, allowing a two-team approach for flap harvesting and preparing the recipient site

muscle. The fascia is elevated with a retractor to identify the sensory nerves and the perforators. Whilst directly visualizing the perforators, the flap is elevated from anterolateral to medial in a subfascial plane. To obtain sufficient pedicle length, the selected perforator with its concomitant vein is dissected down between the erector spinae and quadratus lumborum muscles (Fig. 22.3a). To harvest more subcutaneous tissue, the flap is raised bevelling superiorly and inferiorly creating a gluteal extension in the adipose tissue and the flap is then freed from the abdominal deep fascia. During undermining, care should be taken to leave the fat layer above the superficial fascia in order to avoid donor-site depression. The flap is positioned as it is harvested, with the cranial bevelling supplying the upper pole fullness of the breast whereas the thick inferior gluteal bevelling gives volume and projection to the breast. Because of these typical features, the LAP flap does not need to be shaped and remodelled to obtain a natural breast contour.

The flap can be also harvested with a sensory nerve, if required. The nervi clunium superiores follows the perforators, can be isolated up to 10 cm and anastomosed to the fourth intercostal nerve if one desires to reinnervate the flap. The severing of the nervi clunium superiores can lead to hypoesthesia of the upper buttock, which is rarely bothersome to the patient [13]. At this stage, the lumbar pedicle length and diameter are evaluated. Regardless of the pedicle length and size obtained, the dissection should stop at the level of the processus transversus vertebrae to avoid injury to the spinal nerves [10]. Indeed, postoperative quadriceps weakness and L3–L4 paraesthesia have been reported probably due to neuropraxia caused by an extensive dissection beyond the processus transversus [13]. If the length is adequate (≥6 cm) and/or the artery diameter is more than 0.5 mm, then anastomosis is performed in a similar manner as for a deep inferior epigastric perforator flap. If the length or the calibre of the pedicle is not suitable, a vascular interpositional graft will be necessary[10] (Fig. 22.3c, d). The need of interpositional graft is reported to vary between 57% and 80% of the cases [10, 13]. This is usually harvested from the deep inferior epigastric artery and vein through a small Pfannenstiel incision. Other options are the thoracodorsal vessels or the descending branch of the lateral circumflex iliac artery. The interpositional graft obviates the need for a longer pedicle dissection and provides a better calibre match between the mammary vessels and the flap pedicle. The anastomoses between the vascular graft and the lumbar artery and vein are done on a separate surgical table. Harvesting the deep inferior epigastric segment is straightforward and allows a longer pedicle with a better size match to the diameter of the recipient vessels. The internal mammary vessels are dissected simultaneously using a two-team approach. However, due to the short lumbar perforator length, the internal mammary vessels are dissected over 3–4 cm after removal of one costal cartilage. This makes the microanastomosis easier. Donor-site closure is performed simultaneously during the microanastomosis. As the LAP flap donor site is prone to seroma, a careful closure of the donor site is mandatory. In order to reduce seroma, skeletonizing the iliac crest should be avoided and only limited undermining, mainly inferior, resembling an upper buttock lift, is required. Quilting sutures are used, as well as fibrin glue. Long-acting local anaesthetic is injected subfascially to reduce postoperative pain. Two suction drains

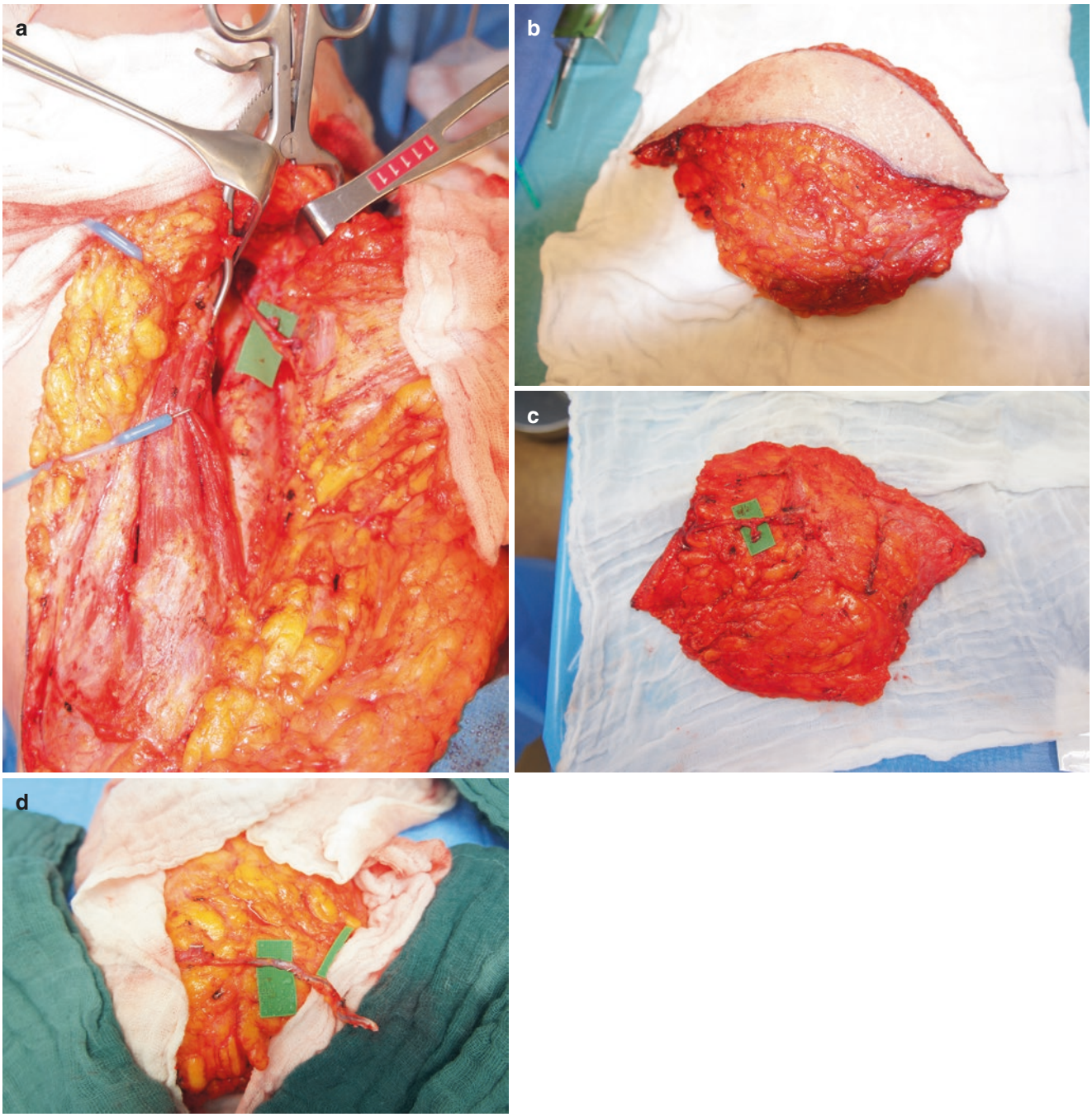

Fig. 22.3 (**a**–**d**) Intraoperative view. To obtain sufficient pedicle length, the selected perforator is dissected down between the erector spinae and quadratus lumborum muscles (**a**). To harvest more subcutaneous tissue, the flap is raised bevelling superiorly and inferiorly creating a gluteal extension in the adipose tissue. Thus, the cranial bevelling supplies the upper pole fullness of the breast, whereas the thick inferior gluteal bevelling gives volume and projection to the breast (**b**). The left LAP flap shows a short pedicle length (less than 6 cm) and small calibre (**c**). A vascular artery-vein bypass is harvested from the left deep inferior epigastric vessels, thereby creating a 12-cm pedicle length and better calibre match with the IM recipient vessels (**d**)

are left in the donor site. Once the microanastomosis is done with the internal mammary vessels, the flap is fixed temporarily with surgical staples to the mastectomy skin. The patient is then turned to the supine position for shaping of the breast. The subcutaneous tissue is fixed to the pectoralis major muscle at the axillary side and to the inframammary fold. The flap is de-epithelialized, depending on the reconstruction type. In some cases, the entire flap is used; in others the distal part of the flap is trimmed if there are signs of venous congestion or ischaemia. The flap is used as a hammock

within the mastectomy pocket without the need for folding the flap onto itself. The mean operating times vary between 424 and 270 min [10, 14]. The size of a LAP flap is usually ample to create a breast of sufficient volume. The mean flap size is about 142 cm^2 (dimensions 22 × 5.28 × 6.5 cm) and the mean flap weight 495 g (range 366–730 g). Additional lipofilling to improve breast contour can be used to improve the quality of the skin damaged from preoperative irradiation. Compared to TMG (average 224 ± 67 g for patients with a mean body mass index of 22 ± 2 kg/m^2), the LAP flap provides correspondingly more tissue in patients with a similar body mass index (BMI) (average 495 g, mean body mass index of 23 kg/m^2) [10].

Technical Variations

- *Technique*: Surgical challenges consist of a careful dissection through the thoracolumbar fascia and tedious dissection of the perforator between the muscles. To harvest more subcutaneous tissue, the flap is raised bevelling superiorly and inferiorly creating a gluteal extension.
- *Pedicle length and size mismatch*: The need for an interpositional graft is reported to vary between 57% and 80% of the cases, due to the short pedicle. This is usually harvested from the deep inferior epigastric artery and vein. Using a two-team approach, no time is lost with the vascular graft harvest.
- *Seroma*: A more anterior flap design preserves the lymphatic drainage over the thick deep fascia over the paraspinal muscle. It is better to avoid aggressive denuding of the iliac crest with a minimal undermining only. Quilting sutures and adequate wound drainage may also reduce the risk of seroma.
- *Contour*: For donor-site closure, only inferior undermining is necessary. The flanks can be beautifully contoured without causing shape deformities, but in unilateral cases, contralateral liposuction may be needed.
- *Hypoesthesia upper buttock*: The severing of the nervi clunium superiores can lead to hypoesthesia of the upper buttock, which is rarely bothersome to the patient. To obtain a sensate flap, the nervi clunium superiores can be isolated and anastomosed to the fourth intercostal nerve.
- *High scar*: The resulting donor-site scar is often too high to be hidden with typical underwear; this can limit indications in young women. In order to obtain a scar as low as possible, it is important to select the lowermost suitable perforator.

Postoperative Care

An abdominal binder or a liposuction garment is applied at the donor site for between 4 and 6 weeks postoperatively. Drains are left in the donor site until they produce less than 20 ml per 24 hours or for a maximum period of 10 days postoperatively. Mobilization of the patient starts on the second postoperative day. Secondary corrections such as nipple reconstruction, breast remodelling with fat grafting and contralateral breast symmetrization are performed 3–6 months after the primary surgery. If necessary, donor site symmetrization is also performed at that time by contralateral flank liposuction to enhance waist contour.

Complications

Complications include revision surgery, partial/complete flap necrosis and seroma formation. The latter can lead to prolonged drainage, serial aspiration and need for excision of seroma capsule. Delayed wound healing can also be problematic and impact upon the timing of adjuvant treatments. In the study of Peters and colleagues including 35 LAP flaps, 6 flaps had to be revised as a consequence of venous thrombosis (17%). Flap necrosis occurred in three cases only (5.7%) [13] In the author's series, there were no cases requiring revision of microanastomoses and no cases of flap failure or flap necrosis (Table 22.1). The follow-up period ranged between 6 and 26 months (average 13 months) in the study of Hamdi and colleagues [10] and between 1 and 48 months (average 18 months) in the study of Peters and colleagues [13]. A high seroma rate at the donor site is relatively common varying from 17% to 78% [10, 13]. In the most recent cases, postoperative seromas are largely avoided by several measures: (1) less flap skin harvested, (2) minimal undermining, (3) a more anterior design of the flap and (4) a meticulous closure technique [10]. A large series of 100 LAP flaps for breast reconstruction in 72 patients has been recently published by Opsomer and colleagues. With a mean follow-up time of 30 months, they reported a total flap revision rate of 22%. The indications for revision were haematoma (3%), venous thrombosis (14%) or arterial thrombosis (6%). Flap necrosis occurred in 9% of the cases, whereas donor-site seroma requiring puncture aspiration was reported in 31% of

Table 22.1 Complications in the author's series [10]

	Flaps	Donor sites (/14)
Revision surgery	0/14	
Partial/complete flap necrosis	0/14	
Seroma		7/14
Prolonged drainage		4
Serial aspiration		1
Excision seroma capsule +/− quilting sutures		2

the patients [14]. This high revision rate can be attributable to a necessary steep learning curve because of the difficult flap dissection, even in expert hands. Furthermore, the need for an interpositional graft, which means an additional anastomosis and longer operative time, is another possible risk factor. The use of an interpositional graft has reported adding 76 min to the mean operative time [13]. Another possible explanation of the reported high revision rate is the fact that, as the LAP is a secondary choice flap for breast reconstruction, it is often performed in tertiary reconstruction after flap failure. In the series published by Opsomer and colleagues, 14 cases of tertiary reconstruction after previous free flap were described [14]. As we reported in a previous publication, the tertiary reconstruction after a total flap failure is always a challenging and higher-risk procedure [17]. As described above, quadriceps weakness and paraesthesia in the territory of L3–L4 [9] can be a temporary complication, reported in 3% of the patients; it spontaneously resolves after intensive physical therapy [13].

Clinical Case

A 53-year-old woman, who had previously undergone abdominoplasty, underwent bilateral mastectomy with implant reconstruction. Later, the patient complained of her unsatisfying result and, feeling uncomfortable with the prosthesis, she asked for autologous breast reconstruction. Because of the previous abdominoplasty, the abdominal donor site was unavailable and a DIEAP flap was not feasible. The preoperative examination revealed a significant amount of subcutaneous fat tissue in the lumbar and flank region; therefore she was a good candidate for breast reconstruction with bilateral lumbar artery perforator flaps (Fig 22.4a, b). The patient underwent a sequential reconstruction in two stages with a 3-month interval between surgical operations. Preoperatively, the perforators were localized with a computed tomographic angiography, confirmed by handheld ultrasound Doppler and marked on the skin. A fusiform skin island was drawn over the perforators obliquely above the iliac crest pointing towards the anterior superior spine. The size of the flap was judged using the pinch test. Flap harvest was performed with the patient in the lateral decubitus position. The recipient vessels were the internal mammary vessels, which were dissected simultaneously in a two-team approach. To obtain sufficient pedicle length, the selected perforator was dissected down between the erector spinae and quadratus lumborum muscles. The left LAP flap showed a short pedicle length, less than 6 cm, and small calibre, thus making necessary an interpositional graft (Fig. 22.3c). A vascular artery-vein bypass was harvested

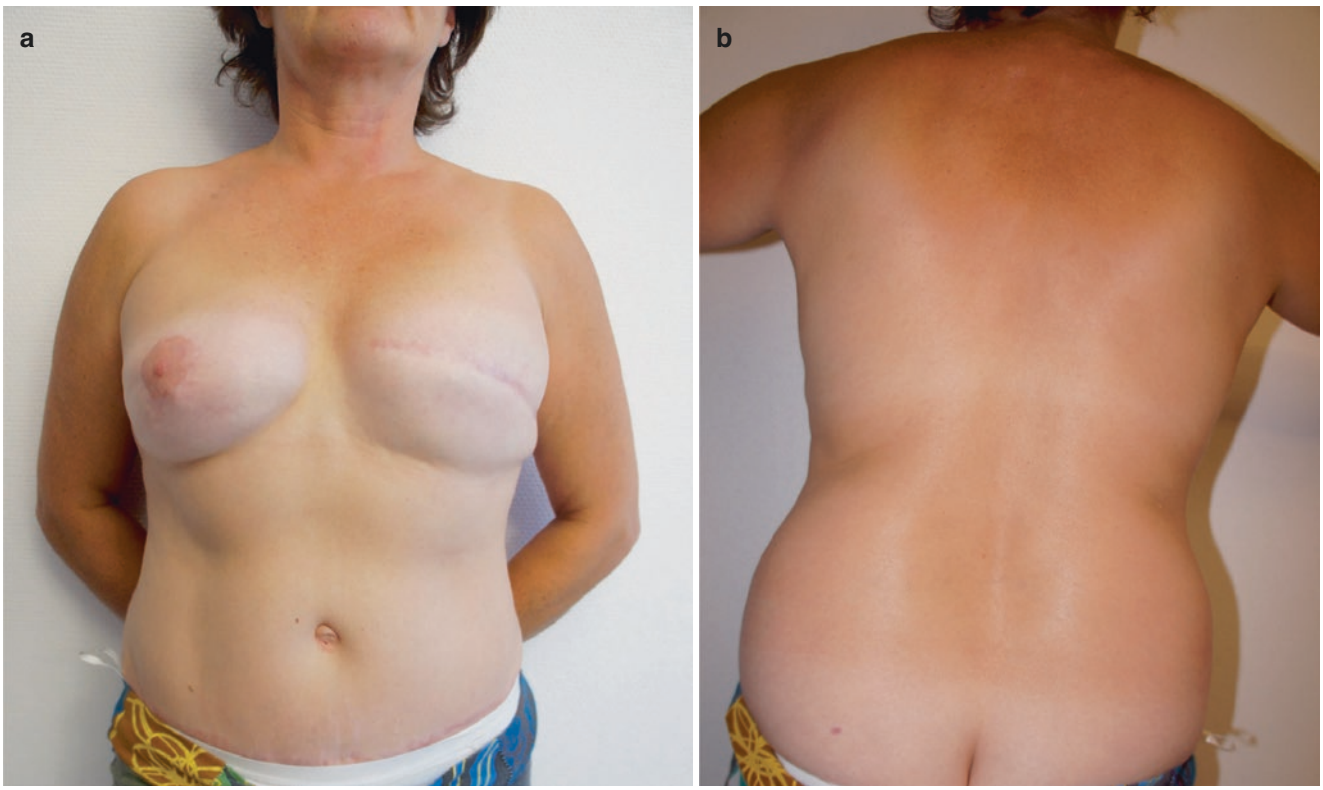

Fig. 22.4 (**a**, **b**) Clinical case, preoperative view. A 53-year-old woman, who underwent bilateral mastectomy with implant reconstruction, was asked to undergo autologous breast reconstruction (**a**). The patient presents a sufficient amount of fat tissue in the so-called love handles in the lumbar and flank regions for bilateral flap harvest (**b**)

from the left deep inferior epigastric vessels, thereby creating a 12-cm pedicle length and better calibre match with the IM recipient vessels (Fig. 22.3d). The IM vessels were dissected for 3–4 cm after removal of one costal cartilage to obtain an easier microsurgical setup. In order to harvest more subcutaneous tissue, the flap was raised bevelling superiorly and inferiorly, and then was positioned as it was harvested, with the cranial bevelling supplying the upper pole fullness of the breast whereas the thick inferior gluteal bevelling giving volume and projection to the breast. Donor-site closure was performed simultaneously during the microanastomosis. In order to reduce seroma, quilting sutures were used during the closure of the donor site. In both sides, the postoperative course was uneventful with no need for revision surgery. The breast reconstructions were both successful with a final pleasant aesthetic result. The resulting donor-site scars were well accepted by the patient in favour of the pleasing flanks contouring (Fig. 22.5a, b).

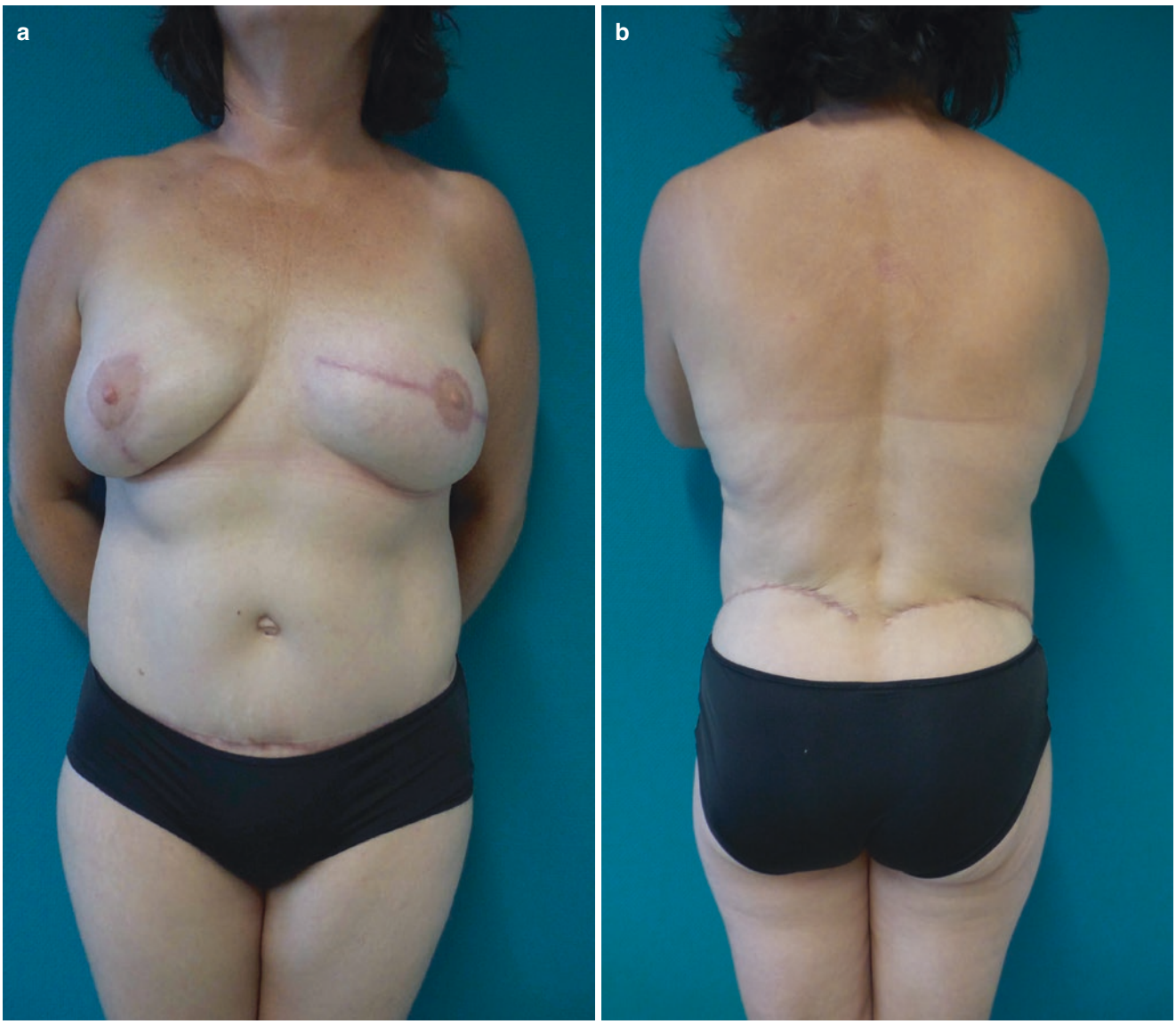

Fig. 22.5 (**a**, **b**) Clinical case, postoperative view. Two-year postoperative view after sequential bilateral LAP breast reconstruction (**a**). Two-year postoperative view of the donor site: The scar is above her underwear, but does not disrupt the buttocks and improves waistline contour (**b**)

Conclusions

The lumbar artery perforator flap is a reliable alternative for autologous breast reconstruction whenever a deep inferior epigastric artery perforator (DIEAP) flap is not feasible. The major advantages of LAP flap are the fat tissue quality and the donor-site contour. The lumbar and flank regions offer an optimal fat quality, soft and pliable, and therefore flap shaping is easier and usually does not require further modelling. Since the LAP flap is designed over a transition area between the back and the buttock, harvesting of a significant amount of tissue in the so-called 'love handles' region is possible without causing shape deformities, but on the contrary creating a pleasing flank contouring. Surgical challenges could be a difficult dissection, an inadequate length of the pedicle and a possible size mismatch. Frequently (57–80%), an interpositional graft is necessary, thus increasing operating time and the surgical risk. Despite the technical difficulties, in comparison with the other second choice free flaps for breast reconstruction like SGAP, TMG or PAP flap, the Lumbar flap seems to be superior in terms of fat tissue quality and quantity. Furthermore, in comparison with SGAP flap, the LAP flap has a lower donor-site morbidity, and despite the visible scar, the flanks can be beautifully contoured.

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Septocutaneous Gluteal Artery Perforator Flap in Breast Reconstruction

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Introduction

In 1976, Fujino performed the first free flap for breast reconstructive purposes. A gluteus maximus myocutaneous flap was used, including skin, fat and muscle. The superior gluteal artery and veins were then anastomosed to the thoracoacromial vessels [1]. Because of a short vascular pedicle, the position of the breast mound was quite high and led to additional vein grafting. For this reason, his technique did not achieve widespread adoption. In 1983, Shaw reported a series of ten patients who underwent breast reconstruction using a superior gluteal myocutaneous microvascular free flap. Technical refinements were added to the work of Fujino, using the mammary artery and vein as recipient vessels for correction of the high position of the breast mound [2]. It was not until 1993 when Allen and Tucker refined the gluteal myocutaneous flap to a perforator flap and introduced the superior gluteal artery perforator (S-GAP) flap [3]. As with other perforator flaps, intramuscular dissection provided a longer vascular pedicle and obviated the need for a vein graft to perform the anastomosis. Moreover, the gluteal muscles were spared with less donor site morbidity as a result. In 2010, LoTempio and Allen published a review of 492 gluteal artery perforator flaps, showing less contour deformity by designing the skin island in the upper buttock superior from medial to lateral and bevelling superiorly. Flap failure occurred in approximately 2% [4]. Over the years, results have improved due to refined surgical skills, with a learning curve of 50–100 procedures for perforator flap breast reconstruction but also the introduction of new imaging technologies such as magnetic resonance angiography (MRA) and computed tomography angiography (CTA). These techniques allow plastic surgeons to preoperatively identify the best perforator and select their surgical strategy in autologous breast reconstruction [5, 6].

After the introduction and development of perforator flaps, confusion arose about the nomenclature. For instance, the flap based on paraumbilical perforators was called PUP (paraumbilical perforator) flap by Koshima [7], but Allen and Treece [8] called it the DIEP (deep inferior epigastric perforator) flap, named after its originating artery. Several attempts were made to reach consensus on the terminology of perforator flaps:

1. During the 5th international course on perforator flaps in 2001 in Gent, Belgium [9]
2. The Canadian proposal, summarised by Gettes et al. [10]
3. The Asian microsurgical community proposal, using more complex nomenclature [11]

Discussion regarding the nomenclature of perforator flaps remains open, and the last proposal by Sinna et al. [12] came in 2010. Taylor established in 2012 a perforator flap nomenclature based on anatomical principles, such as the true subcutaneous course of a perforator [13], making the dissection course easy to understand from the nomenclature, as Kim et al. already suggested in 2004 [14].

They distinguished between perforators running through the muscle (in this chapter indicated as musculocutaneous) and perforators running in the septum between two muscles (in this chapter indicated as septocutaneous) (Fig. 23.1). It is important to distinguish these perforators, as the clinical implication differs. This is particularly true for the S-GAP, a valuable alternative donor site when the abdomen, which remains first choice for free flap breast reconstruction, is not available. The evolution from the S-GAP (superior gluteal artery perforator) flap to the Sc-GAP (septocutaneous gluteal artery perforator) flap reflects the abovementioned principle.

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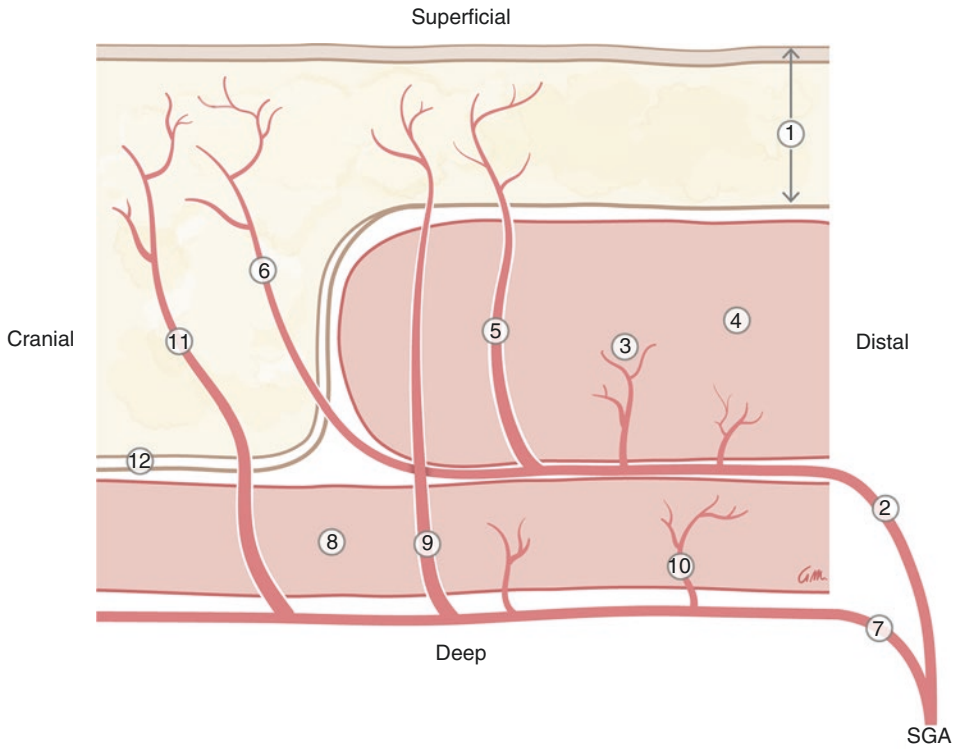

Fig. 23.1 A schematic illustration of the superior gluteal artery (SGA) and its perforators, showing the different musculocutaneous and septocutaneous courses. (1) Skin and subcutis; (2) superficial branch of SGA; (3) muscular branch; (4) gluteus maximus muscle; (5) musculocutaneous perforator; (6) septocutaneous perforator; (7) deep branch of SGA; 8) gluteus medius muscle; (9) musculocutaneous perforator; (10) muscular branch; (11) musculocutaneous perforator; (12) thick fascia of gluteus medius muscle and the cranial margin of the gluteus maximus muscle. (© 2019 by Greet Mommen, www.greetmommen.be)

The dissection of the S-GAP perforator flap is still considered as very challenging and requires a high level of expertise [15]. We first published a preliminary anatomical study [16], followed by a clinical study [17] showing that the dissection of the septocutaneous perforators is easier than dissection of the musculocutaneous perforators of the S-GAP perforator flap, because of the possibility to retract the muscles and expose the perforators. In addition, the aesthetic results in the donor sites are improved.

Anatomy

This paragraph is partly based on Moore Clinically Oriented Anatomy [18], Gray's Anatomy [19], Stone and Stone's Atlas of Skeletal Muscles [20] and own anatomical dissection.

It is of great clinical importance to define the exact borders of the gluteal region, in order to achieve reliable skin projections of underlying osseous and soft tissue structures. The iliac crest bounds the gluteal region cranially, the anterior superior iliac spine (ASIS) and posterior superior iliac spine (PSIS) being important bony landmarks at its beginning and end. The PSISs are visible as dorsal skin dimples. Their interconnecting line indicates the S2 level. The oblique, most caudal fibres of the gluteus maximus muscle bound the gluteal region caudally. Often, the horizontal skin fold of the buttock, indicated as gluteal fold, gluteal sulcus or ruga glutaea horizontalis, is mistaken for the caudal border of the gluteus maximus muscle.

Between the right and the left buttock, the vertical, intergluteal cleft runs to the anus. Synonyms are natal cleft, crena (rima) ani or crena clunium. Caudomedially, deep from the gluteus maximus muscle, the ischial tuberosity is palpable. It forms the proximal attachment of the hamstrings. The sacrotuberous ligament fans from the ischial tuberosity in a cranial direction into the sacrum and the PSIS. Laterally, the greater trochanter is a prominent landmark.

Musculature

In the gluteal region, two muscle layers are present: (1) the superficial layer of the gluteus maximus muscle and (2) the deep layer of the gluteus medius, minimus, piriformis, triceps coxae and quadratus femoris muscles (Fig. 23.2). The gluteus maximus muscle consists of a cranial and a caudal part. When taking a fixed point at the pelvis, the smaller cranial part abducts and laterally rotates the thigh. The larger caudal part extends and laterally rotates the thigh and assists in thigh adduction. With a fixed point distally, the gluteus maximus muscle is a trunk stabiliser during bipedal gait and, synergistic with the hamstrings, raises the trunk. The gluteus medius strongly abducts the femur in the hip joint and moderately rotates the thigh medially. The gluteus minimus muscle also abducts the femur in the hip joint; the anterior part more strongly rotates the thigh medially and flexes the hip. The posterior part laterally rotates the thigh and extends

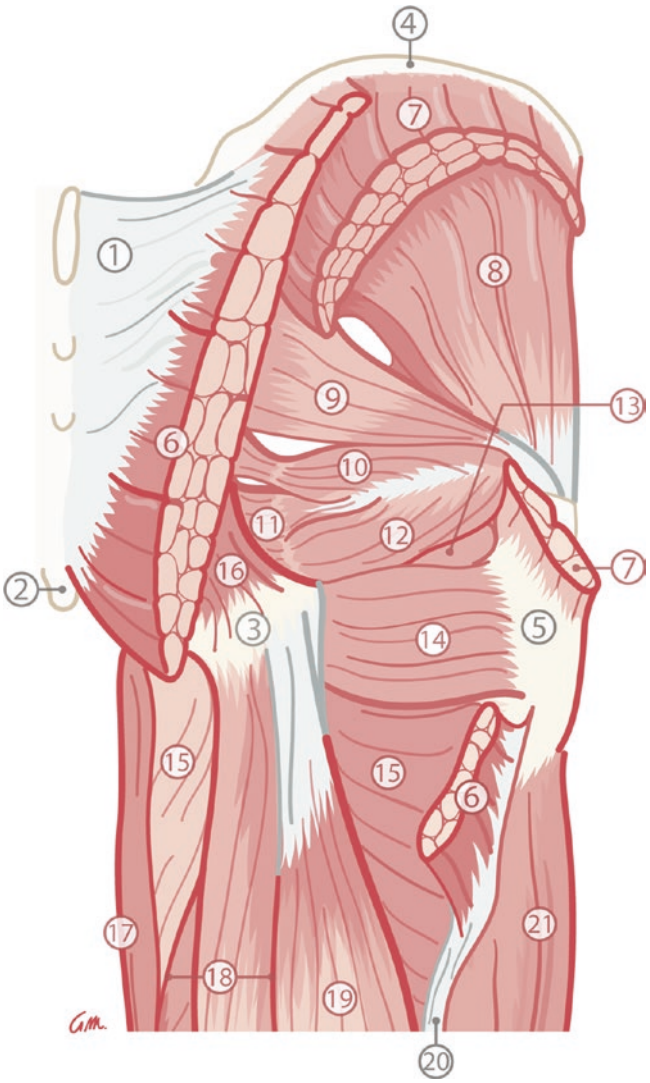

Fig. 23.2 Posterior view of the muscles of the gluteal region and the posterior thigh. (1) Sacrum; (2) Coccyx; (3) Tuber ischiadicum; (4) Crest of ilium; (5) Greater trochanter; (6) Gluteus maximus muscle; (7) Gluteus medius muscle; (8) Gluteus minimus muscle; (9) Piriformis muscle; (10) Superior gemellus muscle; (11) Internal obturator muscle; (12) Inferior gemellus muscle; (13) External obturator muscle; (14) Quadratus femoris muscle; (15) Adductor magnus muscle; (16) Sacrotuberous ligament; (17) Gracilis muscle; (18) Semimembranosus/semitendinosus muscles; (19) Biceps femoris muscle; (20) Linea aspera; (21) Vastus lateralis muscle. (© 2019 by Greet Mommen, www.greetmommen.be)

the hip. The piriformis is an exorotator, abductor, extensor and stabiliser in the hip joint.

The triceps coxae (gemellus superior, internal obturator, gemellus inferior) and the quadratus femoris muscles are lateral rotators, extensors and adductors in the hip joint.

The quadrangular gluteus maximus muscle is the largest, thickest and most superficial muscle of the buttock. Its osseous origins are on the gluteal surface of the ilium, dorsally from the posterior gluteal line, the adjacent inferolateral sacral angle and the lateral coccyx. The connective tissue origins of the gluteus maximus muscle are the sacrotuberous ligament, the erector spinae aponeurosis and the gluteus medius aponeurosis. Gluteus maximus muscle fibres descend obliquely from medial to lateral. The muscle fibres of the cranial part merge with the more lateral fibres of the caudal part. They continue over the greater trochanter as the iliotibial tract, a lateral thickening of the deep fascia (fascia lata) of the upper leg. This continuity is the fascial insertion of the gluteus maximus muscle. The iliotibial tract glides along the greater trochanter over the trochanteric bursa of the gluteus maximus. The deeper medial fibres of the caudal gluteus maximus muscle attach to the gluteal tuberosity of the femur in a bony insertion. The tensor fasciae latae muscle originates from the outer edge of the iliac crest, between the ASIS and a point approximately 5 cm posterior to it, the iliac tubercle. This muscle also continues into the iliotibial tract, eventually inserting at Gerdy's tubercle on the anterolateral condyle of the tibia. Both gluteus maximus and tensor fasciae latae muscles cooperate in stabilising the lateral knee during walking.

The gluteus medius muscle is broad, thick and fan-shaped and originates from a bony insertion on the gluteal surface of the ilium, between the iliac crest, the posterior gluteal line and the anterior gluteal line. It inserts also osseous at the lateral greater trochanter, separated from it by a deeper trochanteric bursa of the gluteus medius. A deep muscle slip at the cranial end of de greater trochanter is optional. A deep, thick, dens connective tissue layer, the deep gluteus medius fascia, covers the cranial gluteus medius muscle. Gluteus medius muscle fibres attach from the inner side to this fascia, and cranial gluteus maximus muscle fibres attach from the outer side (Fig. 23.3). The caudal gluteus medius is covered by the gluteus maximus and bordered (sometimes covered) by the piriformis muscle. A thin areolar fascia is separating the three muscles. The caudal border of the gluteus medius muscle may blend with the piriformis muscle. The craniomedial gluteus maximus origin is quite thin. More to the lateral, the muscle becomes thicker and prominent. Finding an intermuscular septum between the gluteus maximus and medius muscles is therefore easier at a distance of approximately 7 cm from the midline.

The gluteus minimus muscle is the thinnest and smallest gluteus muscle. It is also fan-shaped and originates from the gluteal surface between the anterior and inferior gluteal lines and, posteriorly, from the mid-part of the greater sciatic notch. The aponeurotic continuation of the converging muscle fibres fuses with the cranial part of the triangular iliofemoral ligament, a thickening of the anterior hip joint capsule; hereafter, as a capsular expansion, it inserts to the anterior surface of the greater trochanter.

Although all muscles discussed next are more caudally and deeper than the surgical dissection of the Sc-GAP flap, they are described below to complete the muscular topography of the gluteal region. Besides, the piriformis muscle is

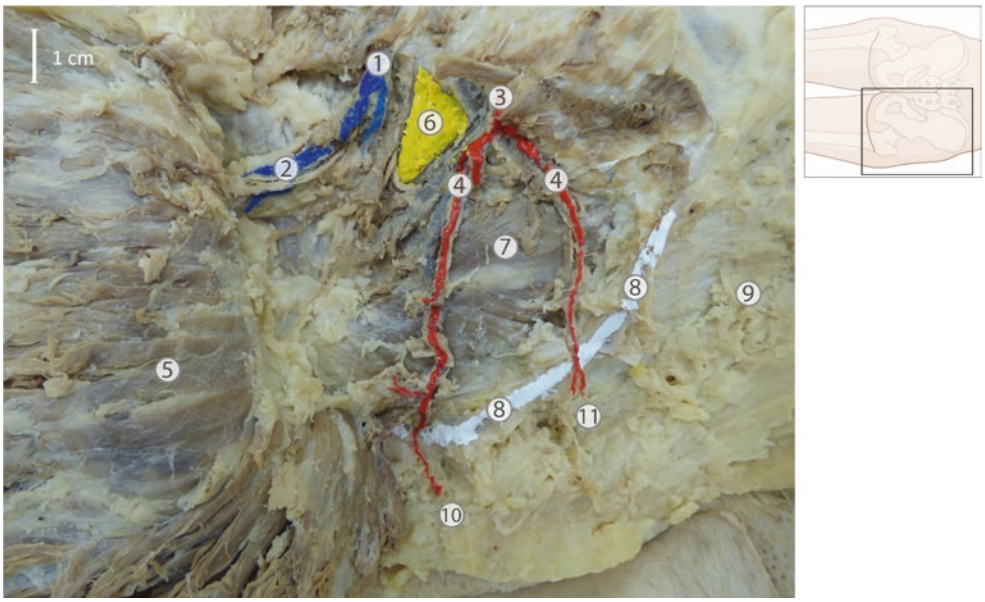

Fig. 23.3 Cadaveric dissection of the gluteal region. (1) Infrapiriform foramen, (2) Inferior gluteal artery pedicle, (3) Suprapiriform foramen, (4) Superior gluteal artery pedicle, (5) m. gluteus maximus (detached and reflected distally), (6) m. piriformis, (7) m. gluteus medius, (8) m. gluteus maximus, superior margin, (9) m. gluteus medius, fascia, (10) Sc perforator, (11) Sc perforator (© 2019 by Greet Mommen, www.greetmommen.be)

an important key structure to understand vascularisation and innervation in the gluteal region.

The piriformis muscle is a pear-shaped muscle, originating from the inner (anterior) surface of the sacrum, the posterior inferior iliac spine (PIIS), the adjacent sacroiliac joint capsule and, sometimes, the pelvic (inner) part of the sacrotuberous ligament. Its insertion at the cranial end of the trochanteric fossa often blends with the more caudally and posteriorly inserting triceps coxae muscle group. The cranial border of the piriformis muscle also sometimes blends with the caudal border of the gluteus medius muscle.

The triceps coxae muscles, composed of the gemellus superior, internal obturator and gemellus inferior muscles, are next caudal group. The flat rectangular quadratus femoris muscle is the most caudal muscle in the deep gluteal layer. It lies between the inferior gemellus and (cranial edge of) the adductor magnus muscles.

Vascularity

The superior and inferior gluteal arteries (SGA and IGA) supply the gluteal region. Both are direct branches from the internal iliac artery. The comitating venous tree has a similar branching pattern, draining into the internal iliac vein (Fig. 23.4).

The superior gluteal artery (SGA), being the largest branch of the internal iliac artery, originates from its posterior trunk. Fänder et al describe, as a case study, a left missing posterior trunk. The trunk branches (iliolumbar artery, lateral sacral arteries and SGA) in this case ramified directly from the common iliac artery [21]. The SGA runs posteriorly and pierces the pelvic fascia between the lumbosacral trunk and the first sacral nerve root. Within the lesser pelvis, it supplies the piriformis, internal obturator muscles and hipbone. It leaves the pelvis via the *greater sciatic foramen*, cranial to the piriformis muscle (suprapiriform foramen) and immediately branches into (1) superficial and (2) deep branches upon entry into the gluteal region. The superficial branch of the SGA enters the septal plane between the gluteus medius and maximus muscles and forms two clinical important branches: (1) muscular branches, supplying the gluteus maximus muscle and (2) septocutaneous perforators, traversing the intermuscular septum between the gluteus medius and maximus muscles, eventually supplying the subcutis and the skin.

The superficial SGA branch anastomoses with branches of the IGA, branches of the medial circumflex femoral artery and posterior branches of the lateral sacral artery. Cormack and Lamberty [22] describe a superficial SGA branch traversing the septum between the gluteus medius and maximus muscles, dividing into a posterior, intermediate and anterior branch. Septocutaneous perforators from the anterior branch pierce the deep gluteus medius fascia in the superolateral gluteus maximus edge to supply the (sub)cutis.

The deep SGA branch proceeds between the gluteus medius muscle on one hand and the gluteus minimus and piriformis muscles on the other. It ramifies into a superior and an inferior division. The superior division of the deep SGA supplies the gluteus medius muscle and continues along the cranial border of the gluteus minimus muscle, supplying this muscle too. Next, it proceeds along the ASIS and anastomoses with the deep circumflex iliac artery and the ascending branch of the lateral circumflex femoral artery. The inferior division of the deep SGA, like the superior one, runs between the gluteus medius and minimus muscles, supplying

them both. Eventually, it also anastomoses with the lateral circumflex femoral artery. One branch, in the trochanteric fossa, connects with the IGA and the ascending branch of the medial circumflex artery. Branches, perforating the gluteus minimus muscle, reach the hip joint to supply it.

From the deep SGA branch arise musculocutaneous perforators that run through the gluteus medius and maximus muscles to reach the (sub)cutis. They are not applicable as Sc-GAP pedicle, because of the difficult dissection of their intramuscular trajectory. The superficial and deep divisions of the SGA meet near the suprapiriform foramen. At this point, a converging network (caput medusa) of large, fragile blood vessels is present. Clinically, the dissection of the pedicle strictly should stop before reaching this network.

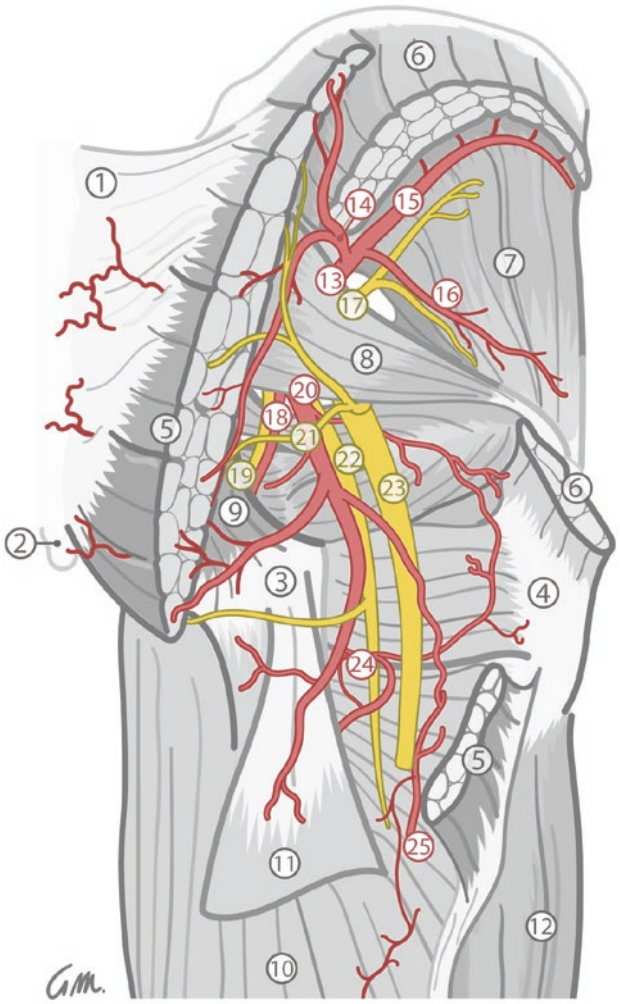

Fig. 23.4 Arteries and nerves of the gluteal region and the posterior thigh. (1) Sacrum; (2) Coccyx; (3) Tuber ischiadicum; (4) Greater trochanter; (5) Gluteus maximus muscle; (6) Gluteus medius muscle; (7) Gluteus minimus muscle; (8) Piriformis muscle; (9) Sacrotuberous ligament; (10) Adductor magnus muscle; (11) Origin of hamstrings; (12) Vastus lateralis muscle; (13) Superior gluteal artery (SGA); (14) Superficial SGA branch; (15) Deep SGA branch (superior division); (16) Deep SGA branch (inferior division); (17) Superior gluteal nerve; (18) Internal pudendal artery; (19) Pudendal nerve; (20) Inferior gluteal artery (IGA); (21) Inferior gluteal nerve; (22) Posterior cutaneous femoral nerve; (23) Sciatic nerve; (24) Termination of medial circumflex femoral artery; (25) First perforating artery. (© 2019 by Greet Mommen, www.greetmommen.be)

The inferior gluteal artery (IGA) is the largest terminal branch of the anterior trunk of the internal iliac artery. IGA descends anterior from the sacral plexus and the piriformis muscle and posterior from the internal pudendal artery. Inside the lesser pelvis, it supplies the piriformis and pelvic floor muscles. It also supplies the fundus of the bladder, the seminal vesicles, the prostate and the perianal fat. It leaves the greater sciatic foramen caudally from the piriformis muscle (infrapiriform foramen) to supply gluteus maximus, triceps coxae, quadratus femoris and hamstring muscles. Extrapelvic IGA anastomoses with SGA, internal pudendal, obturator and medial circumflex femoral artery.

Nerve Supply

The many nerves that innervate the gluteal region are divided into a superficial and a deep group. The deep group clinically is the most important one. The skin of the buttock is innervated by the superficial cluneal nerves, divided into a superior, a middle and an inferior group. The superior cluneal group, located in the Sc-GAP flap region, originates from dorsal branches of L1–3. The middle cluneal group originates from S1–3 segments, and the inferior cluneal group is supplied from the posterior femoral cutaneous nerve. The seven deep gluteal nerves originate from the sacral plexus, leaving the lesser pelvis through the greater sciatic foramen. Six of them emerge caudal to the piriformis muscle (infrapiriform foramen), and one, the superior gluteal nerve, emerges cranial to this muscle (suprapiriform foramen). The superior gluteal nerve is formed by the dorsal branches of the ventral rami of L4–5 and S1. Together with the SGA, it leaves the lesser pelvis through the suprapiriform foramen (see above). It accompanies the deep SGA branch between the gluteus medius and minimus muscles, dividing into a superior branch, that innervates only the gluteus medius muscle, and an inferior branch that supplies both gluteus medius and minimus muscles and also the tensor fasciae latae muscle.

The following six nerves all leave the lesser pelvis caudal to the piriformis muscle, through the infrapiriform foramen. For the innervation of the exorotator muscles, the cranial to caudal muscle topography is followed.

The inferior gluteal nerve arises from the dorsal branches of the ventral rami of L4–5 and S1–2. It leaves the pelvis superficially from the sciatic nerve and laterally from the pudendal nerve and internal pudendal artery and accompanies the IGA. It gives of branches that innervate the gluteus maximus muscle (Fig. 23.5).

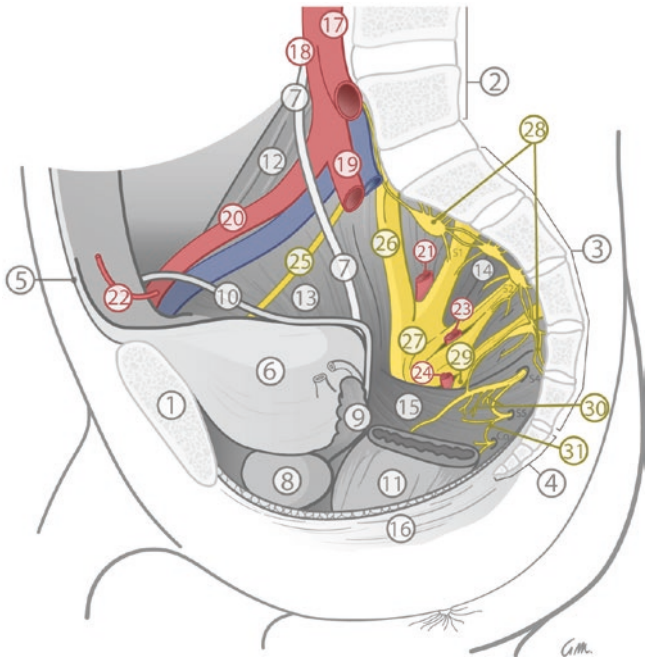

Fig. 23.5 Illustration of a dissection of the side wall of the pelvis, showing the both the sacral and the coccygeal plexuses. (1) Pubis; (2) Lumbar vertebrae; (3) Sacral vertebrae; (4) Coccyx; (5) Median umbilical ligament; (6) Bladder; (7) Ureter; (8) Prostate; (9) Vesicula seminalis; (10) Ductus deferens; (11) Rectum; (12) Psoas major muscle; (13) Internal obturator muscle; (14) Piriformis muscle; (15) Coccygeus muscle; (16) Levator ani muscle; (17) Abdominal aorta; (18) Right common iliac artery; (19) Right internal iliac artery; (20) External iliac artery; (21) Superior gluteal artery; (22) Inferior epigastric artery; (23) Inferior gluteal artery; (24) Internal pudendal artery; (25) Obturator nerve; (26) Lumbosacral trunk; (27) Sacral plexus; (28) Sympathetic trunk; (29) Pudendal nerve; (30) Visceral branches; (31) Nerve to coccygeus muscle. (© 2019 by Greet Mommen, www.greetmommen.be)

The pudendal nerve leaves the infrapiriform foramen most medially and continues into the pudendal (Alcock's) canal, accompanying the internal pudendal vessels. It divides into sensory and muscular branches to the anorectal, perineal and external genital regions.

The sciatic nerve is the main branch of the sacral plexus and the largest nerve of the body, in both length and cross-sectional area [23]. It consists of the medial tibial nerve, arising from the ventral branches of the ventral rami of L4–5 and S1–3, and the lateral common peroneal nerve from the dorsal branches of the ventral rami of L4–5 and S1–2. Though the sciatic nerve usually does not innervate the pelvic region, it is a well palpable landmark in the gluteal region.

The posterior femoral cutaneous nerve arises from the dorsal branches of the ventral rami of S1–2 and from the ventral branches of the ventral rami of S2–3. This nerve supplies a large skin region in the posterior thigh, as far as the popliteal fossa. It also gives rise to, usually three to four, inferior cluneal nerves (see above). A perineal branch innervates the skin of the perineum, the scrotum in male and the labium majus in female.

The nerve to the piriformis muscle arises from the dorsal branches of the ventral rami of S1–2 (sometimes only S2), entering the muscle from the anterior.

The nerve to the internal obturator and gemellus superior muscles is derived from the ventral branches of the ventral rami of L5 and S1–2 and leaves the infrapiriform foramen medially from the sciatic nerve. It enters the gemellus superior cranially, at its posterior surface, and the internal obturator muscle at its pelvic surface.

The nerve to the gemellus inferior and quadratus femoris muscles arises from the ventral branches of the ventral rami of L4–5 and S1. A cranial branch supplies the gemellus inferior muscle. A second branch enters the anterior quadratus femoris muscle. It also innervates the hip.

Preoperative Planning

In our institute, MRA is performed preoperatively with satisfying results. Although other imaging modalities are available to facilitate in preoperative planning, such as Doppler ultrasound or CTA [24, 25], we prefer to use MRA. MRA does not suffer from the high interobserver variation [25, 26] which is inherent to ultrasound exams in general, nor does it use ionising radiation like CTA. The latter is especially important as surgical planning often needs to be performed in (relatively) young women [27, 28].

The most important advantages of performing preoperative MRA are its excellent soft tissue contrast and the absence of radiation exposure. However, in some institutes or countries, MRA might be less available due to the relatively long acquisition times of these exams. Also, women with contraindications for MRA exams, such as claustrophobia, known allergic reactions to the contrast agent used and the presence of metal implants in their bodies, are not able to undergo these exams.

In our institute, the MRA exams are being performed on a 1.5 Tesla MRI scanner (Ingenia, Philips Healthcare, Best, The Netherlands) using a four-channel body coil. First, a sagittal, balanced T1-weighted fast field echo (FFE) is performed with a field of view (FOV) of 430 × 430 mm and a slice thickness of 10 mm. The in-plane resolution is 1.68 × 1.68 mm. Echo time (TE) and repetition time (TR) are 1.62 ms and 3.2 ms, respectively. Flip angle is 65 degrees.

Next, 15 mL of gadobutrol 1.0 mmol/l (Gadovist, Bayer Healthcare Pharmaceuticals, Berlin, Germany) is administered through an intravenous catheter, preferably placed in the antecubital vein. An automatic injector is used to ensure a continuous flow rate of 1.5 ml/s, followed by a saline chaser. After contrast administration, a transverse, balanced, T1-weighted FFE sequence is performed using the following sequence parameters: FOV 450 × 450 mm,

in-plane resolution 1.29 × 1.31 mm, slice thickness 6 mm, TE 1.93 ms, TR 3.9 ms and flip angle 65 degrees. Finally, a transverse, T-weighted FFE sequence ('THRIVE') is acquired with a FOV of 490 × 330 mm and a slice thickness of 3 mm. Other sequence parameters are in-plane resolution 0.95 × 0.95 mm, TE 4.1 ms, TR 8.2 ms and flip angle 10 degrees.

We acknowledge that sequence protocols used for this purpose can vary, especially if different machines from different vendors are used. Fat suppression can be useful in the interpretation of the images, but preferences may vary among radiologists. The most optimal MRA protocol therefore depends on the MR hardware available, contrast agents used and radiologist's preference. The abovementioned protocol is intended to provide institutes with some practical outlines of the protocol that we use successfully, but it should be emphasised that settings need to be optimised for each individual institute.

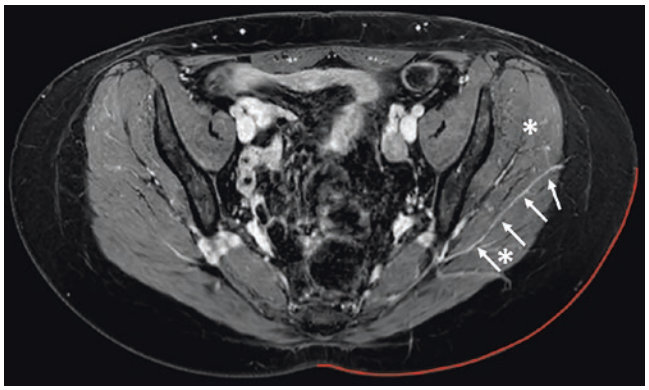

Fig. 23.6 Example of transverse T1-weighted, fat-suppressed THRIVE sequence of the pelvis, showing the septocutaneous perforator on the left side (arrows), running between the gluteal muscles (asterisks). For preoperative planning, the curvature is measured from the midline towards the expected exit of the perforator through the gluteal muscles. In this example, the estimated length was 26 cm (red line)

Patient Preparation

- Step 1: As mentioned before, preoperative perforator mapping helps to device the surgical technique and to determine whether or not a patient has a suitable septocutaneous perforator. Only those patients (75%) are scheduled for breast reconstruction with Sc-GAP. The MRA protocol described above is used to assess the septocutaneous perforators, which are considered suitable for surgery with a pedicle length of 6 cm or more.
- Step 2: The projection of the septocutaneous perforator on the surface of the skin is evaluated using MRA. Contrary to the abdominal region, which has a flat surface, the gluteal region is curved. Therefore, the distance of the perforator is calculated from the midline on the curvature of the gluteal region (*x*-axis) (Fig. 23.6).

  To determine the craniocaudal position of the perforator, the ASIS is identified as a landmark (*y*-axis) (Figs. 23.7 and 23.8). Depending on the preference of the surgeon or the institute, alternative landmarks can be used in assessing the craniocaudal position, such as the umbilicus.
- Step 3: Several landmarks are drawn on the patient's skin before surgery. It is very important that the patient positioned the same as in surgery with a cushion under the hip while making your preoperative drawing. The skin in the gluteal region is quite mobile due to the subcutaneous tissue, and therefore, it can move easily with respect to the muscles. A different position can lead to a shift in the position of the septal plane and the perforators. First, the midline is indicated as line A and a perpendicular line is drawn at the level of the cranial end of the crena analis (line B). The cranial margin of the gluteus maximus muscle is identified, where it arises from the thick fascia of the gluteus medius and marked as line C. The last line that is drawn is a curved line D, which marks the iliac crest (Fig. 23.9). The anatomical landmarks and septocutaneous perforators can be confirmed using colour Doppler (Esaote MyLab 25 Color Doppler and a LA523, 4–13 MHz probe).
- Step 4: Putting all this information together provides an accurate location of the identified perforators with the desired location and length. The flap design has changed while we gained experience with the Sc-GAP flap. In the first cases, the flap contour was drawn elliptically, like the DIEP flap, always completely on the superficial projection of the intermuscular septum between the gluteus maximus and medius muscle. This ensured that the flap was centred on the targeted perforator and that, when this perforator could not be found or was damaged, alternative septocutaneous perforators can be used as a pedicle.

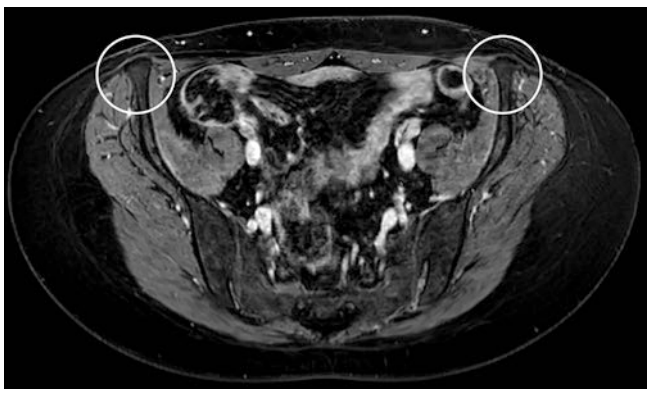

Fig. 23.7 Example of transverse T1-weighted, fat-suppressed THRIVE sequence of the pelvis, in which the iliac crest on both sides can be easily identified for preoperative measurements (circles)

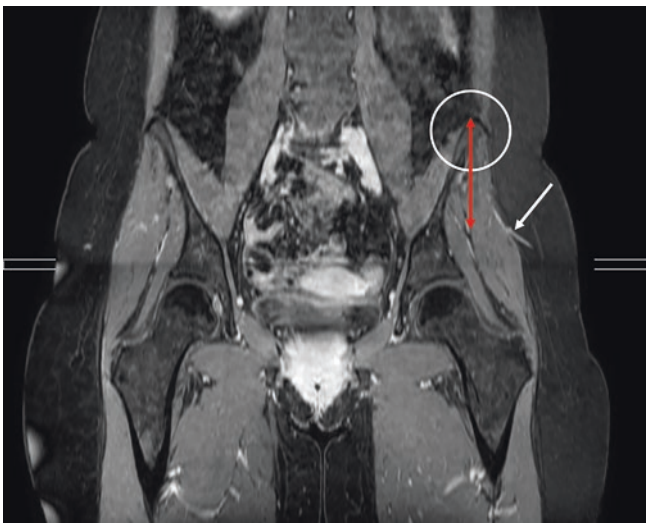

Fig. 23.8 Example of T1-weighted, fat-suppressed THRIVE sequence of the pelvis, reconstructed in the coronal plane. Based on the findings of previous figures, the exit of the perforator through the gluteal muscles can be identified (white arrow), as well as the iliac crest (circle). Next, the distance from the iliac crest to the expected exit of the perforator can be estimated, in this case 8 cm (red arrow)

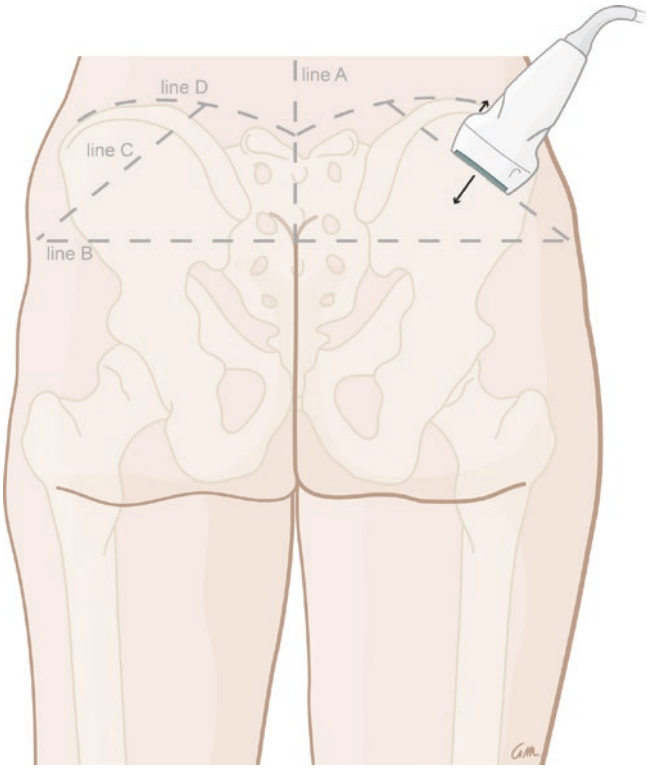

Fig. 23.9 A schematic illustration of the preoperative landmarks that are used, such as the cranial margin of the gluteus maximus muscle. Line A: midline; Line B (perpendicular to line A): cranial end of the crena analis; Line C: cranial margin of the gluteus maximus muscle; Line D: iliac crest. With the probe positioned parallel to the cranial margin of the gluteus maximus muscle, its location can be identified. (© 2019 by Greet Mommen, www.greetmommen.be)

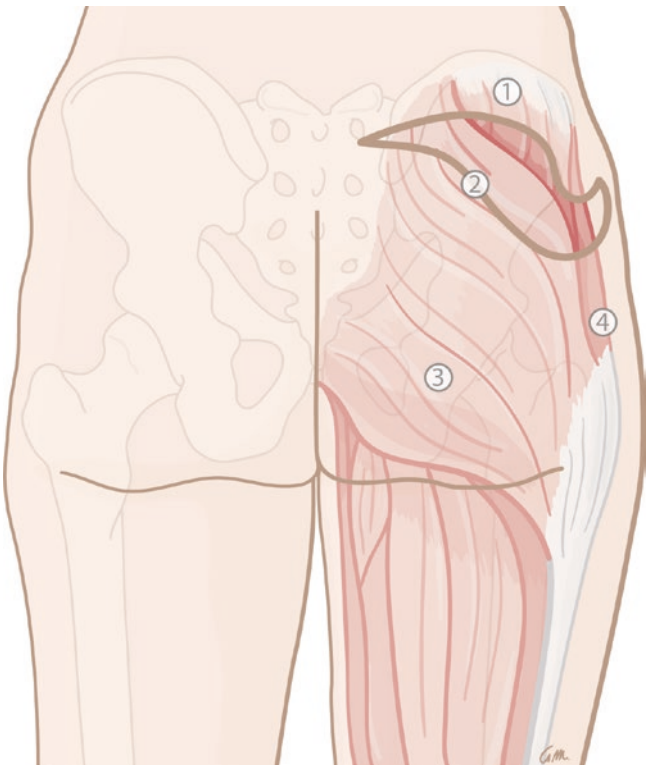

Fig. 23.10 A schematic illustration of the S-shaped design of the Sc-GAP flap. (1) Gluteus medius muscle; (2) S-shaped Sc-GAP flap; (3) gluteus maximus muscle; (4) tensor fasciae latae muscle. (© 2019 by Greet Mommen, www.greetmommen.be)

Currently, the flap design has changed to an S-shape to avoid dog ears at the medial and lateral end of the flap (Fig. 23.10). To assess the maximal width of the flap, a pinch test is used.

The flap is located just a bit more cranial than the drawing of the standard S-GAP flap (Fig. 23.11).

Surgical Technique

The patient's position is dependent on the timing of reconstruction. In cases of primary reconstruction, the oncologic surgeon first performs the mastectomy when the patient is in supine position. Subsequently, the patient is turned to prone position so the reconstructive surgeon is able to harvest the Sc-GAP flap. When secondary reconstructions are performed, the patient is already in prone position at the start of the surgery.

Harvesting of the flap starts at the cranial side of the skin island. Dissection is proceeded caudally until the superior margin of the gluteus maximus muscle is identified and the fascia is opened. This is important, as it reveals the inferior margin of the gluteus maximus mus-

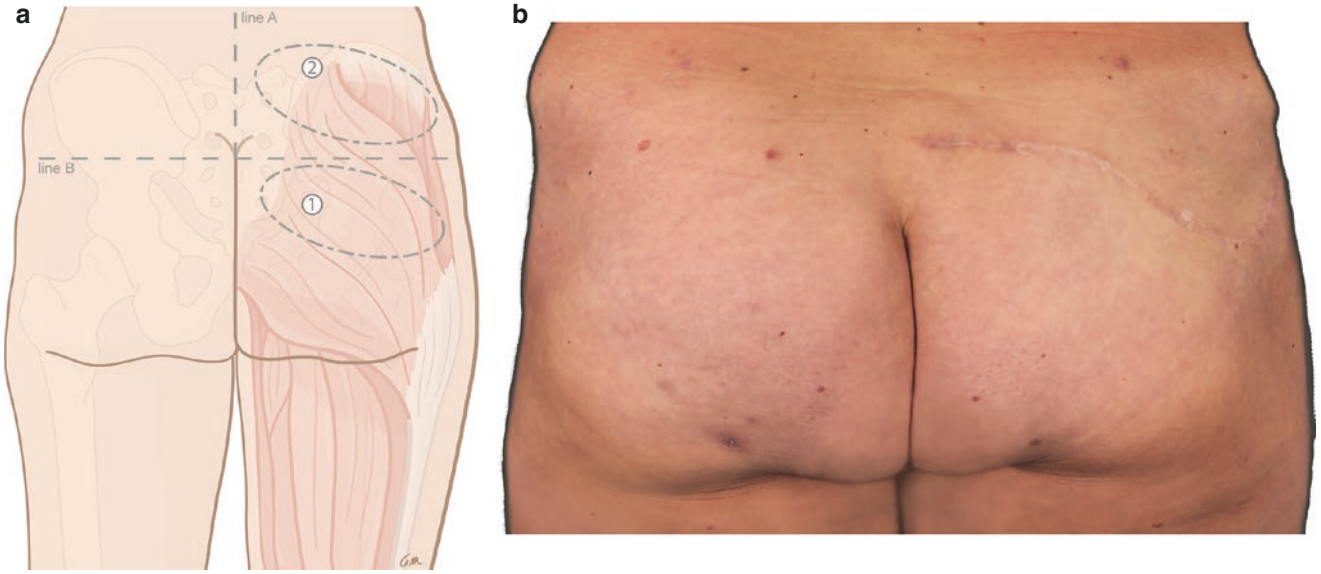

Fig. 23.11 (**a**) A schematic illustration of the position of the standard S-GAP flap (1) and the Sc-GAP flap (2). (**b**) An example on a patient, showing the scar is located mostly above the horizontal line B (cranial end of the crena analis). (© 2019 by Greet Mommen, www.greetmommen.be)

cle, which is the entry to the plane between the gluteus maximus and medius muscles. Pulsation of the perforators in the septal plane can be palpated. The septal plane is very loose and to expose the septocutaneous perforators, the gluteus maximus and medius muscles are easily separated. If it is possible to preserve more than one perforator, this is first choice. Otherwise, the most lateral perforator is selected and followed back under the gluteus maximus to the origin of the superior gluteal artery. The length of the pedicle should be at least 6 cm. The vascular pedicle is clipped and dissected and the flap is harvested. Thereafter, the donor site is closed so the patient can be turned in supine position for preparation of the internal mammary vessel for microsurgical anastomosis. A coupler device is used for anastomosis of the vein. After flap inset, suction drains are placed at each individual donor site and flap.

The following technical tips are useful to overcome common surgical pitfalls during the Sc-GAP flap procedure:

1. The key point of a successful dissection of the septocutaneous perforators is the identification of the septal plane between the gluteus maximus and gluteus medius muscles.
2. If the pedicle length on the MRA is no longer than 6 cm, do not consider the patient suitable for breast reconstruction using the Sc-GAP flap. If the pedicle is not long enough, the microsurgical anastomosis with the internal mammary vessels will be very difficult.
3. Septocutaneous perforators are surrounded by fat and connective tissue, making them more compact and less flexible than the traditional musculocutaneous perforators. When positioning the flap on the breast, attention must be given to the original orientation of the pedicle and not to twist or kink it.
4. The flap is oriented just cranial to the margin of the gluteus maximus muscle to ensure the perforator is included in the skin island of the flap. This also improves the patient's body contour at the donor site.
5. Enable yourself with a proper visualisation during dissection. If this is not the case, the gluteus maximus muscle can partially be detached from its origin from the sacral bone and later be reattached.
6. Do not lift the gluteus maximus muscle too fast if you are not familiar with the anatomical considerations in the gluteal area. The muscular and musculocutaneous branches of the superficial branch of the SGA can be easily damaged.
7. Draw the patient in the exact same position as she will be during surgery: with a cushion under the hip. The skin in the gluteal region is quite mobile due to the subcutaneous tissue and therefore it can move easily with respect to the muscles. A different position can lead to a shift in the position of the septal plane and the perforators.

Postoperative Care

The postoperative care of the Sc-GAP flap breast reconstruction does not differ from the standard DIEP flap breast reconstruction. The patient gets medical thrombosis prophylaxis stockings (MTPS) before surgery, which will stay on as long as the patient has not mobilised. The first

24 hours after surgery the Sc-GAP flap is monitored every hour. Flap colour, temperature, capillary refill and Doppler sounds are checked. Patients have to wear a band around the abdomen for 6 weeks to reduce seroma formation in the donor site and a sports bra to relief the pressure on the vascular pedicle of the Sc-GAP flap. Suction drains at the abdomen and neo-mammae are monitored and removed if they have not produced more than 30 mL/24 hours. The patient receives adequate pain medication. The average hospital admission is 4–6 days. Fourteen days after surgery, the stitches are removed. They will receive prophylactic low molecular weight heparins (LMWHs) for 6 weeks postoperatively.

Clinical Case

A 37-year-old woman presented herself with a history of breast cancer in the right breast and therefore underwent a total mastectomy with complete axillary lymph node dissection in 2012. She received radiotherapy and chemotherapy. In 2013, she was seen in our institution because she desired a prophylactic contralateral mastectomy and reconstruction of both breasts in the same procedure.

On physical examination, a slender woman was seen. She had a mastectomy scar on the right side of her thorax and a healthy, non-operated breast contralateral (B-cup). She had insufficient abdominal tissue for bilateral breast reconstruction (Fig. 23.12). She did, however, have enough tissue in the gluteal region.

Preoperative imaging was performed which showed present septocutaneous gluteal artery perforators on both sides.

In 2013, she underwent a delayed Sc-GAP flap reconstruction on the right breast. Nine months later, she underwent an immediate Sc-GAP flap breast reconstruction on the left. No complications occurred. Secondary corrections were performed on both breasts and donor sites to minimise the contour deformity (Fig. 23.13). Her nipple-areola complex tattoo was performed elsewhere.

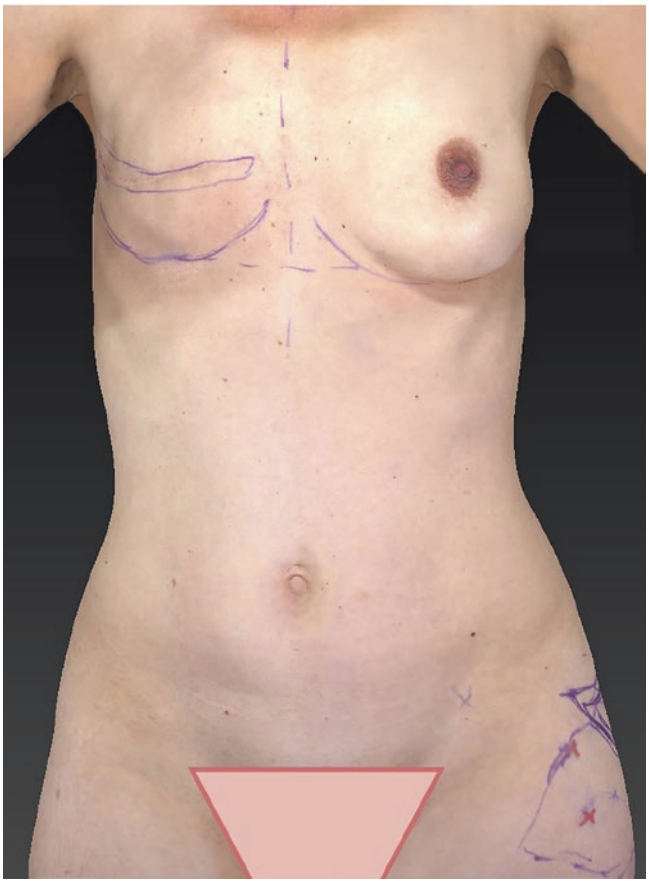

Fig. 23.12 Preoperative photo of a patient who previously underwent unilateral mastectomy on the right side. (© 2019 by Greet Mommen, www.greetmommen.be)

Conclusions

The septocutaneous gluteal artery perforator flap is a viable alternative for autologous breast reconstruction. In our opinion, this technique is easier to master than the dissection of the traditional musculocutaneous gluteal artery perforators. Therefore, the authors believe the Sc-GAP flap is valuable addition in the repertoire of plastic and reconstructive surgeons worldwide.

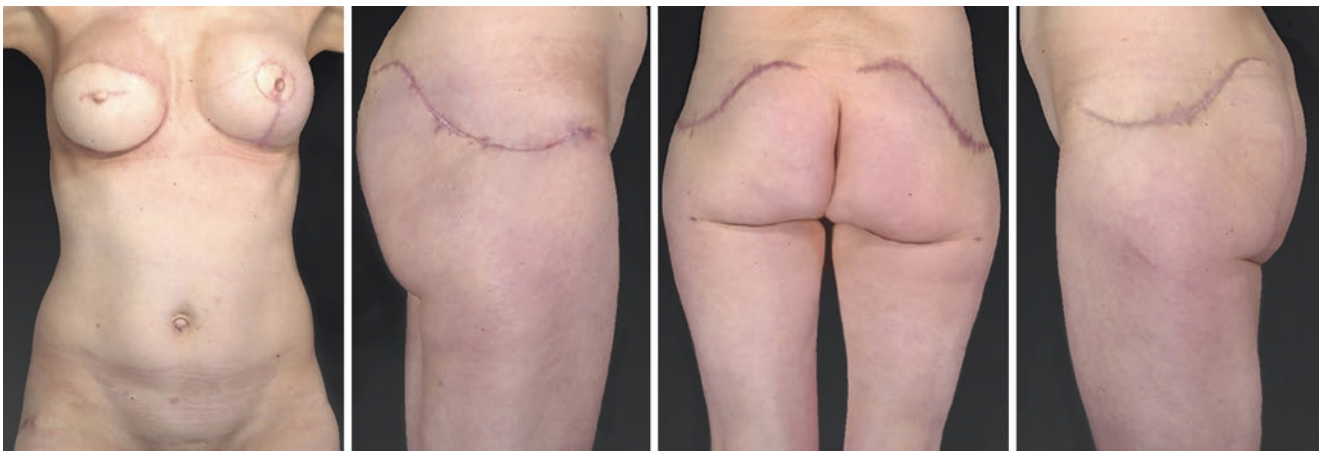

Fig. 23.13 Photos of the patient 1 year postoperatively. (© 2019 by Greet Mommen, www.greetmommen.be)

Acknowledgements We would like to thank Greet Mommen, medical scientific illustrator at Maastricht University, Department of Anatomy and Embryology, for the realisation of the illustrations in this chapter. Her ideas and active contribution were essential to help clarify and visualise the concepts as described above. We also would like to thank Paul van Dijk, histologic technician at the same department, for the excellent photography of the cadaveric dissection.

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Inferior Gluteal Artery Perforator Flap in Breast Reconstruction

24

Toshihiko Satake

Introduction

Natural appearance and highly aesthetic restoration with long-term results are achieved by autologous breast reconstruction. Free flap from buttocks as an alternative to lower abdominal flap have become an ideal option for autologous tissue over the past four decades.

Allen et al. first described the superior gluteal artery perforator (SGAP) for breast reconstruction in 1993 [1]. Subsequently in 2002, the inferior gluteal perforator (IGAP) flap was introduced for ischial pressure sore reconstruction by Higgins et al. [2], followed by Guerra et al. in 2004 [3] for breast reconstruction.

Although gluteal artery perforator (GAP) flaps require intraoperative positioning change, substantial dissection, and mismatched venous caliber anastomosis, these flaps provide a longer vascular pedicle than gluteal musculocutaneous flaps and adequate soft tissue for breast reconstruction while preserving gluteal muscle function and decrease the exposure risk of the sciatic nerve [4, 5]. In addition, GAP flaps have a high fat-to-skin ratio and thicker, firmer, and more globular fat tissue, providing a good projection of the reconstructed breast in contrast to abdominal flaps.

The SGAP flap and profunda artery perforator (PAP) flap [6, 7] have become popular breast reconstruction procedures as alternatives to the deep inferior epigastric artery perforator (DIEP) flap and are now extensively used when the abdominal tissue cannot be used. Use of the IGAP flap, however, is not widespread, and there are only few papers describing its use for breast reconstruction [3–5, 8–12].

Inferior gluteal crease displacement is uncommon if a unilateral SGAP flap is harvested from the superior buttock without an extensive skin harvesting (Fig. 24.1a). However, if a unilateral small IGAP flap is harvested from the inferior buttock in a slim hip patient, buttock projection and the inferior gluteal crease can be easily distorted (Fig. 24.1b). Postoperative inferior buttock deformity and asymmetry of the inferior gluteal crease that result from harvesting the IGAP flap are the significant aesthetic and functional disadvantages compared with the SGAP flap (Fig. 24.1a, b). Although the IGAP flap has several limitations, our patients prefer usage of the tissues from both inferior buttocks with a symmetrical donor site, camouflaging the donor liner scar with the gluteal crease (Fig. 24.1c). This preferential tendency is an indication of the importance of buttock aesthetics as symmetrical buttock volume, shape, and gluteal crease to the patients. Preserving symmetry between the flap harvest site and the contralateral site is crucial, and therefore, we have been using stacked IGAP flaps harvesting method for unilateral breast reconstruction.

There are two major concepts regarding the use of bilateral IGAP flaps for unilateral breast reconstruction. One is to provide adequate tissues to restore a relatively large and high-projection breast in a slim patient, and the other is to harvest two smaller IGAP flaps from both donor sites to achieve natural inferior buttock volume and shape. There are two advantages of stacked IGAP flaps at the recipient site. The first advantage is that breast projection can be easily enhanced by using a gluteal crease or by overlapping both IGAP flaps. There is also more flexibility when using two flaps to cover various breast defects. The second advantage is the easy reach of the recipient vessel, even with a shorter pedicle. While stacked IGAP flaps require two free flaps with microsurgical anastomosis, each flap is closer to the corresponding recipient vessel than a single IGAP flap. The shorter flap pedicle also decreases donor-site morbidity.

In this study, we describe unilateral autologous breast reconstruction using stacked IGAP flaps in our institute to outline the indications and surgical techniques.

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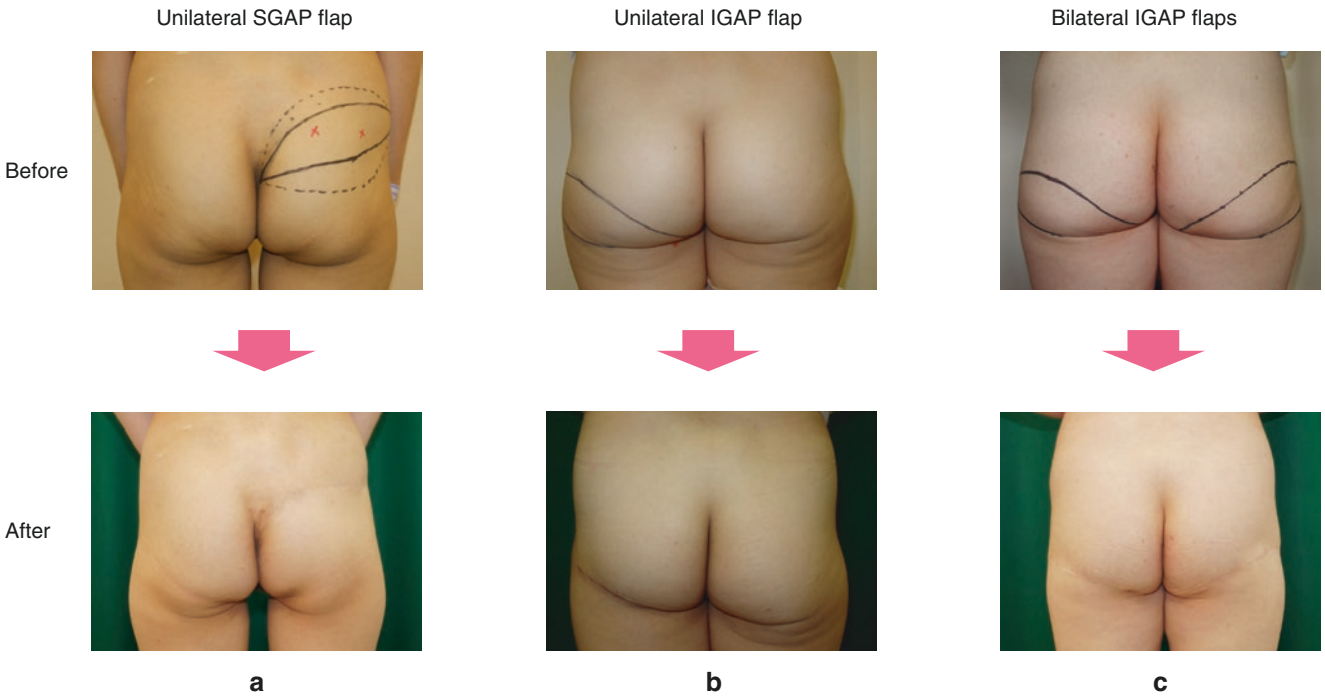


Fig. 24.1 Donor-site deformities after GAP flap harvesting. Before (upper) and after (below) the surgery. (**a**) Typical case of unilateral SGAP flap harvesting. Although postoperative scar is apparent, cranial migration of inferior gluteal fold is not apparent. (**b**) Typical case of unilateral IGAP flap harvesting. Although postoperative scar is not so apparent, asymmetry of inferior gluteal fold is apparent. (**c**) Typical case of bilateral IGAP flap harvesting. Although postoperative scars and deformities are apparent, both inferior gluteal folds are symmetric

Anatomy

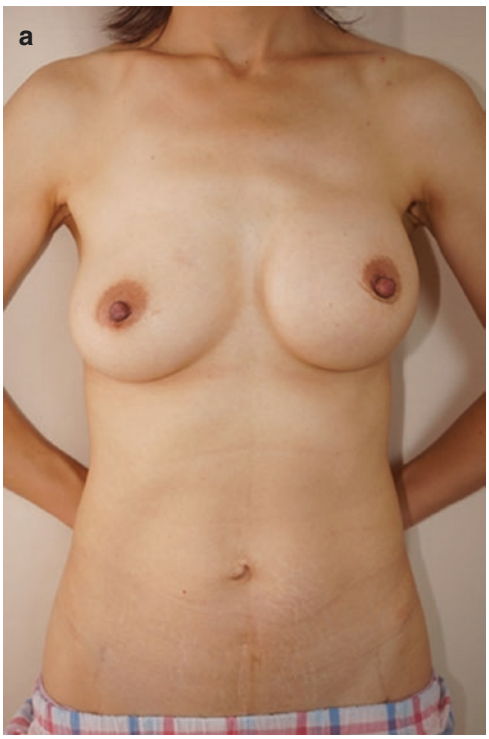
The inferior gluteal vessel is the terminal branch of the posterior division of the internal iliac vessel that exits the pelvis through the greater sciatic foramen and then passes through the inferior to the piriformis muscle [13]. The inferior gluteal vessel is accompanied by the internal pudendal vessels, the pudendal nerve, the posterior femoral cutaneous nerve, and the sciatic nerve [14] and supplies the lower half of the gluteus maximus and provides perforators to the overlying gluteal skin. The mean number of IGAPs (≥0.5 mm) in a fresh cadaver study was 8 ± 4 per region [14]. In contrast, an in vivo anatomical study revealed nine IGAPs per region with a 0.4-mm mean arterial internal vessel diameter [15].

Patient Selection

GAP flaps allow for preservation of the structure and function of the gluteal muscles, providing thick and dense gluteal fat that facilitates reconstruction of the breast projection with and without ptosis. IGAP flaps have several advantages: they can be harvested without sciatic nerve exposure and have a longer vascular pedicle up to 10 cm, compared with the inferior gluteal musculocutaneous flaps [4–8, 16–18]. These flaps offer a good option for patients with saddlebag hips because of the improved postoperative donor contour [4]. Gluteal and thigh flaps are indicated for those who are nulliparous or have inadequate abdominal tissue, prior abdominal surgeries, prior abdominal flap reconstruction, and prior liposuction in our institute [12]. A breast size greater than a C cup with moderate projection and mastectomy weight over 350 g is a candidate for stacked IGAP flaps for unilateral breast reconstruction, especially for slim hip patients with high-projection breast.

Because the gluteal skin color and texture differ from that of native breast skin, IGAP flaps are especially indicated for nipple-sparing (Figs. 24.2a, 24.3a, and 24.4a) or skin-sparing mastectomy patients. For delayed reconstruction after modified radical mastectomy, tissue expansion is indicated prior to reconstruction.

The unresolved disadvantage of single GAP flaps for unilateral breast reconstruction is the lack of volume. Boyd et al. reported that over 10% of SGAP flaps require revision implant augmentation [19]. Kronowitz reported that 83% of standard elliptical GAP flaps is insufficient in volume [20]. IGAP flaps are superior to SGAP flaps in terms of available tissue volume [3, 5, 8]. Mizabeigi et al., however, reported that 14% of patients underwent ipsilateral implant augmentation even after IGAP flap reconstruction [9]. It may be that slim patients lack not only abdominal tissue but also inferior gluteal tissue volume. In such cases, stacked IGAP flaps should be considered. Stacked IGAP flaps for a single unilateral breast reconstruc-



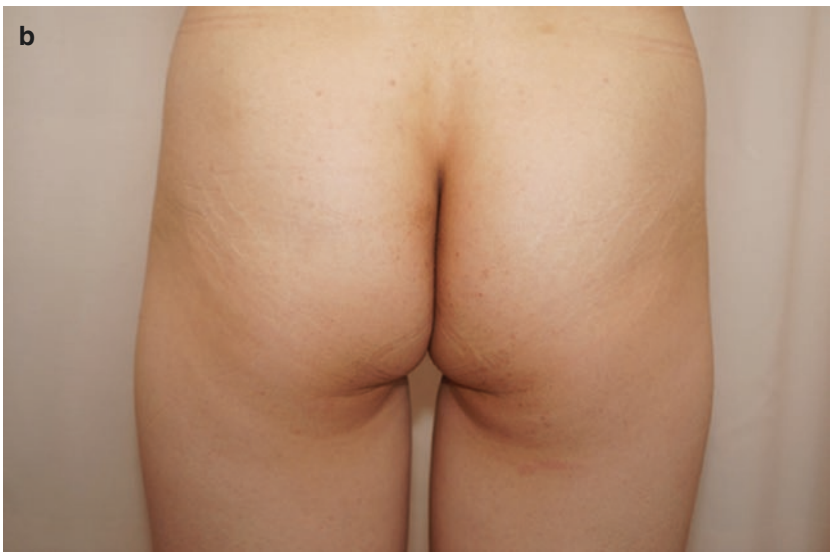
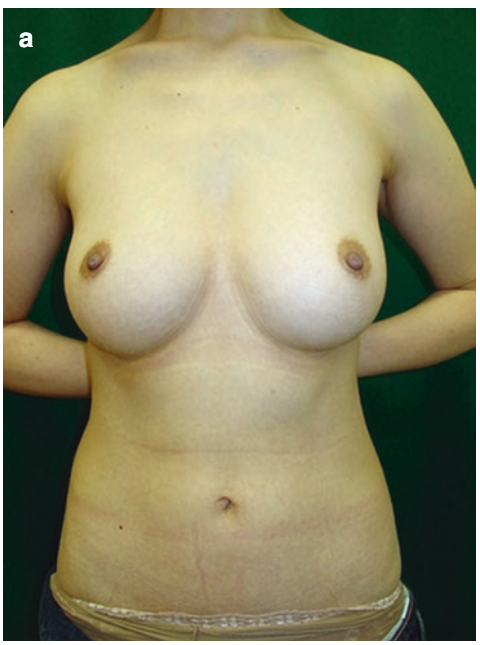


Fig. 24.2 Case 1. (**a**) Preoperative view of a 38-year-old patient after a left nipple-sparing mastectomy due to ductal carcinoma in situ. Insertion of tissue expander under the pectoralis major muscle 12 months postoperatively. (**b**) Preoperative view of the donor site. Patient's buttock is slim, and enough adipose tissue is not available in lower lateral part



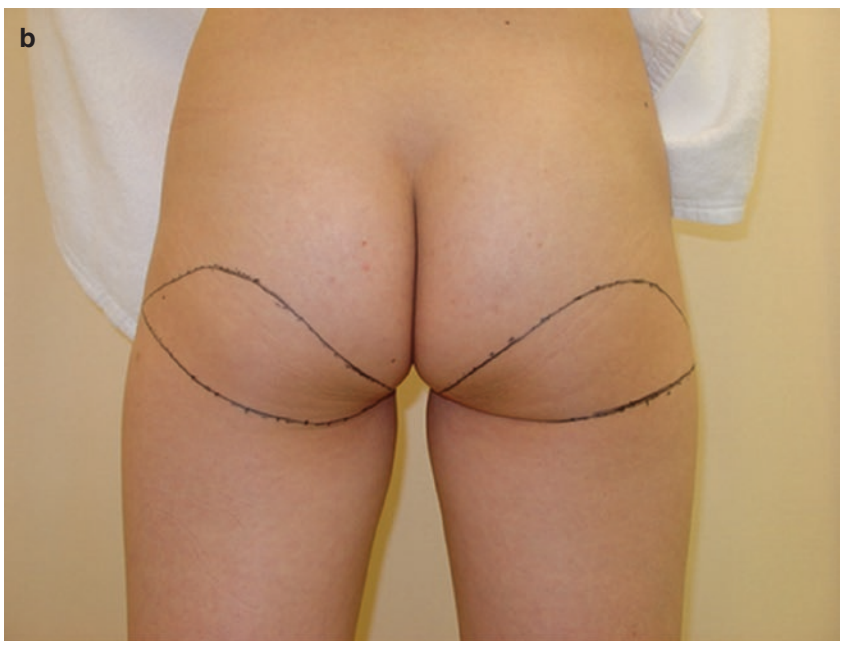


Fig. 24.3 Case 2. (**a**) Preoperative view of a 33-year-old nulliparous patient with left breast invasive ductal carcinoma before nipple-sparing mastectomy and immediate breast reconstruction using stacked IGAP flaps. (**b**) Preoperative view of the donor site. The skin paddle (measured 7.0 × 27.0 cm) of the stacked IGAP flaps was designed superior to the inferior gluteal folds

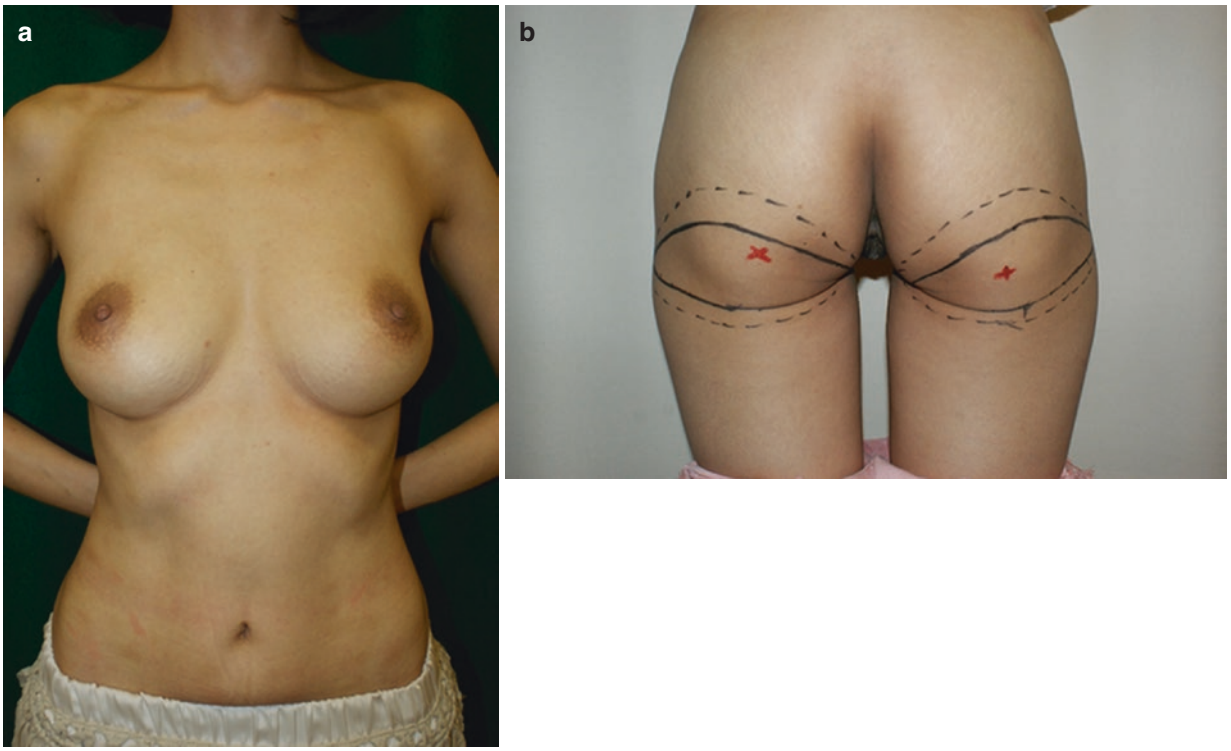


Fig. 24.4 Case 3. (**a**) Preoperative view of a 29-year-old nulliparous patient with right breast ductal carcinoma in situ before nipple-sparing mastectomy and immediate breast reconstruction using stacked IGAP flaps. (**b**) Preoperative view of the donor site. The skin paddle (measured 6.0 × 25.0 cm) of the stacked IGAP flaps was designed superior to the inferior gluteal folds

tion provide abundant gluteal tissue for high-projection breast reconstruction in a slim patient.

The inferior gluteal volume and shape and the location of the medial crease tend to be imbalanced by unilateral IGAP flap harvesting. Because stacked IGAP flaps comprise two smaller flaps of the same size sharing the breast defect compared with the original unilateral IGAP flap, gluteal skin and fat can be harvested without significant gluteal deformity or asymmetry of the inferior buttock volume and shape. As the buttock is an important element of sexual attraction, iatrogenic gluteal irregularities pose significant embarrassment to the patient [21–23]. Cuenca-Guerra et al. reported that supragluteal fossettes, a V-shaped crease, lateral depression, and an inferior gluteal crease are important aesthetic characteristics of the gluteal region [20].

Preoperative Planning and Patient Preparation

Preoperatively, the skin islands of bilateral IGAP flaps are marked in a standing position. A horizontal lazy-S skin paddle parallel to the inferior medial gluteal crease and lateral following curve is indicated for patients with slim hips to reduce lateral hip depression. The horizontal lazy-S skin paddle is centered with the longitudinal axis 3.5 cm superior to the inferior gluteal crease (Figs. 24.3a, 24.4a, and 24.5a). The inferior border of the ellipse lies along the medial inferior gluteal crease and lateral following curve. The flap width is judged by a pinch test, and a flap width up to 7 cm is harvested.

The flap length may be up to 25.0 cm transversely. Patients undergo preoperative computed tomographic angiography (CTA) prior to breast reconstruction to identify the size, location, and course of large perforators at the donor site preoperatively (Fig. 24.6). Handheld Doppler probe is used in reference to the CTA images to identify perforators within the skin paddle with patients in prone position.

Surgical Technique

The recipient site is subsequently prepared for smooth microsurgical anastomosis with the patients' positioned supine. At least two recipient vessels in the medial (internal mammary perforator or vessel) and lateral (lateral thoracic vessel or serratus branch of thoracodorsal vessel) sites are prepared. Microsurgical anastomosis of the second IGAP flap to the recipient vessel is quickly completed to avoid a prolonged ischemia time. After the breast wound is temporarily draped with large occlusive dressing films, the patient is positioned prone.

Prior to flap harvesting, re-design of the skin paddle and fat pad outline is again performed based on the mastectomy

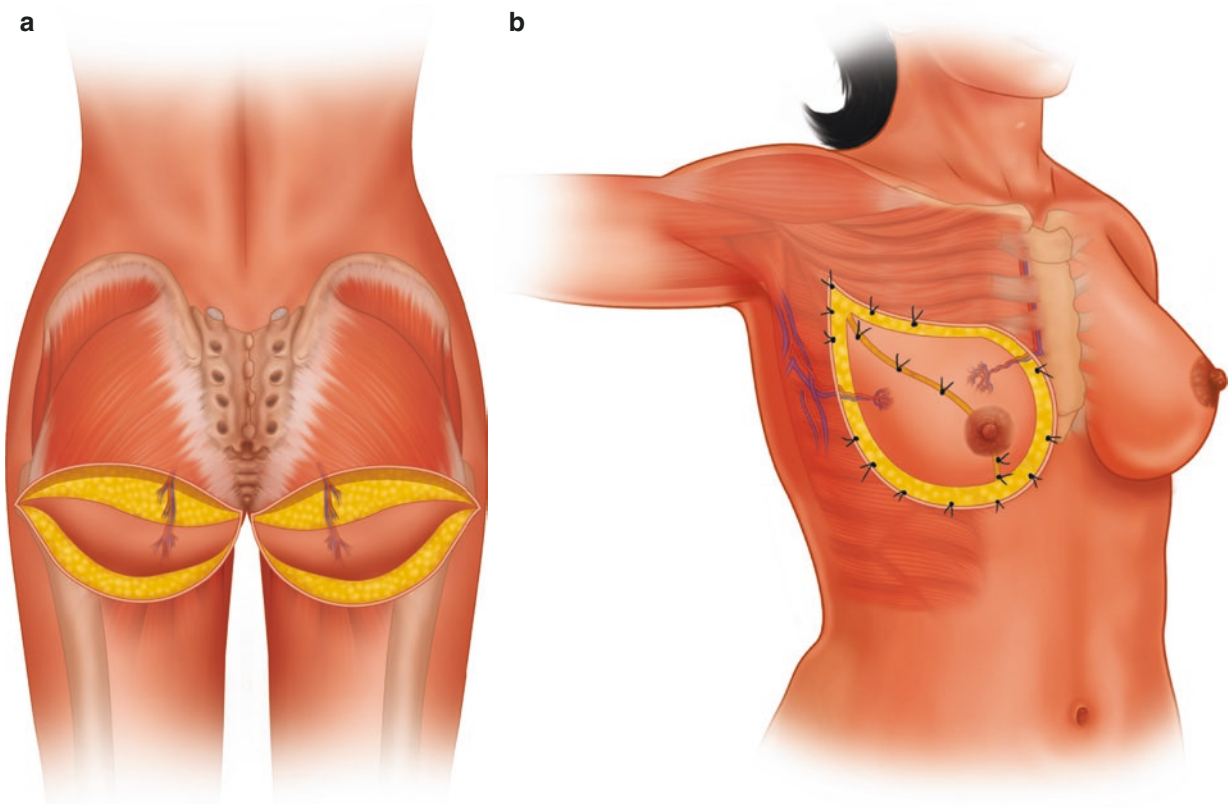


Fig. 24.5 (**a**) Design and harvesting of stacked IGAP flaps. The horizontal lazy-S skin paddle centered with a longitudinal axis 3.5 cm superior to the inferior gluteal crease. (**b**) The bilateral IGAP flaps are placed vertically on the pectoralis major muscle and anastomosed medially and laterally to the recipient vessels

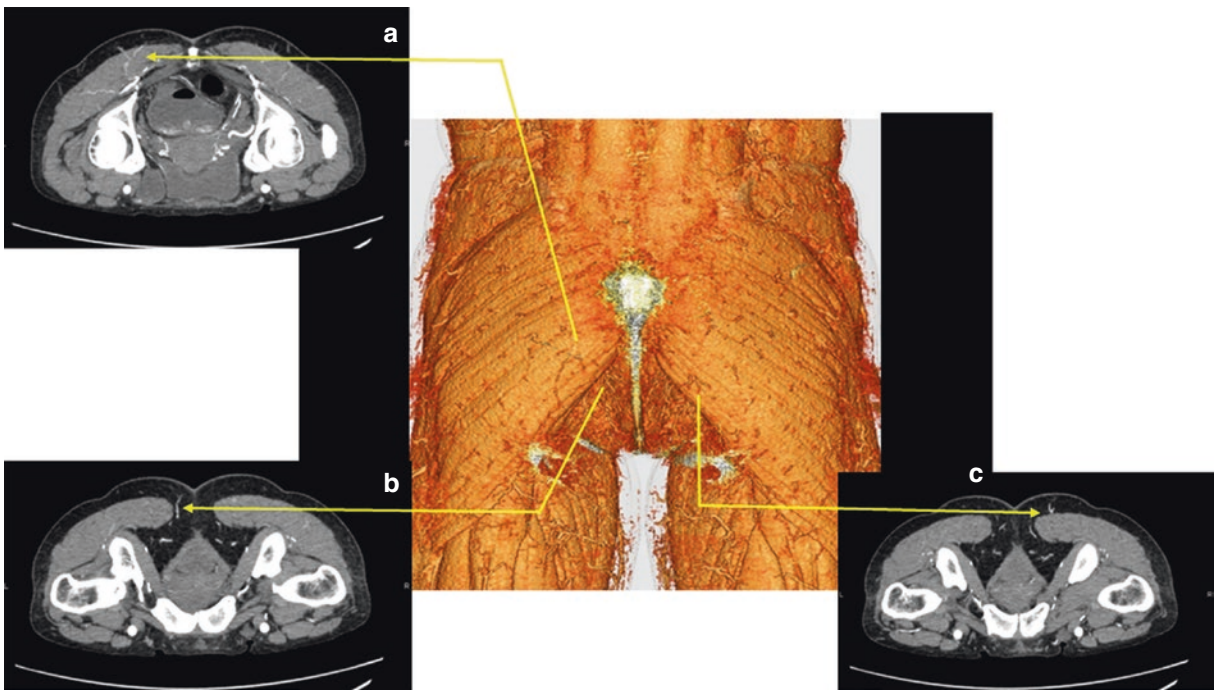


Fig. 24.6 Computed tomographic angiography. (**a**) Two musculocutaneous perforators from inferior gluteal vessel are identified at the medial portion of the left gluteal maximus muscle. (**b**) One septocutaneous perforator identified from margin of the left gluteal maximus muscle. (**c**) One musculocutaneous perforator from inferior gluteal vessel is identified at the medial portion of the right gluteal maximus muscle. Among the several perforators, we select one or two large perforators located close to the medial or lateral one third of the IGAP flap to facilitate easy microsurgical anastomosis and flap inset

specimen or anticipated tissue defect. The incision is made along the skin markings, and subcutaneous dissection is performed above the superficial fascial plane to harvest an ample amount of adipose tissue in the flap. Perforators from the inferior and superior gluteal vessels have a network of anastomosing vessels in the center of the buttock called the "choke vessels," allowing for circulation between adjacent angiosomes. Therefore, the adiposal lobe including the flap is extended more superiorly to maximize transferable tissue as required. Dissection then proceeds laterally to medially under the deep fascia of the gluteus maximus muscle to detect the perforators. During dissection, a large drop of fat is arranged in a deep plane onto the iliotibial tract and the light color fat is preserved on the ischium. Concurrently with subfascial dissection, several musculocutaneous perforators arise from the inferior gluteal vessels at the inferior half of the gluteus maximus muscle. Among them, we select one or two large perforators located close to the medial or lateral one third of the IGAP flap to facilitate easy microsurgical and flap inset (Figs. 24.8a, and 24.9a). For deeper dissection into the gluteus maximus and down to the sacral fascia, a large surgical field with wide splitting of the originating muscle is required for safety and easy development (Fig. 24.9a). Pedicle dissection proceeds toward its origin from the inferior gluteal vessel to harvest the desired pedicle length and vessel diameter. Under the sacral fascia, the perforating artery and vein diameter differ from each other and have multiple communications with several branches that must be ligated before pedicle resection. After assessing flap perfusion with indocyanine green angiography, the pedicles of both IGAP flaps are divided and donor wounds are closed.

The patient is then positioned spine, and the bilateral IGAP flaps are placed on the pectoralis major muscle and anastomosed medially and laterally to the recipient vessels (Fig. 24.5b). A mismatch size microvascular anastomosis with the recipient vein should be excluded to avoid compromising venous outflow. These skin paddles of both flaps are denuded and placed vertically (Fig. 24.8b). For patients with high-projection breasts, the boundary lines of both flaps are overlapped to achieve thickness. In patients with breast ptosis, the inferior limbs of the flaps are folded and mounted to protrude beyond the inframammary fold.

The selection of recipient vessels for stacked IGAP flaps is very important for flap inset. In our cases, both internal mammary vessels and the serratus branch of the thoracodorsal vessels were common recipient vessels [12]. Combined use of the internal mammary vessels and the thoracodorsal vessels tend to restrict breast shape to a horizontal orientation with inadequate breast projection [24]. Bilateral IGAP flaps are separated from each other and can be arranged freely on the pectoralis major muscle. None of the patients complained of bulkiness after reconstruction.

In our first 20 cases, internal mammary vessels were used as the main recipient vessels for 12 medial IGAP flaps (60%), and the serratus branch of the thoracodorsal vessels was used for 10 lateral IGAP flaps (50%). There were 26 flap pedicles (65%) with 1 artery and 1 vena comitans and 14 flap pedicles (35%) with 1 artery and 2 venae comitantes. Mean pedicle length was 4.55 cm. Mean diameter of the artery was 1.44 mm.

Mean vein diameter was 2.06 mm and the maximum vein diameter was 3.02 mm. A larger caliber vein for GAP flap anastomosis to a smaller recipient vein sometimes leads to compromised venous outflow with a potential risk of thrombosis. Mizabeigi et al. reported 13% with delayed venous thrombosis [9]. To avoid venous thrombosis, the recipient vein should be dissected proximally and the same caliber venous anastomosis between the pedicle and recipient vein should be considered, especially when the pedicle vein is only one vena comitans. In immediate reconstruction cases, mean mastectomy weight was 416.9 g, and mean flap weight at final inset was 448.5 g. In delayed cases, mean tissue expander weight was 530.6 g and the mean flap weight at final inset was 487.9 g.

Technical Variations

There are several reports of bilateral breast reconstructions using stacked GAP flaps [5, 25, 26]. Stacked SGAP flap is a suitable alternative for stacked IGAP flaps for unilateral breast reconstruction using autologous tissues. Displacement of the inferior gluteal crease and pain from sitting during the early postoperative period are rare in patients undergoing reconstruction with stacked SGAP flaps. Although the upper gluteal scar and depression resulting from SGAP flap harvesting can be concealed by underwear or swimwear, they are quite conspicuous when the patient is naked. In this regard, because the postoperative gluteal aesthetics following stacked IGAP flaps harvesting is superior to that of stacked SGAP flaps harvesting, we prefer to use stacked IGAP flaps.

Careful consideration must be given to the contralateral breast cancer risk and reconstruction procedure in patients for whom bilateral GAP flaps are indicated. After using the bilateral gluteal tissue, autologous tissues including bilateral lower abdominal flaps, proximal medial thigh flaps, lumbar flaps, and latissimus dorsi musculocutaneous flaps are candidate future donor sites. However, the quality of the fat tissue from these donor sites differs from that of the buttock, and it is difficult to reconstruct a breast of about the same shape and size of the reconstructed breast.

Postoperative Care and Complications

For postoperative microsurgical monitoring, IGAP flap with a sentinel small skin paddle was examined for skin color, temperature, size, capillary refill, and skin perforator signals using a handheld Doppler until postoperative day 5, in cases after skin-sparing mastectomy or modified radical mastectomy. Buried stacked IGAP flaps in cases after

nipple-sparing mastectomy are confirmed with color duplex sonography, every 3 h for the first 48 h, every 6 h for the next 24 h, and every 12 hours for the following 48 h.

In a series of 20 patients, 1 patient underwent 2 additional operations for postoperative venous thrombosis between the pedicle and recipient veins, and we were unable to salvage lateral IGAP flap. The deep fat layer of the congested flap was therefore removed and re-grafted as a thin composite graft. Because the graft became necrotic, it was removed, and free fat grafting was required for re-reconstruction. One patient had palpable partial fat necrosis (2.5%), which was managed conservatively.

At the donor site, we recommended the patients to wear a tight hip girdle to protect donor sites and to prevent postoperative seroma formation. Half of the patients had complicated donor-site seroma in our cases, which were treated with subcutaneous aspiration once a week from 2 to 4 weeks postoperatively. Three patients had paresthesias bilaterally along the posterior thigh that resolved within 6 months.

The size of the reconstructed breast in comparison with the contralateral breast was approximately the same in 75% ($n = 15$) of our patients, smaller in 20% ($n = 4$), and larger in 5% ($n = 1$). Three patients with a smaller reconstructed breast underwent fat grafting and one received contralateral reduction mammoplasty to achieve a symmetric breast shape and size. The patient with a larger reconstructed breast underwent reduction using a liposuction technique. One patient underwent fat grafting to correct bilateral shallow hollows created by flap harvesting at the gluteal donor site.

Mizabeigi et al. reported that 39% of patients underwent local tissue arrangement at the IGAP flap donor site [9]. There are some secondary procedures to restore resulting gluteal deformities using a de-epithelized skin flap [22], infragluteal flap [27–29], or fat grafting [30, 31]. Although we had one patient who underwent fat grafting to restore lateral buttock depression, we think that the smaller two IGAP flaps reduce gluteal donor aesthetic complications. When breast reconstruction using stacked IGAP flaps requires more tissue, it is important not to harvest excess gluteal soft tissue, and, in such a case, secondary fat grafting to the reconstructed breast should be considered. During GAP flap reconstruction, surgeons should make every effort to preserve these important anatomic landmarks.

Clinical Cases

Case 1

A 38-year-old multiparous patient after a left nipple-sparing mastectomy due to ductal carcinoma in situ (Fig. 24.2a, b). She underwent tissue expander insertion under the pectoralis major muscle 12 months postoperatively. We chose stacked IGAP flaps for her left breast reconstruction on behalf of the DIEP flap, since her lower abdominal wall was very thin and had a mid-abdominal scar. However, both lateral buttocks were slim and also did not have enough volume available (Fig. 24.2b). After preparation of the recipient site including expander removal and positioning change, we harvested both IGAP flaps (Fig. 24.7a, b). Each flap was elevated with a 6.0 × 24.0 cm lazy-S-shaped skin paddle, including 3.0 cm superior and 2.0 inferior adipose lobe (Fig. 24.7b). Removed tissue expander weight, total harvested flap weight, and final inset flap weight were 490 g, 430 g, and 412 g, respectively (Fig. 24.8a, b). There was no complication postoperatively (Fig. 24.11a, b).

Case 2

A 33-year-old nulliparous patient with left breast invasive ductal carcinoma underwent nipple-sparing mastectomy and immediate breast reconstruction using stacked IGAP flaps

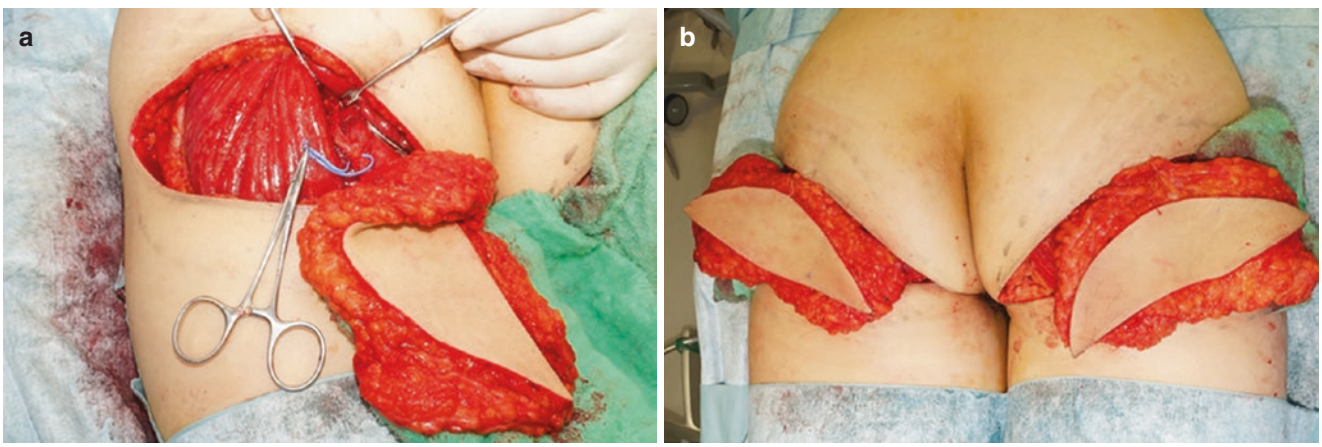


Fig. 24.7 Case 1. (**a**) Pedicle of the left IGAP flap was dissected under the sacral fascia and examined flap circulation using indocyanine green angiography. (**b**) Stacked IGAP flaps were elevated with a 6.0 × 24.0 cm lazy-S-shaped skin paddle, including 3.0 cm superior and 2.0 inferior adipose lobe

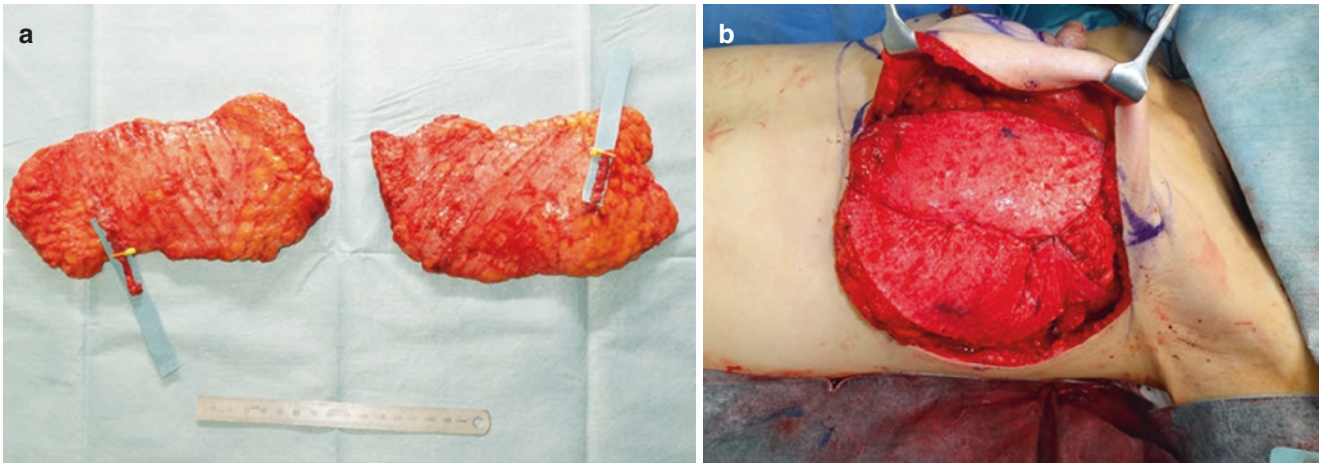


Fig. 24.8 Case 1. (**a**) After both pedicle separations, the final inset flap weight (left and right IGAP flaps) was 412 g. (**b**) After both microsurgical anastomoses, both skin paddle of the IGAP flaps were de-epithelialized and arranged above the left pectoralis major muscle

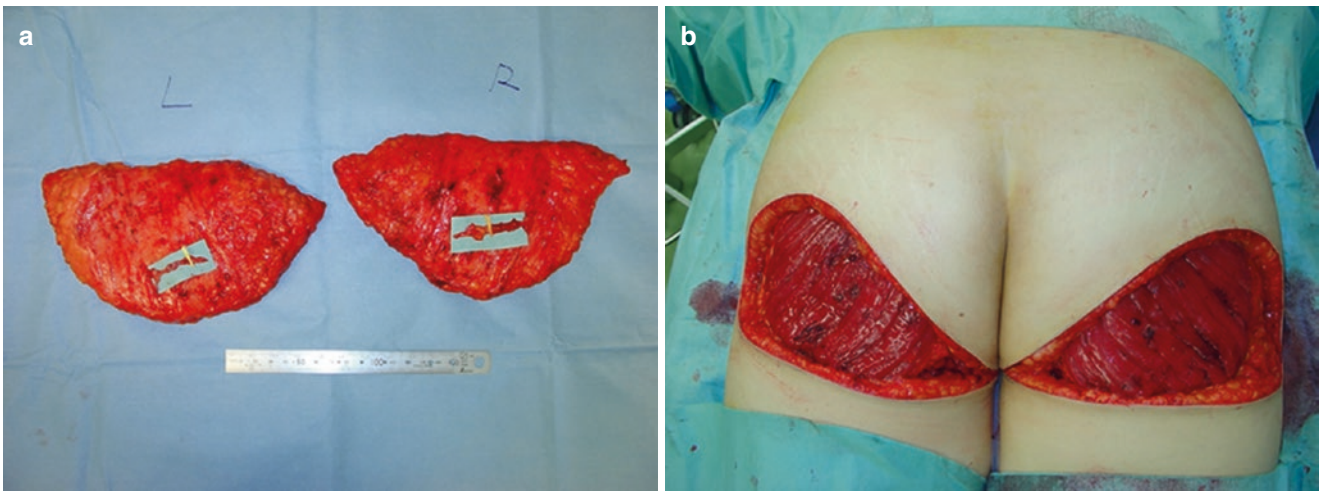


Fig. 24.9 Case 2. (**a**) Pedicle length of the left and right IGAP flaps are 4.7 cm and 5.4 cm, respectively. (**b**) Donor site after harvesting of the both IGAP flaps. Both gluteus maximus muscles are preserved and donor wounds were closed

(Fig. 24.3a, b). Mastectomy weight, total harvested IGAP flaps weight, and final inset flap weight were 485 g, 480 g, and 468 g, respectively (Fig. 24.9a). During the microsurgery, pedicle of the left IGAP flap was anastomosed to the internal mammary perforator (Fig. 24.10a), while pedicle of the right IGAP flap was anastomosed to the serratus branch of the thoracodorsal vessel (Fig. 24.10b). Her postoperative course was uneventful (Fig. 24.12a, b).

Case 3

A 29-year-old nulliparous patient with right breast ductal carcinoma in situ underwent nipple-sparing mastectomy and immediate breast reconstruction using stacked IGAP flaps (Fig. 24.4a, b). Mastectomy weight was 317 g, and the final inset flap weight (left and right IGAP flaps) was 280 g and did not have enough volume to reconstruct her right breast (Fig. 24.13a). Three sessions of complementary fat grafting were performed, with each 12-month interval to revise the reconstructed volume and shape. A total of 202 ml of fat was transferred from the posterior in the first procedure (Fig. 24.13b), 255 ml from the anterior thigh in the second procedure (Fig. 24.13c), and 172 ml from the abdomen in the third procedure (Fig. 24.13d). The patient was satisfied with the final appearances not only of both breasts but also of the donor sites including both buttocks and thighs (Fig. 24.14a, b).

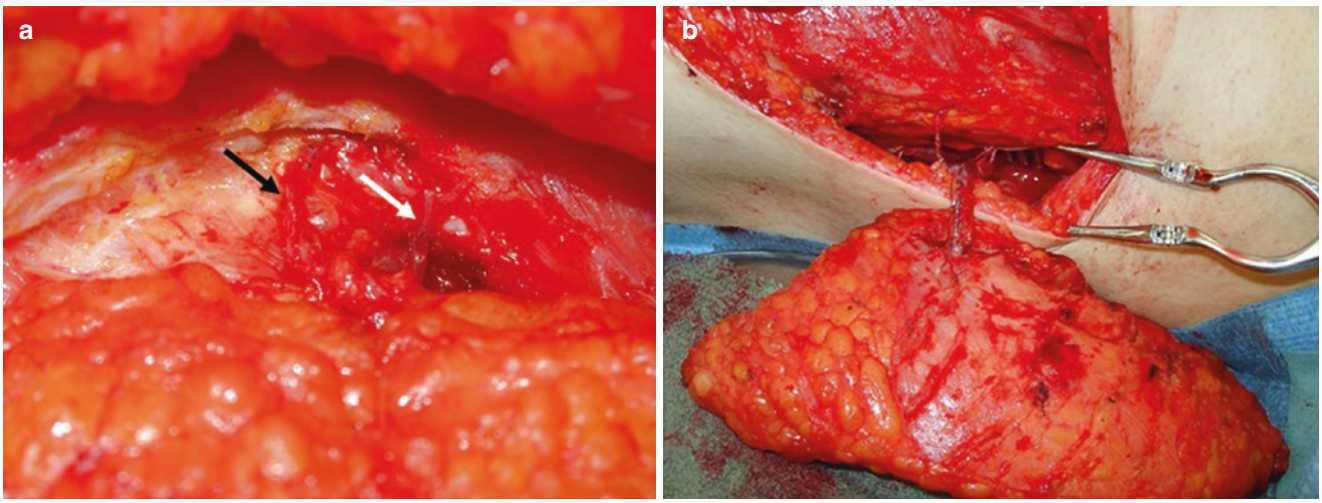


Fig. 24.10 Case 2. (**a**) Pedicle of the left IGAP flap was anastomosed to the internal mammary perforator. Black and white arrows indicate arterial and venous anastomosis, respectively. (**b**) Pedicle of the right IGAP flap was anastomosed to the serratus branch of the thoracodorsal vessel

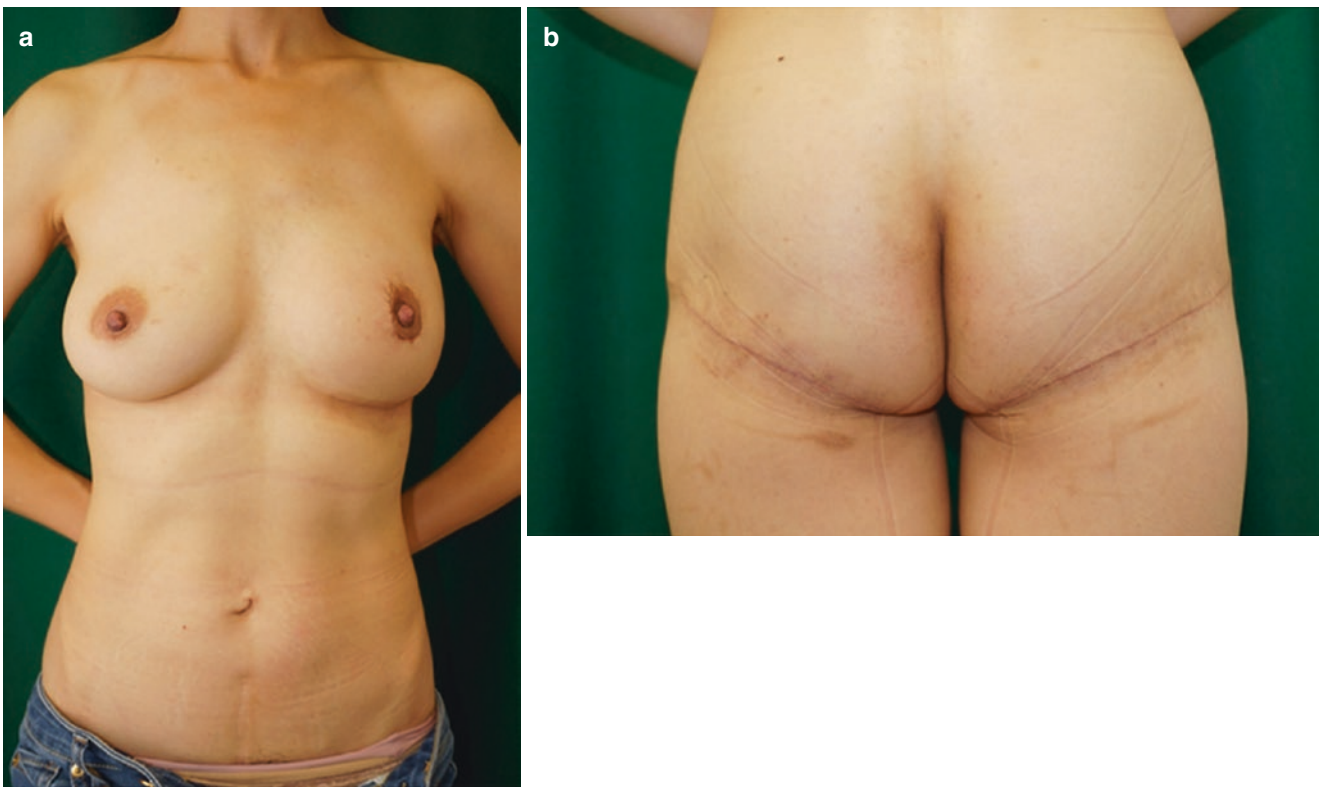


Fig. 24.11 Case 1. (**a**) Postoperative view of the patient at 3 months after delayed breast reconstruction after tissue expansion. During the reconstruction, the left nipple-areola complex was needed to transfer inferiorly by local flap, since lower pole of the breast was overexpanded. (**b**) Postoperative view at 3 months shows both flap donor sites

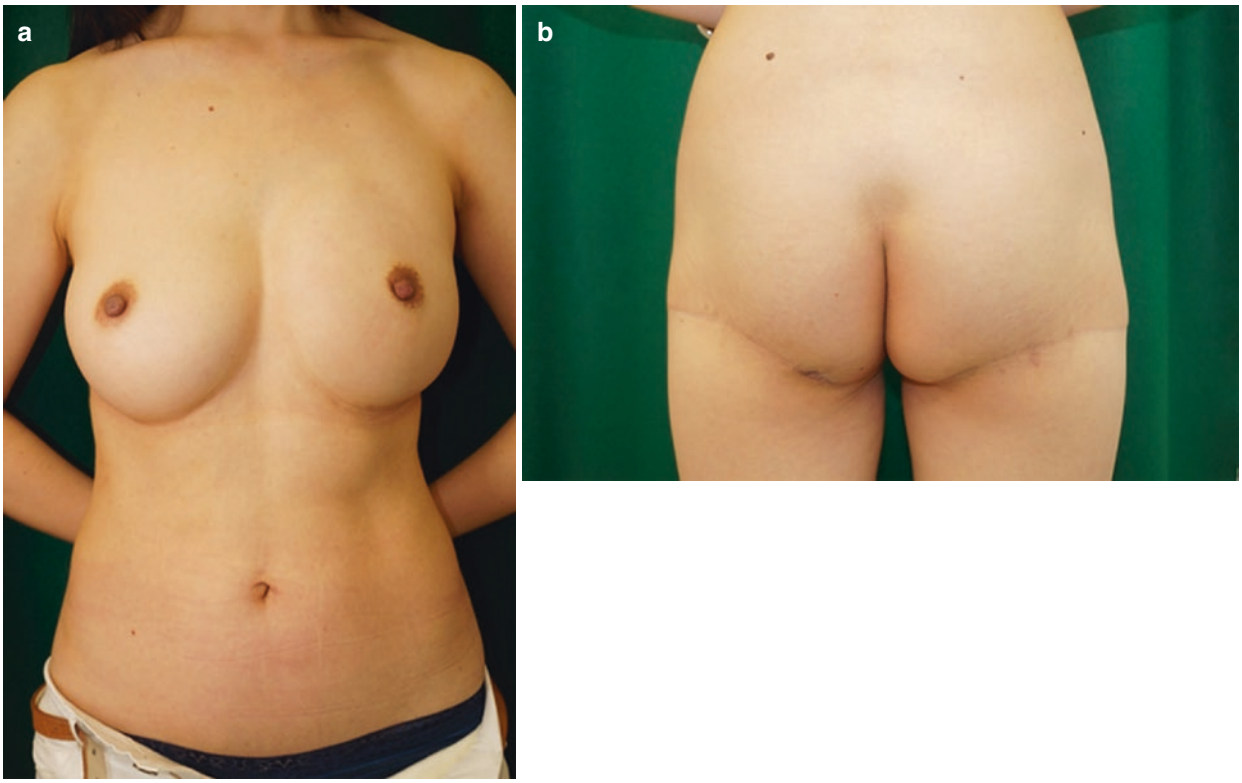


Fig. 24.12 Case 2. (**a**) Postoperative view of the patient at 3 years after immediate breast reconstruction. (**b**) Postoperative view at 3 years shows both flap donor sites

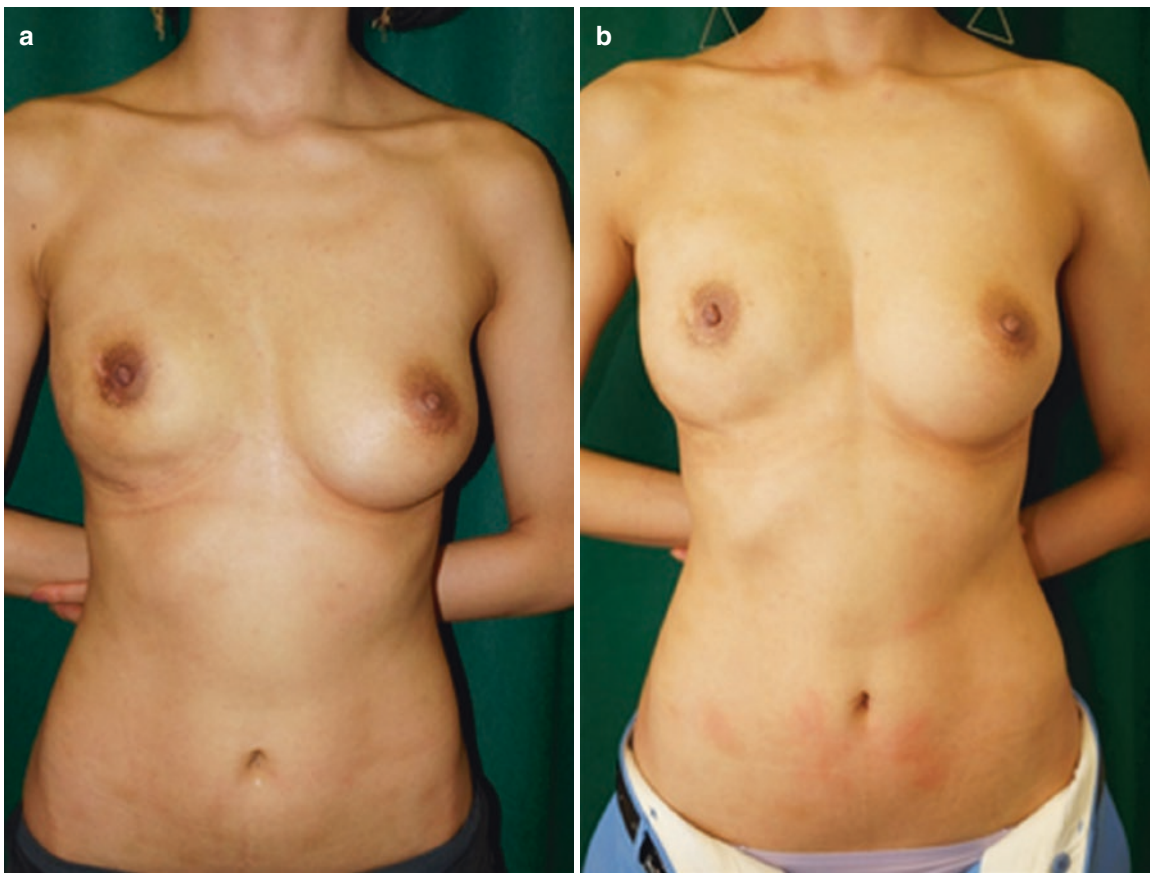


Fig. 24.13 Case 3. Serial photographs taken before and after surgery. (**a**) One year after immediate breast reconstruction using the stacked IGAP flaps. (**b**) One year after the first fat grafting. (**c**) One year after the second fat grafting. (**d**) One year after the third fat grafting

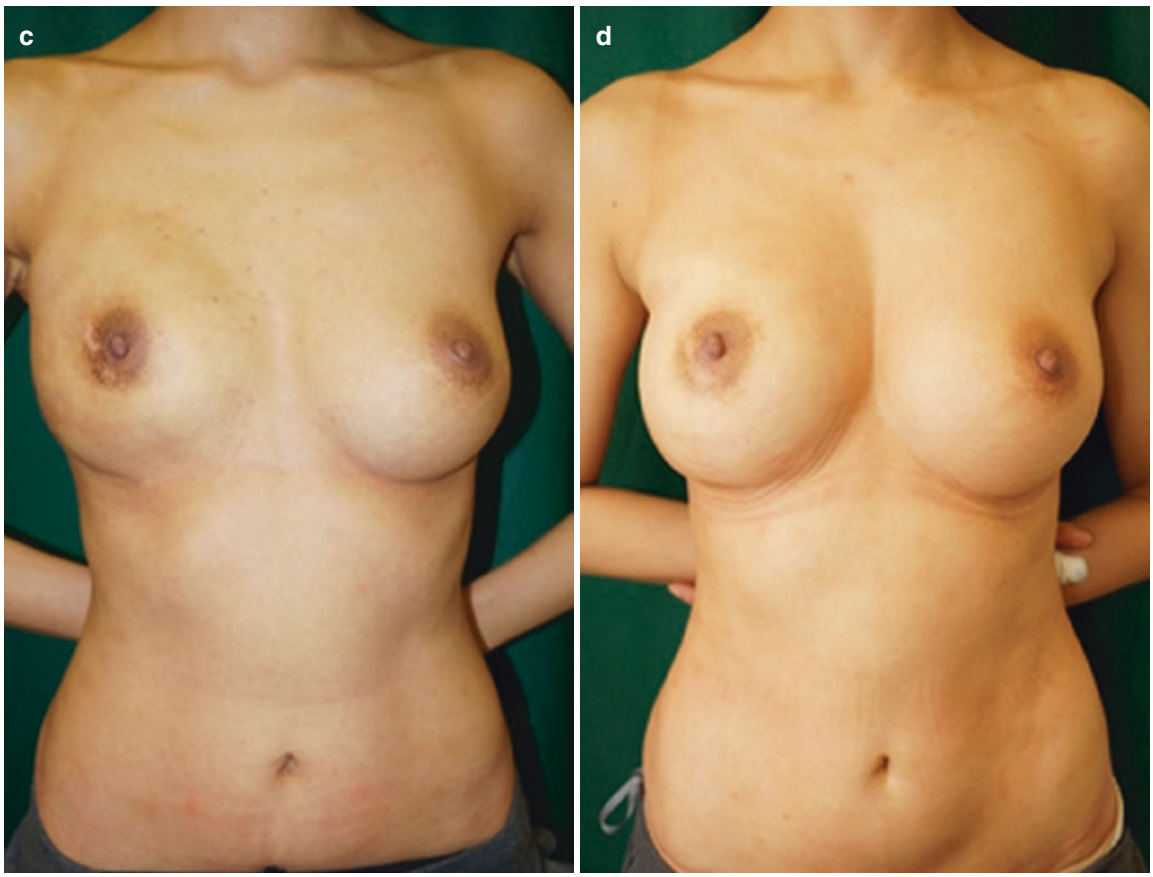


Fig. 24.13 (continued)

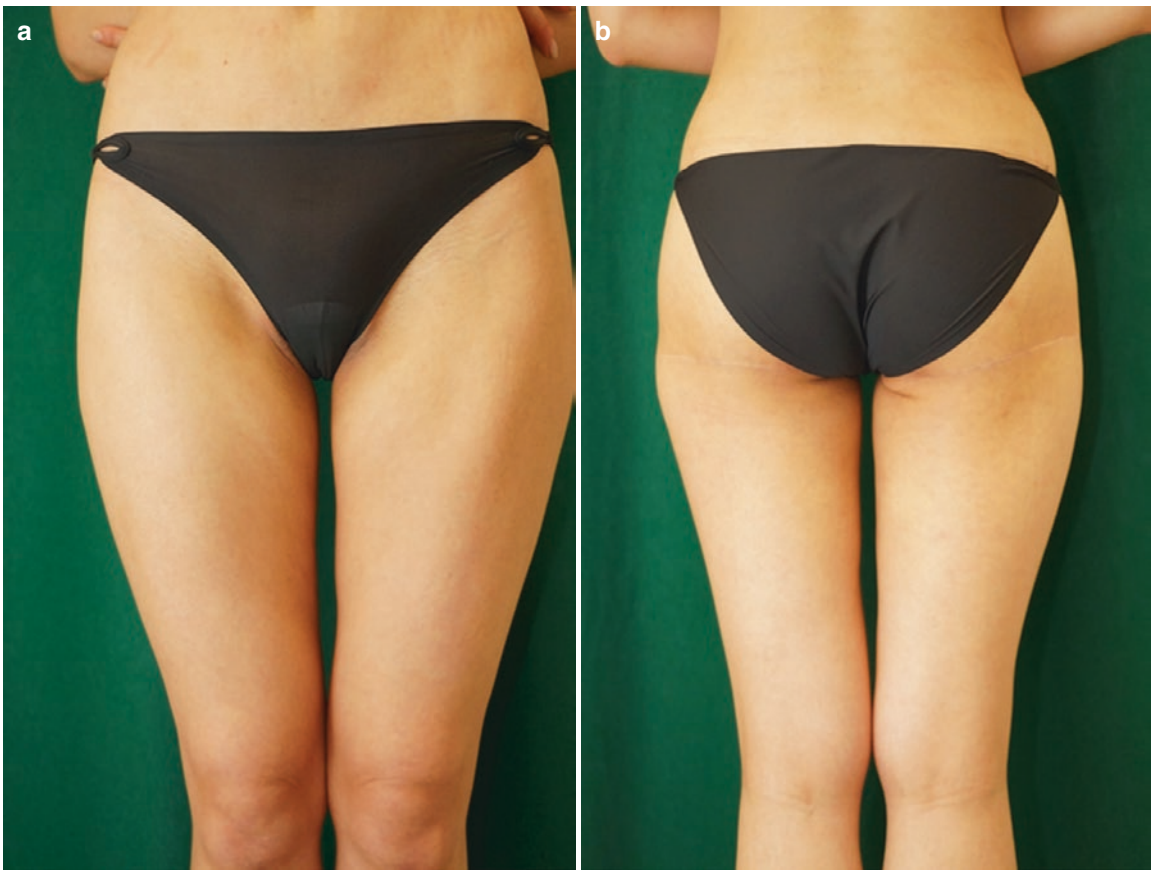


Fig. 24.14 Case 3. Postoperative views of the donor sites including IGAP flap harvesting and serial fat grafting. (**a**) Anterior view. (**b**) Posterior view

Conclusions

The use of stacked IGAP flaps should be considered as an alternative for breast reconstruction in patients whose breast size is greater than a C cup with moderate projection and a mastectomy weight greater than 350 g, particularly those with slim hips, insufficient abdominal tissue, and high-projection breasts.

Although the use of stacked IGAP flaps for unilateral breast reconstruction requires technically demanding dissections, the procedure provides thick, dense, and abundant gluteal fat, which facilitates reconstruction of the breast projection with and without ptosis. Patients can spare gluteal skin and fat without significant gluteal deformity or asymmetry of the inferior buttock volume and shape.

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Lateral Thigh Perforator Flap in Breast Reconstruction

25

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Introduction

Within breast reconstructive surgery, our group has built up a reputation over the years by introducing several new flaps for autologous breast reconstruction and numerous alternative donor sites. The history of breast reconstructive surgery clearly shows the importance of innovating: from implant-based breast reconstruction (IBBR) to autologous breast reconstruction. The tissue that is used for breast reconstruction transformed from local pedicled flaps to free tissue transfer and the first myocutaneous flaps transformed into muscle-sparing perforator flaps to minimize donor-site morbidity. These are just a few examples of the changes within breast reconstructive surgery. Since its introduction in 1994, the abdominal region is first choice for autologous breast reconstruction, because of the relative straightforward dissection due to the widely studied anatomy of the epigastric vessels [1, 2]. In addition, it provides good aesthetic outcomes at the donor site, using the excessive subcutaneous abdominal tissue, which is troublesome for many women. However, the abdomen may not be suitable as a donor site for every woman. Also, the patient's wishes should be considered, not every patient wishes a scar in the abdominal region. The patient's wish and habitus are becoming more essential in donor-site selection. Therefore, many alternative donor sites have been explored to provide tailor made autologous breast reconstruction [3]. The lateral thigh, for example, provides, like the abdomen, sufficient subcutaneous tissue for breast reconstruction [4].

Before the lateral thigh was used for breast reconstruction by Elliott et al. in 1990 [5], MacKenzie described the first experience with the tensor fasciae latae (TFL) flap for reconstruction of the abdominal wall in 1924 [6]. In the years that followed, the TFL flap was found to be useful as a pedicled rotational flap for reconstruction of lower leg injuries and coverage of groin defects and decubitus ulcers [7, 8]. Elliot used the TFL myocutaneous free flap for breast reconstruction, which was later refined to a perforator flap by Kind and Foster [9], providing a longer vascular pedicle and less donor-site morbidity. However, since preoperative vascular mapping was not routine at the time, evaluation of the perforator was limited to handheld Doppler examination. With the introduction of magnetic resonance angiography (MRA) and computed tomography angiography (CTA), it is possible to preoperatively assess and select a suitable perforator. Recent radiologic and anatomical studies provided the vascular anatomy and common perforator branches in the lateral thigh region, showing consistent septocutaneous perforators, which facilitate the dissection and harvest of the flap [10–12]. In 2012, we performed a pilot study on the radiological considerations and clinical cases, which has led to the introduction of the septocutaneous tensor fasciae latae (Sc-TFL) flap for breast reconstruction by our group [13]. As mentioned before (Chap. 23), septocutaneous perforator dissection has shown to be easier than the dissection of musculocutaneous perforators, because of the possibility to retract the muscles and expose the vessels.

The perforators running in the dorsal septum between the TFL muscle and the gluteus medius muscle form the base of the TFL flap. Advantages of these perforators, compared to those in the ventral septum, are a longer pedicle, more subcutaneous tissue, and less tension on the donor site.

Thereafter, we performed a prospective analysis of over 100 Sc-TFL flaps and refined the surgical technique. The

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initial flaps had a width of 9 cm to ensure that the perforator was included in the skin island. However, the width was associated with an increased risk of wound dehiscence at the donor site, and therefore, the width was limited to just 6 cm. In addition, quilting sutures were introduced to approximate the wound edges and minimize the dead space. Patients were postoperatively bothered by the contour defect at the hip, introducing liposuction distally of the donor site, which was no longer beveled. Linda Truluck Perry then proposed a new, simplified name for better patient understanding: the lateral thigh perforator (LTP) flap [4].

Anatomy

The tensor fasciae latae (TFL) muscle arises from the outer edge of the iliac crest, between the anterior superior iliac spine (ASIS) and the iliac tubercle, which is orientated approximately 5 cm posterior to the ASIS. TFL muscle fibers are in a fascial compartment, consisting of a superficial and a deep, dens connective tissue layer of the fasciae latae. TFL muscle fibers only insert to the deep layer. The TFL compartment is adjacent to the rectus femoris/vastus lateralis compartment anteriorly and to the gluteus medius/minimus compartment posteriorly. The investing planes between these three compartments are the anterior and posterior intermuscular septa (Figs. 25.1 and 25.2).

The distal end of the TFL muscle belly is at about the transition of the proximal one third of the thigh to the distal two thirds, where the superficial and deep compartment layers fuse and continue into the longitudinal oriented iliotibial tract (ITT), a double-layered, thick part of the fasciae latae. Coming from posterolateral, the fascial insertion of the gluteus maximus muscle continues over the greater trochanter, also merging into the ITT. Distally, the ITT ends on the anterolateral tibial epicondyle (Gerdy's tubercle).

The lateral femoral cutaneous nerve (LFCN), near the ASIS, follows an interfascial fatpad and then emerges into the subcutaneous layer. It supplies the skin of the anterolateral and lateral thigh through anterior and posterior branches. The LFCN emerging point, course with respect to the ASIS, and the LFCN branching pattern are variable [14].

The superior gluteal nerve (SGN, L4 and L5) innervates the TFL muscle. Blood vessels from the superior gluteal artery (SGA) and from the ascending branch of the lateral circumflex femoral artery (LCFA) supply the TFL. Grob et al. dissected 19 cadaveric hemipelvic specimens from 12 human bodies and showed that the SGN runs along the deep medial TFL border, in fact in the abovementioned anterior intermuscular plane, entering the muscle near the entry point of the ascending branch of the LCFA [14].

TFL perforators are studied by anatomic dissection, cross-sectional imaging, and clinical studies [4, 15, 16]. Perforator vascularization is variable, confusing the terminology concerning blood vessels and flaps. Based on the course of the perforators from the ascending branch of the LCFA, three TFL perforator flap types can be distinguished:

- Type 1: flaps based on septocutaneous perforators running in the anterior intermuscular septum, between the TFL and the vastus lateralis/rectus femoris muscles
- Type 2: flaps based on musculocutaneous perforators running through the TFL
- Type 3: flaps based on septocutaneous perforators running in the posterior intermuscular septum, between the TFL and the gluteus medius/minimus muscles

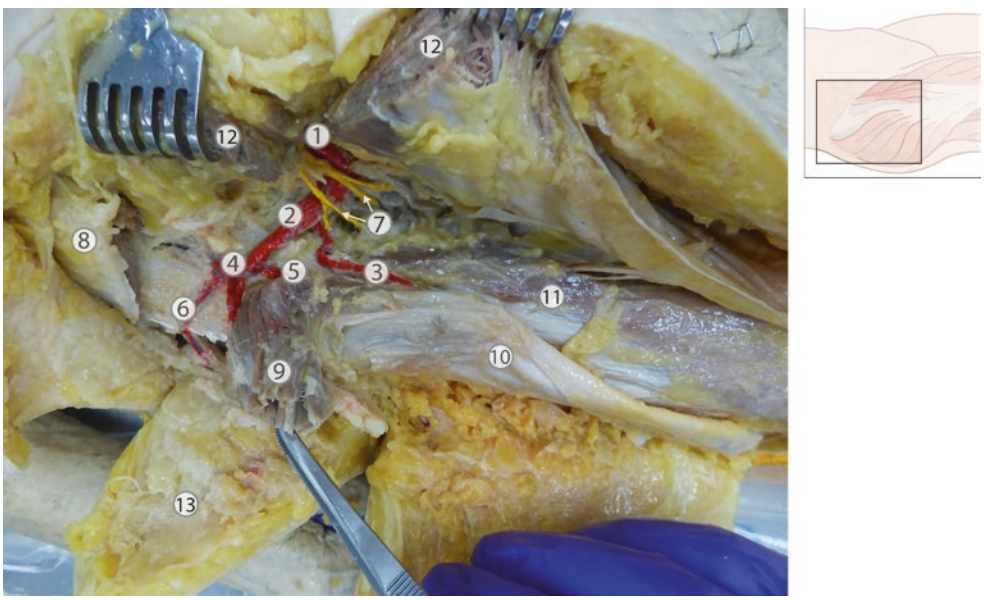

Fig. 25.1 A cadaveric dissection of the gluteal region. (1) Profunda femoris artery (PFA); (2) lateral circumflex femoral artery (LCFA); (3) descending branch of the LCFA; (4) ascending branch of the LCFA; (5) transverse branch of the LCFA; (6) septocutaneous perforator of the anterior branch of the LCFA; (7) femoral nerve; (8) TFL (transected); (9) TFL (reflected); (10) iliotibial tract (ITT); (11) vastus lateralis muscle; (12) rectus femoris muscle (transected); (13) LTP flap. (© 2019 by Greet Mommen, www.greetmommen.be)

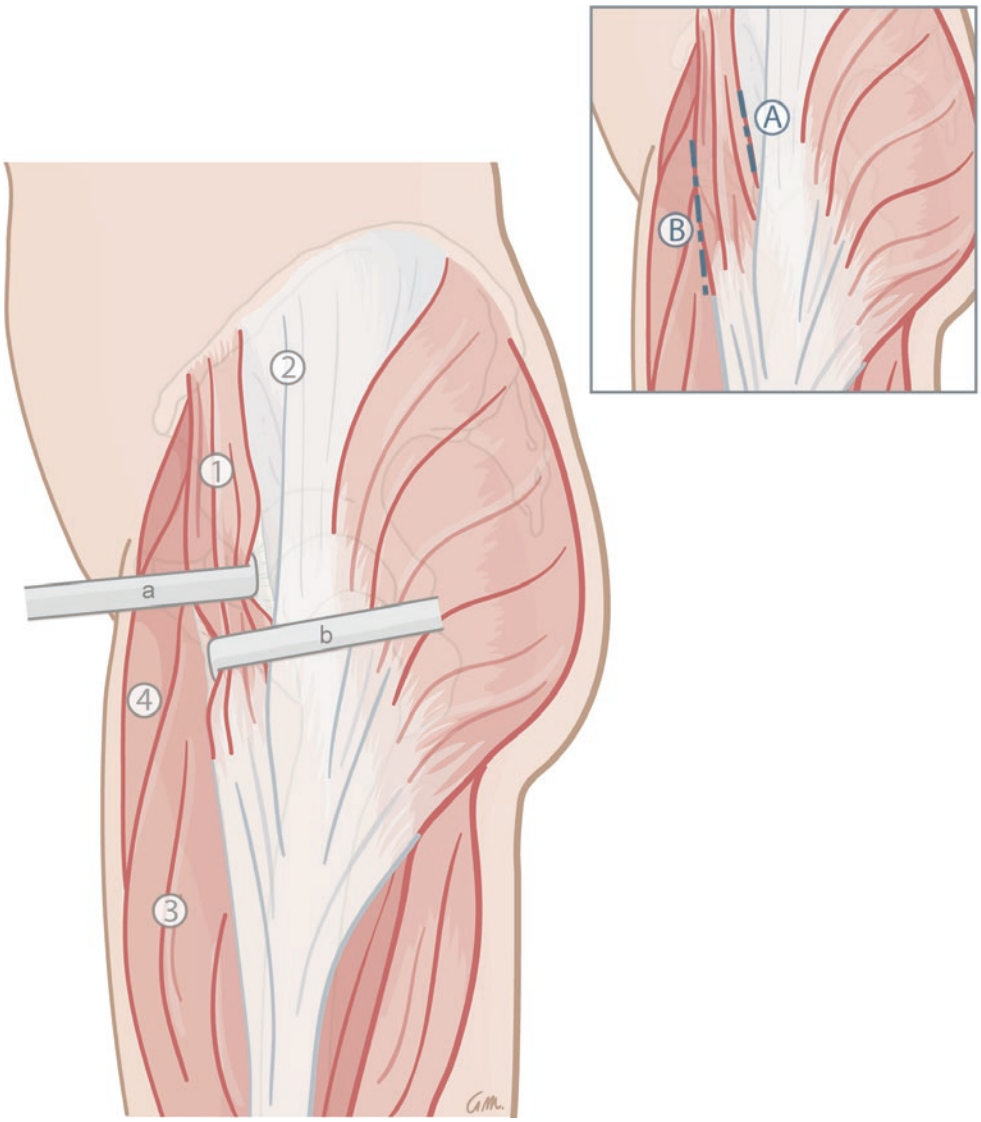

Fig. 25.2 A schematic view of the septa of the tensor fasciae latae muscle (TFL). (a) hook in posterior septum, (b) hook in anterior septum, (1) m. tensor fasciae latae, (2) m. gluteus medius, (3) m. vastus lateralis, (4) m. rectus femoris, (A) posterior septum, between TFL and gluteus medius muscle, (B) anterior septum, between TFL and vastus lateralis/ rectus femoris muscle. (© 2019 by Greet Mommen, www.greetmommen.be)

The LCFA branching pattern is quite variable [10, 15, 17]. Nevertheless, a septocutaneous LCFA perforator running in the posterior intermuscular septum is always present. This makes a type 3 flap, named lateral thigh perforator (LTP) flap or septocutaneous tensor fasciae latae (Sc-TFL) perforator flap, very eligible for reconstruction; the perforator dissection is straightforward and yields usually large-caliber vessels. In addition, the nerves and perforators of the tensor fasciae latae muscle itself are not compromised.

Preoperative Planning

For the preoperative radiological imaging protocol, please refer to section "Preoperative Planning" in Chap. 23, "The Septocutaneous Gluteal Artery Perforator (Sc-GAP) Flap in Breast Reconstruction."

Since preoperative perforator mapping has become routine in autologous breast reconstruction, patients undergo preoperative imaging using MRA and color Doppler. Only patients with a suitable caliber and pedicle length (6 cm or longer) are considered eligible for LTP flap breast reconstruction.

The following parameters were systematically assessed:

1. The number of septocutaneous perforators of the ascending branch of the LCFA.
2. The distance from the anterior superior iliac spine (ASIS) to where the septocutaneous perforators enter the subcutaneous fat determines the craniocaudal position (*y*-axis) (Figs. 25.3 and 25.4). An alternative landmark can be the umbilicus, depending on the preferences of the institute.
3. The maximal pedicle length: the distance from the origin of the ascending branch of the LCFA to where the septocutaneous perforators emerge from the fascia and enter the subcutaneous fat (*x*-axis).

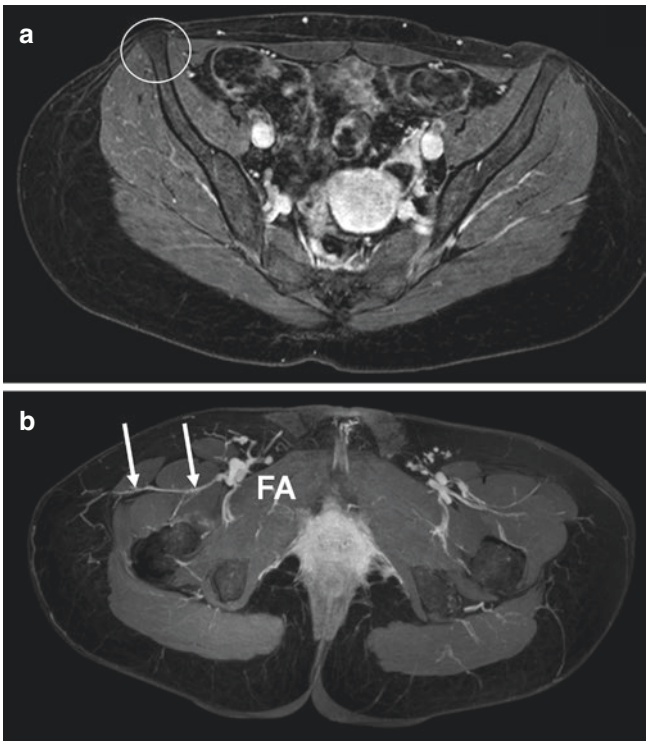

Fig. 25.3 Example of a T1-weighted contrast-enhanced MR image of the pelvis. In (**a**), the iliac crest can be observed (circle). From this point, the craniocaudal distance toward exit of the LTP (**b**, arrows), which originated from the femoral artery (FA), can be calculated. In this case, the distance was approximately 9 cm (*y*-axis)

Landmarks on the patient's body are identified before flap design. The first line that is drawn is a vertical line from the ASIS to the lateral border of the patella, which indicates the anterior margin of the LTP flap. The second line is horizontal at the level of the pubic bone. Drawing is an essential step. The flap can be oriented depending on the excessive fat deposition of the thighs and should not be bigger than 6 cm wide. The perforators are always located laterally of the vertical line. To identify and mark the perforators in the thigh area, a Doppler device is used. The relationship between the height of the perforator and the pubic bone can be assessed using MRA or CT. The most cranially located perforator that runs in the posterior septum with the largest caliber is selected, because the height of the scar depends on this. The more cranially, the more the scar will be covered when wearing underwear. Then, a line can be drawn horizontally, according to the technique described in Chap. 23, "The Septocutaneous Gluteal Artery Perforator (Sc-GAP) Flap in Breast Reconstruction."

When the proper perforator is selected, the flap can be designed, which is a horizontal or oblique skin island (Fig. 25.5). The pinch test is performed to assess the width of the flap, which is usually 6 cm. The average length of the LTP flap varies between 18 and 22 cm. As mentioned before, it is important not to make your flap dimensions too big, because this is associated with a higher risk of wound dehiscence and contour deformities of the thigh.

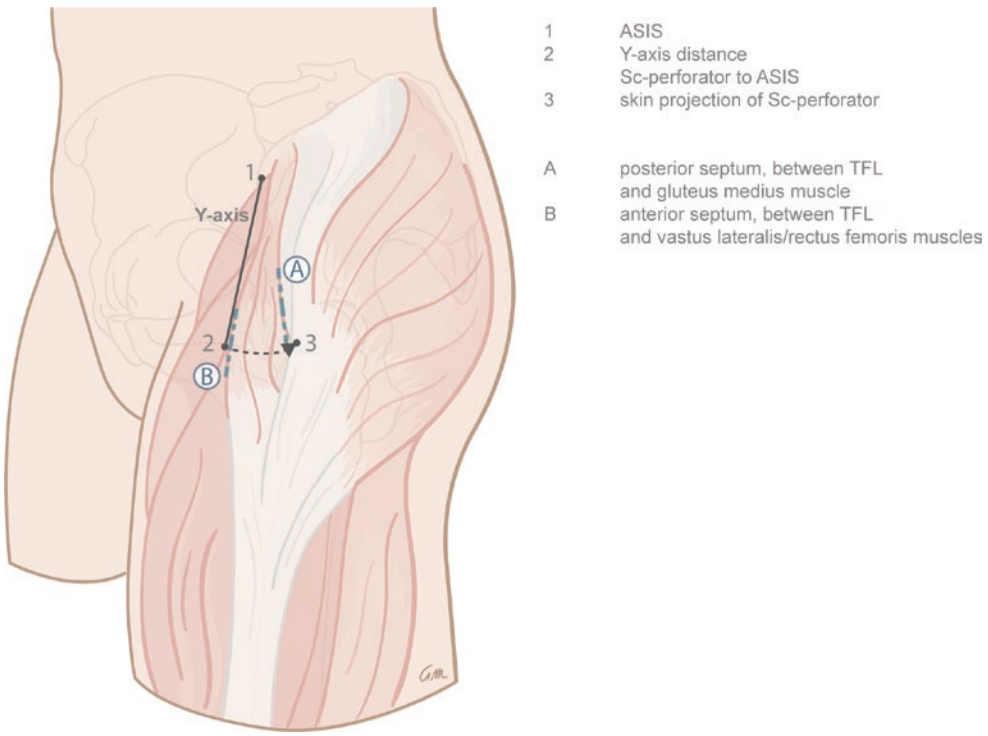

Fig. 25.4 The ASIS is used as a preoperative landmark to determine the height of the septocutaneous perforator (*y*-axis). The distance of the perforator from the midline on the surface of the patient was determined with identification of the septum of the TFL. A color Doppler examination was performed. (© 2019 by Greet Mommen, www.greetmommen.be)

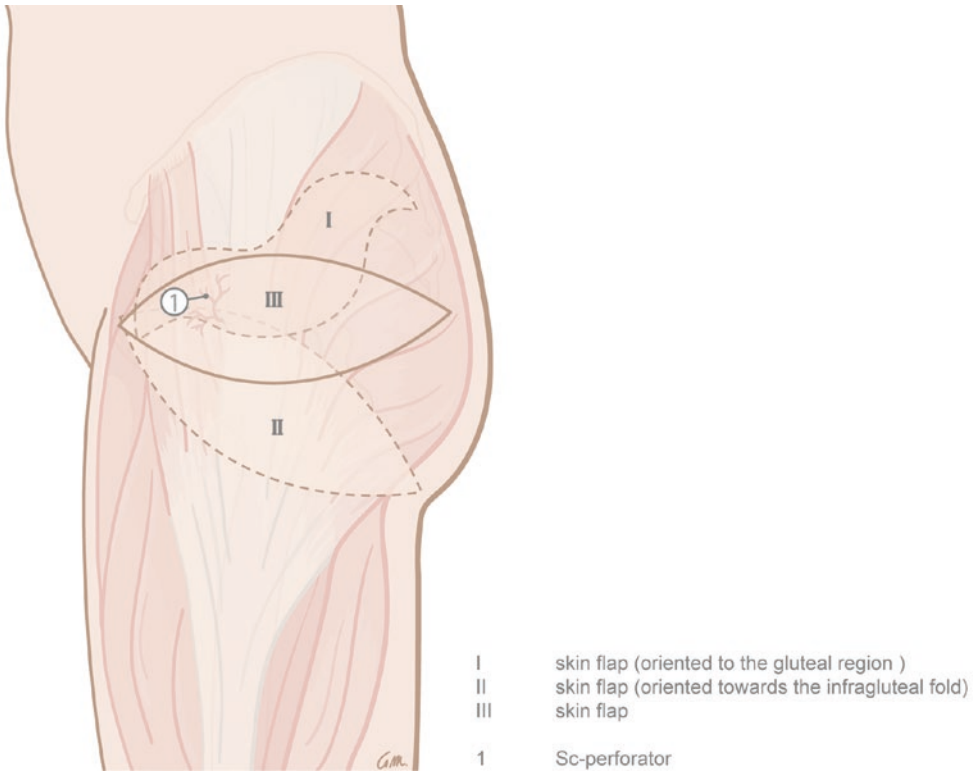

Fig. 25.5 A schematic illustration of the flap design and its potential variations that include the septocutaneous perforator. The skin island can be adjusted to the habitus of the patient, but generally the skin island is drawn the same as option III. (© 2019 by Greet Mommen, www.greetmommen.be)

Surgical Technique

During surgery, two teams work simultaneously, which is possible because the patient is in supine position with the arms alongside the body. In case of a primary breast reconstruction, one or two teams, depending on the unilateral or bilateral character of the surgery, perform mastectomy or prepare the internal mammary vessels for microscopic anastomosis. Another concurrent team works at the donor site, harvesting the LTP flap from medial to lateral, following the preoperative markings. The full surgical technique is shown in the supplemental video and explained by the following steps (Video 25.1).

At the anterior border of the LTP flap, it is important to identify the lateral cutaneous femoral nerve (LFCN) and not to damage it during dissection (Fig. 25.6).

Then, proceed the dissection above the fascia of the TFL muscle. Identify the posterior septum (Fig. 25.7), which is easy to recognize because of the very thin fascia of the TFL, showing the muscle fibers underneath. This is contrary to the fascia of the gluteus medius muscle, which is very thick and white.

Then, the fascia covering the posterior septum is opened longitudinally over the whole width of the LTP flap design. Now, the septocutaneous perforators can be identified (Figs. 25.8 and 25.9).

The perforator is dissected to its origin from the ascending branch of the LCFA. Dissection can be performed using blunt materials, because the muscles are easily separated from each other. Sometimes, it is necessary to include a cuff of fascia, to prevent any damage to the perforator; during blunt dissection, all muscular branches that come across are ligated. Now, the perforator can be clipped and dissected. The length of the pedicle usually lies between 6 and 8 cm. Microsurgical end-to-end anastomosis is performed to the internal mammary vessels. The arterial anastomosis is hand-laid. A coupler device is used to carry out the venous anastomosis.

Thereafter, the breast can be shaped, and the recipient site can be closed. Using Doppler signal, the arterial and venous perforator locations are determined for postoperative flap monitoring. To approximate the wound edged of the donor site, the subcutaneous tissue is caudally undermined. With quilting sutures, the subcutaneous tissue is approximated and attached to the fascia to reduce dead space; then liposuction of the thigh is performed to reduce contour deformity at the donor site. Lastly, suction drains are placed at each individual donor site and neo-mamma.

Additional procedures, such as dog ear correction or symmetrical surgeries, are performed in a second stage. Usually, a second liposuction session at the donor site is necessary to achieve the desired contour.

The following technical tips are useful to overcome common surgical pitfalls during the Sc TFL flap procedure:

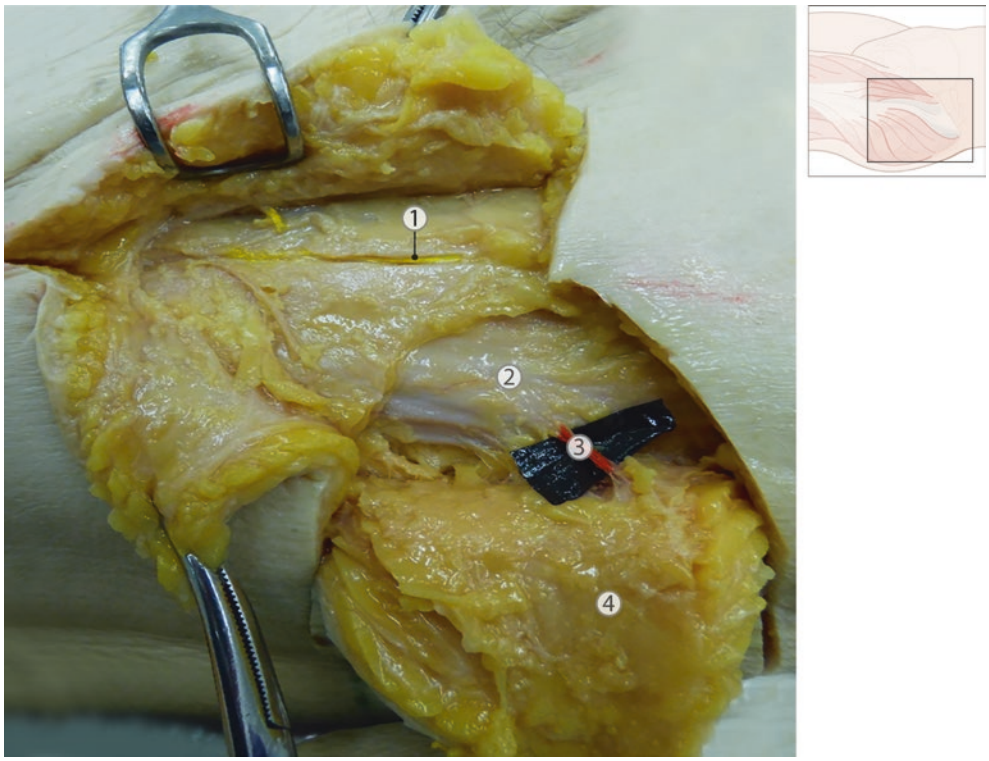

Fig. 25.6 A cadaveric dissection showing the LCFN (1). The tensor fasciae latae muscle (2) gives off a musculocutaneous perforator (3) to the LTP flap (4). (© 2019 by Greet Mommen, www.greetmommen.be)

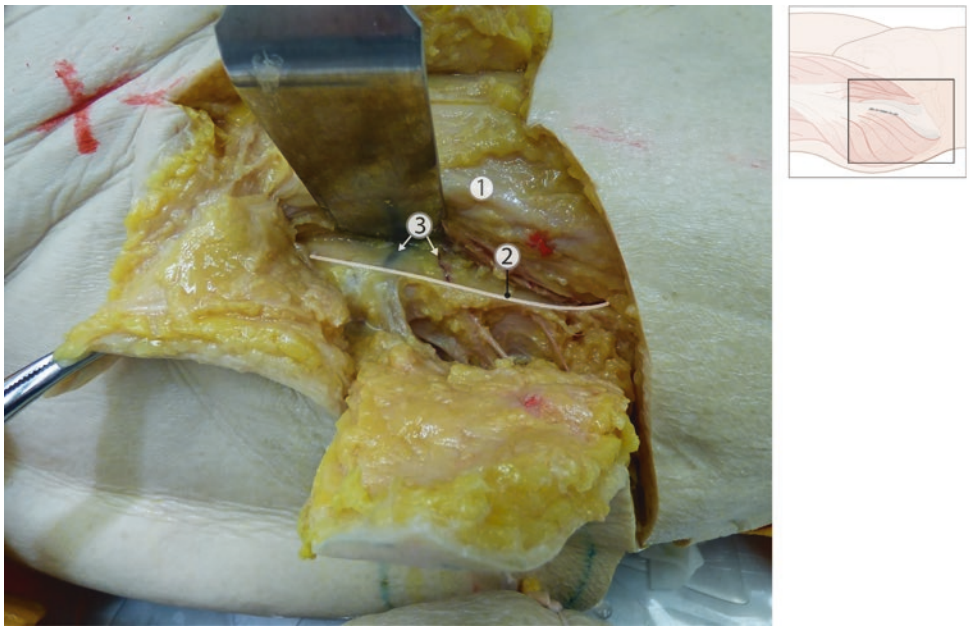

Fig. 25.7 A cadaveric dissection showing the posterior septum (2) between the TFL (1) and gluteus medius muscles with the septocutaneous perforators (3) running in it. (© 2019 by Greet Mommen, www.greetmommen.be)

1. Do not bevel. This will result in more contour deformity.
2. Be very careful while dissecting and leave the LCFN intact.
3. Dissect the pedicle until you find the caput medusae, and then stop. The caput medusae is made of all the branches of the LCFA.
4. Special attention should be paved to the position of the pedicle after anastomosis: no kinking or twisting of the pedicle is accepted. Because you are dealing with septocutaneous perforators, they are not as flexible as the regular musculocutaneous perforators of the DIEP flap for example.

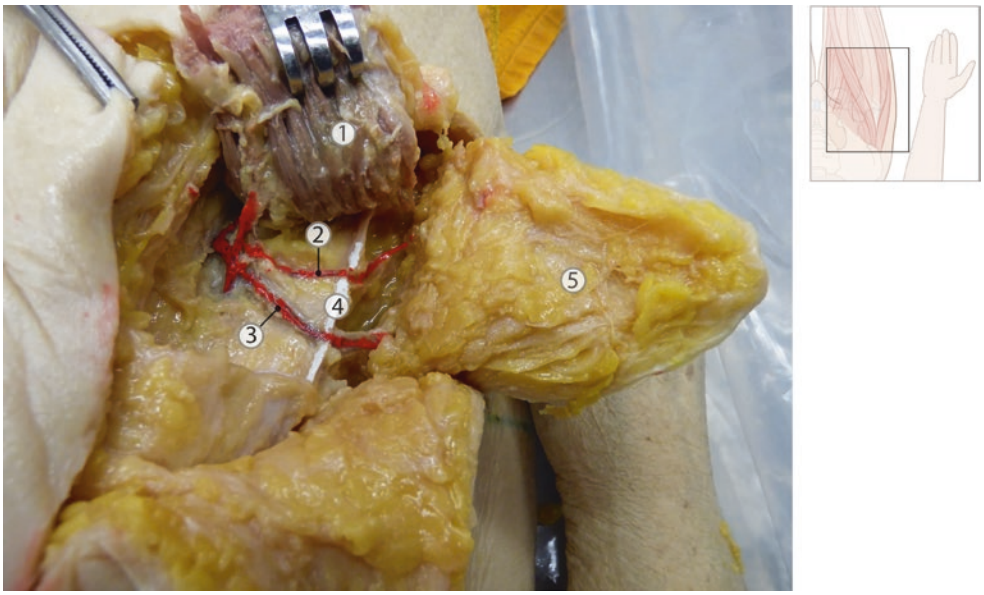

Fig. 25.8 A cadaveric dissection representing the clinical situation. The TFL muscle (1) is transected and the caudal part of it reflected and reveals the posterior septum (4) and the septocutaneous perforators (2 and 3) running in the septum toward the LTP flap (5). (© 2019 by Greet Mommen, www.greetmommen.be)

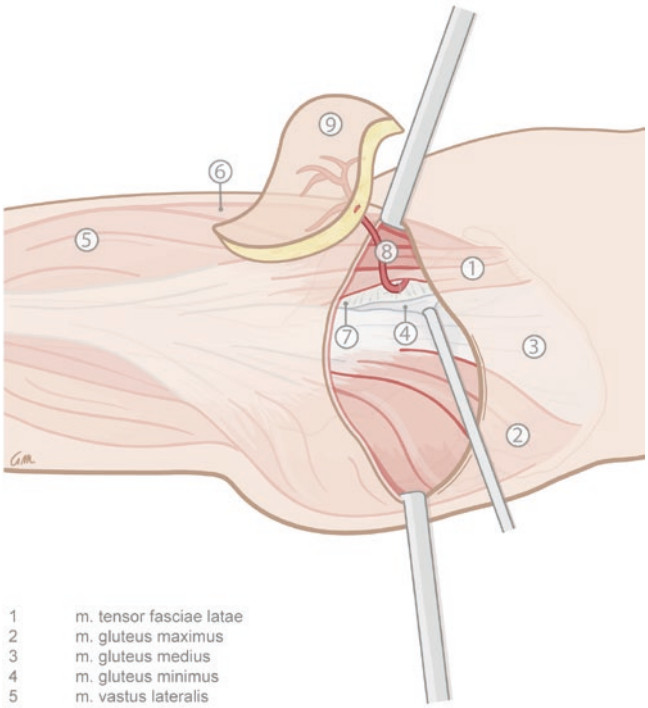

Fig. 25.9 A schematic representation of how the LTP flap is harvested. (© 2019 by Greet Mommen, www.greetmommen.be)

Postoperative Care

Before surgery, the patient gets medical thrombosis prophylaxis stockings (MTPS), which will be worn until the patient mobilizes. After surgery, the LTP flap will be monitored every hour on color, temperature, and capillary refill for the first 24 hours. In addition, the arterial and venous perforator locations are checked. Suction drains will have to be monitored on production and will be removed if they have less production than 30 mL/24 hours. Naturally, the patient will get adequate pain medication during hospital admission and after discharge. The average hospital admission is 4–6 days. The patient receives prophylactic low molecular weight heparins (LMWHs) for 6 weeks. During these 6 weeks, the patient needs to wear compression pants and a sports bra. After 2 weeks, the stitches are removed. This is the standard postoperative care for autologous free flap breast reconstruction.

Clinical Case

A 45-year-old woman came to the Department of Plastic Surgery in our institution because she was known with a family history with early breast cancer. Although no genetic abnormalities were found, she desired a bilateral prophylactic mastectomy and autologous breast reconstruction. Furthermore, she was a healthy woman without medication. She did not smoke.

On medical examination we saw a woman with a normal physique and a C-cup (Fig. 25.10). The jugulum-nipple distance was 21 cm on both sides. Her BMI was 22.7, so her abdominal tissue was insufficient for bilateral breast reconstruction. Therefore, the lateral thigh was chosen as the donor site. Unfortunately, no preoperative photos were taken of the donor sites.

To determine the status of the perforators, preoperative imaging was performed using MRA. This showed septocutaneous perforators on both sides.

A nipple-sparing mastectomy was performed combined with an immediate breast reconstruction using the LTP flap bilaterally (Fig. 25.11). The skin islands are located in the inframammary fold (IMF).

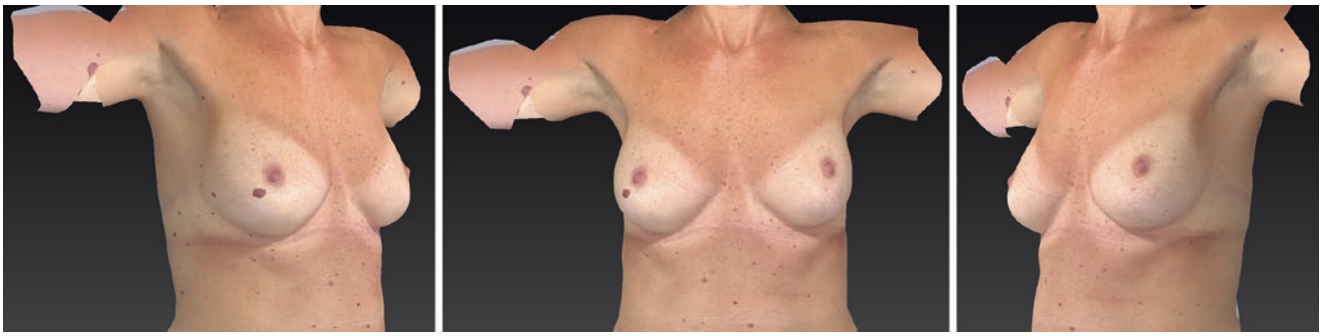

Fig. 25.10 Preoperative photos of a patient undergoing bilateral breast reconstruction. (© 2019 by Greet Mommen, www.greetmommen.be)

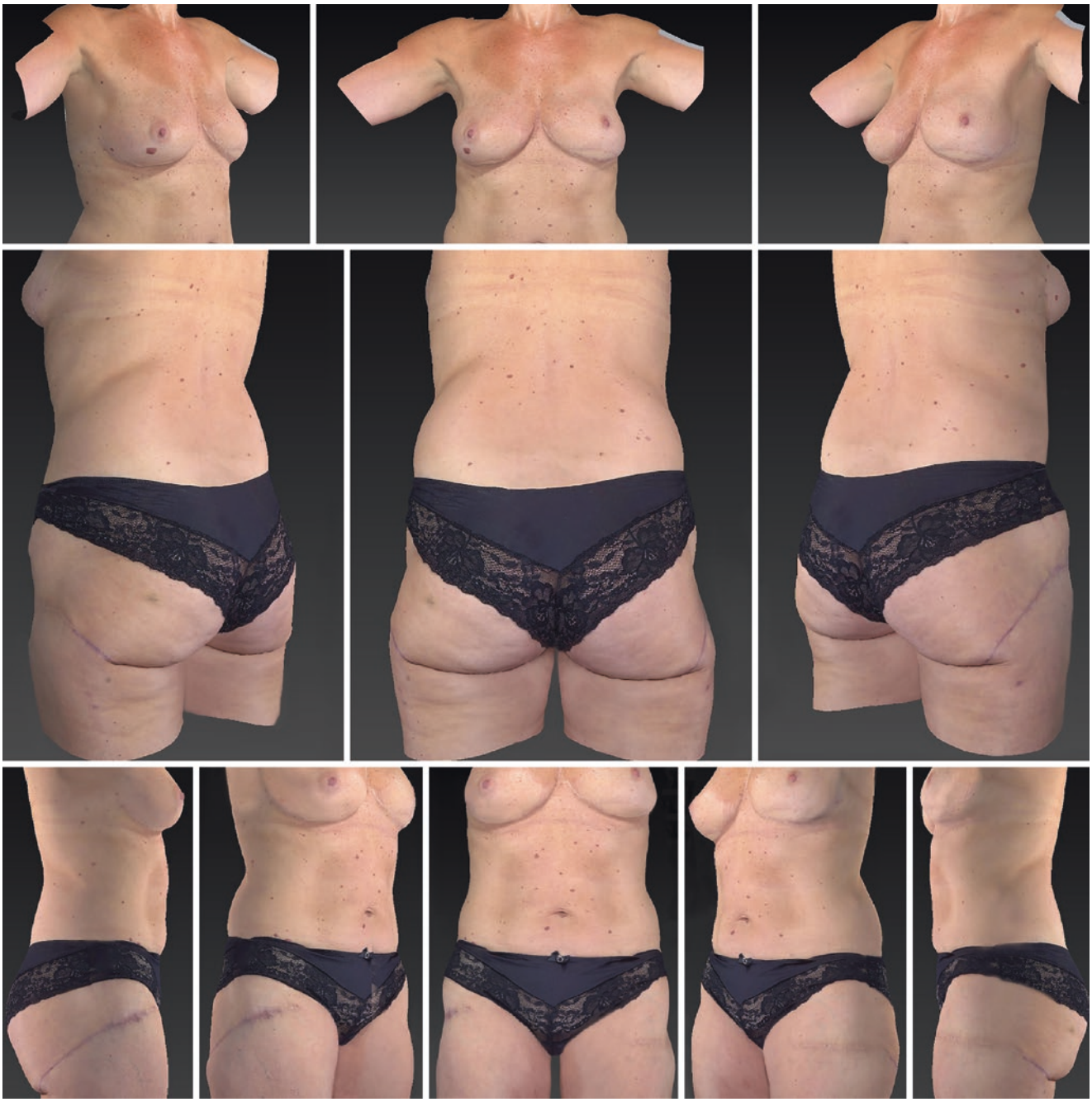

Fig. 25.11 Photos of a patient 1 year postoperative after bilateral nipple-sparing LTP flap breast reconstruction. (© 2019 by Greet Mommen, www.greetmommen.be)

Conclusions

The lateral thigh is an excellent alternative donor site to harvest a free flap for autologous breast reconstruction, when the abdominal region is not available or not desirable. The lateral thigh provides sufficient subcutaneous tissue and with appropriate anatomical knowledge and microsurgical skills, should be within every plastic surgeons portfolio. The most notable advantage of the lateral thigh perforator flap is the easy, blunt dissection of septocutaneous perforators, which obviates the need for intramuscular dissection. Surgical refinements have led to less donor-site morbidity and more aesthetic pleasing results. Before its introduction, the S-GAP flap was second choice at our institution. Ever since, the LTP flap has taken its place.

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Transverse Upper Gracilis Flap in Breast Reconstruction

26

Gottfried Wechselberger and Karl Schwaiger

Introduction

The free myocutaneous gracilis flap with its characteristically transverse orientation of the skin paddle was first described by Yousif et al. [1, 2] in 1992. These studies could show the cutaneous perforators, originating from the gracilis muscle and supplying the overlying fat pad and skin, orientated as a transverse perforasome. Especially in the USA, the synonym "TUG" (transverse upper gracilis flap) for the same flap is used. This term could be seen historically, because at the beginning of the flap harvest only the upper portions of the muscles were taken. First breast reconstructions using this versatile flap were described in early years at the turn of the millennium [3–6]. Wechselberger and Schoeller [5, 6] technically refined the flap, making its application a valuable option in autologous breast reconstruction. They started to harvest the whole muscle based on the major perforator in order to gain more volume and to reduce contour deformity at the donor site.

The most important advantages of this flap are the following:

- Constant anatomy
- Easy to harvest, easy two-team approach (flap harvest is a straightforward procedure, lasting about 45–60 min)
- Low donor-site morbidity
- Hidden scar within a natural fold
- Easy bilateral harvest possible

The following sections should give a practical overview and surgical road map for performing a TMG free flap breast reconstruction.

Anatomy

The TMG flap consists of the proximal two thirds of the gracilis muscle, harvested on the more proximal major pedicle, and the overlying transverse-oriented fat and skin. The TMG flap is a type II blood supply according to the classification of Mathes and Nahai. Flap harvest is done using the major pedicle, which is the more proximal one, entering the muscle about 10 cm distal to the pubic bone. The mean length of the pedicle is about 6–8 cm [7]. The average safe cutaneous transverse perforasome is about 10–12 cm long vertically and about 25–30 cm long horizontally (see section "Preoperative Planning and Patient Preparation").

Vascular supply: gracilis vessel from the medial femoral circumflex system.

Innervation: nerve branch from the obturator nerve (for breast reconstruction not necessary), entering the muscle about 0.5–1 cm proximal from the vascular pedicle.

Artery: caliber of about 2 mm, *vein*: usually two concomitant veins (Fig. 26.1).

Patient Selection

The TMG free flap can be used for breast reconstruction after skin-sparing mastectomy, simple mastectomy, or partial breast defects.

One of the most important advantages of the TMG free flap is the low donor-site morbidity combined with the hidden scar. Conclusively, this flap is an ideal option for young women with small- to medium-sized breasts and failure of excess abdomi-

Electronic Supplementary Material The online version of this chapter (https://doi.org/10.1007/978-3-030-34603-4_26) contains supplementary material, which is available to authorized users.

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H. F. Mayer (ed.), *Breast Reconstruction*, https://doi.org/10.1007/978-3-030-34603-4_26

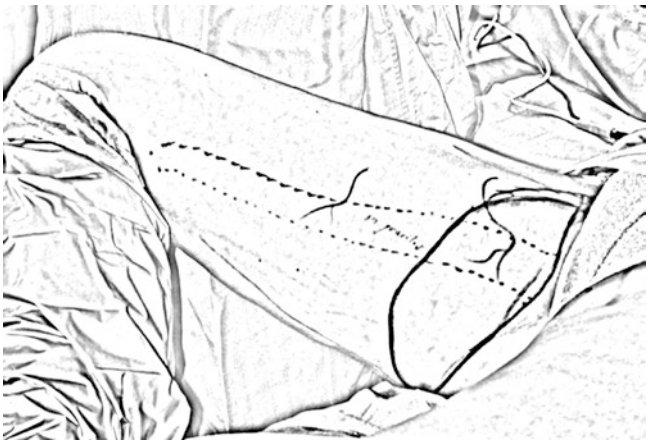

Fig. 26.1 Typical dimensions of the skin island of the TMG flap. The underlying structures are outlined, namely, the gracilis muscle with the anticipated course of the principal (proximal) and minor (distal) pedicle

Table 26.1 Guidelines for flap selection in autologous breast reconstruction [8]

Patient/donor-site characteristics	Preferred flap
Excess tissue in the lower abdomen, lacks girth in upper thigh; patient would profit from abdominoplasty procedure	DIEP
Flat abdomen with possible scarring, redundancy of tissue in the medial upper thigh region; patient would profit from medial thighplasty procedure	TMG
No excess tissue in lower abdomen or medial upper thigh setting of bilateral reconstruction or unilateral reconstruction of small- to moderate-sized breast TMG	TMG

nal tissue. Thus, when it comes to scars, the TMG flap might even be superior to the DIEP flap because the scar is concealed in a natural fold even when the patient is entirely naked.

One of the strongest advantages of the TMG flap is bilateral reconstruction. In small- to medium-sized breasts, we believe that it should be the first choice except for those cases that would benefit from abdominoplasty anyway. In patients with a rather wide gap between their thighs, tissue deficiency resulting from flap harvest might become more visible, and this fact should be discussed preoperatively. In cases where a patient would be an ideal candidate for either a DIEP flap or a TMG flap, the decision is based on discussing with the candidate preoperative and postoperative photographs of comparable patients. Table 26.1 lists guidelines for flap selection in autologous breast reconstruction [8, 9].

Preoperative Planning and Patient Preparation

Preoperative marking of the patient is done in standing position with abducted legs. The width of the skin island is assessed by means of a pinch technique to ensure tension-free closure (8–10 cm on average, and up to 12 cm in older patients and patients after noticeable weight loss). A crucial aspect is the strict limitation of flap width to a dimension that is tolerated and evaluated by this preoperative pinching test in the standing position. If a sufficient flap size is not predicted by this simple preoperative test, we decide to either take two narrower flaps or exclude the patient from a TMG flap reconstruction. By applying this algorithm, many wound-healing problems and resulting unsightly scars can be avoided.

The posterolateral skin incision should not extend past the midline of the posterior thigh, to prevent visibility of the scar at the dorsal aspect of the thigh and injury of the posterior femoral cutaneous nerve, with possible subsequent neuroma formation [10].

Due to the absolutely constant anatomy, no preoperative imaging, such as ultrasound or computer tomography angiography, is necessary (Fig. 26.2).

Surgical Technique

In general anesthesia, the patient is placed in supine position. The leg, where the flap is harvested, is placed in a slightly flexed position in the hip and abducted and externally rotated and flexed in the knee joint. The surgeon is on the opposite side, starting with the flap harvest by incising the skin along the preoperative marking.

The raising of the adipocutaneous portion of the flap is started close to the groin where the tendon of the adductor longus muscle is palpated. The skin island is harvested with the underlying fascia. At the dorsal border of this muscle, a first view of the vascular pedicle of the TMG flap is possible. Then, with the surgical assistant lifting the leg and flexing it in the hip, the posterior part of the skin island extending into the gluteal crease is incised down to the musculature. Care has to be taken not to injure the branches of the posterior femoral cutaneous nerve. In the next step, the fascia at the caudal border of the island overlying the gracilis muscle is opened and the muscle is freed bluntly. The minor pedicle to the muscle should be identified and ligated or clipped. During dissection of the tendon of the gracilis muscle, care has to be taken not to injure the saphenous nerve [8].

Using electrocautery, the muscle is cut as distally as possible after palpating it between two fingers. Then, the origin of the muscle is separated from the pubic bone using also electrocautery. The branch of the obturator nerve supplying the gracilis muscle is ligated, and the vascular pedicle is dissected free up to its origin from the deep femoral vessels. Care has to be taken to either clip or ligate all side branches into adjacent muscles, especially the one into the

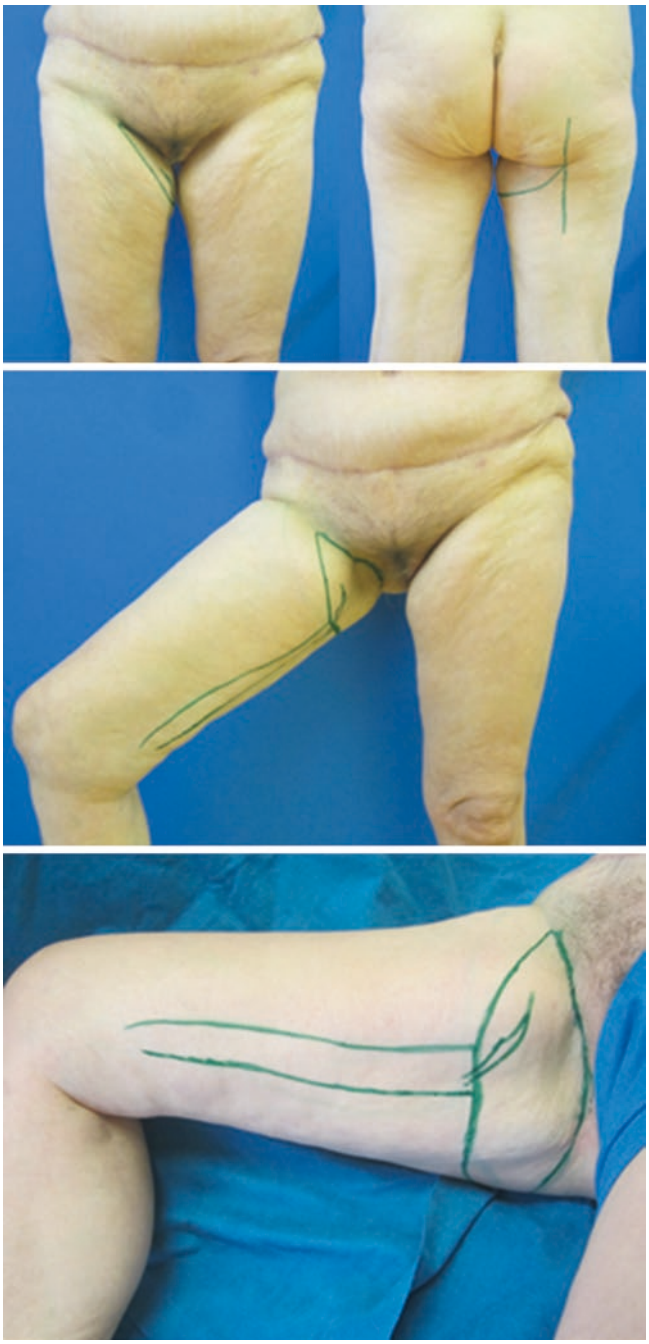

Fig. 26.2 Preoperative flap design. The skin island can range from 8 to 12 cm in width and can be as long as 30 cm; particular care has to be taken not to extend the posterolateral skin incision past the midline of the posterior thigh to prevent injury of the posterior femoral cutaneous nerve and subsequent neuroma formation [9]

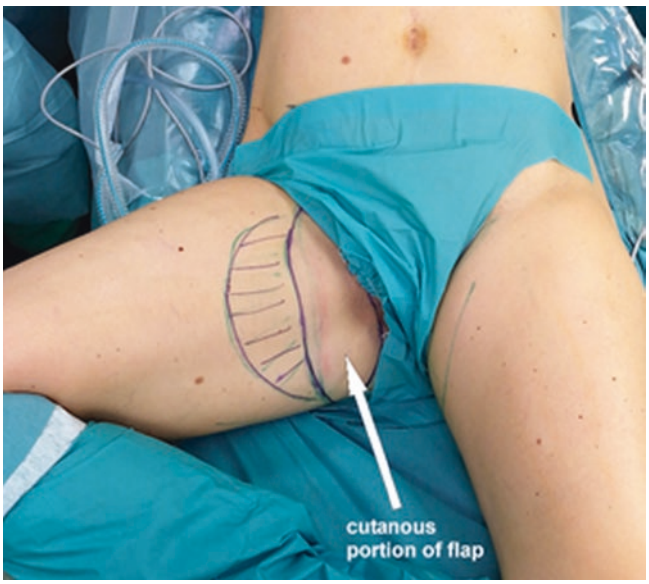

Fig. 26.3 Intraoperative patient positioning. At the region of the marked skin, subcutaneous tissue should be included during flap harvest in order to include the main vascular skin perforators

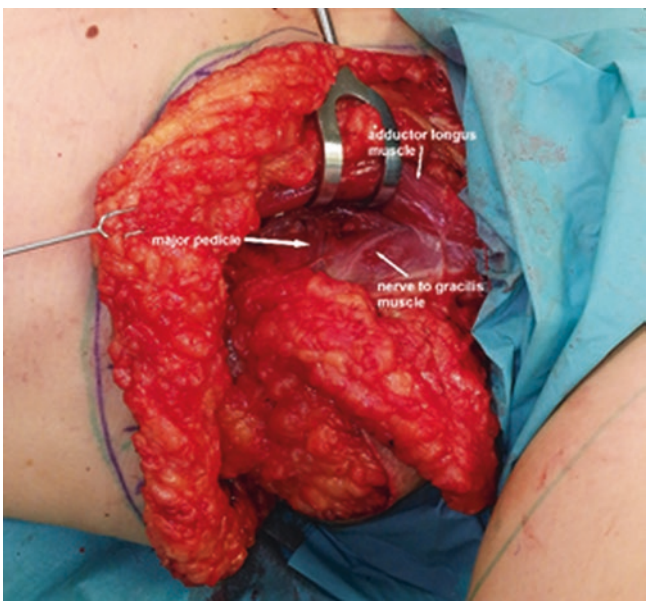

Fig. 26.4 The anterior portion of the skin island is lifted off the adductor longus muscle. At the dorsal border of the muscle, the main pedicle of the TMG flap is encountered in the adipofascial space

adductor longus muscle, to prevent bleeding. The adductor longus muscle is then retracted and lifted upward by the assistance and the pedicle dissected close to its origin. The flap is transferred to the recipient site (internal mammary vessels), and the donor site is closed primarily in a typical medial thigh lift fashion, avoiding dog-ears by advancing the lower wound edge to the midline of the wound. A drainage should be placed within the wound [8, 9] (Fig. 26.3, 26.4, 26.5, and 26.6).

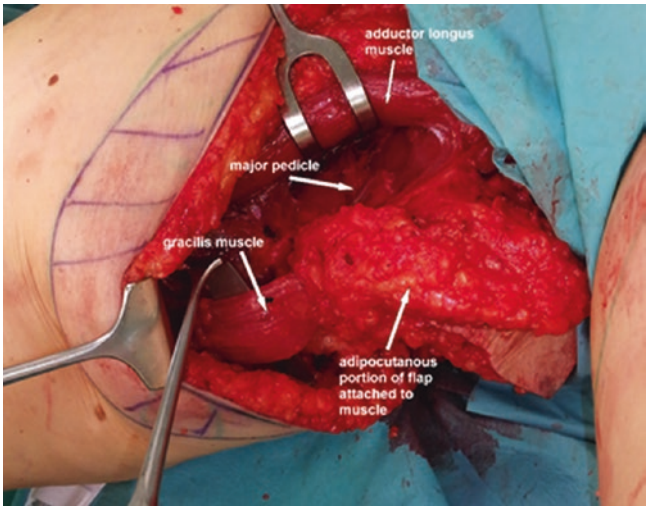

Fig. 26.5 The skin island is attached to the gracilis muscle where numerous small perforators enter the adipocutaneous portion of the flap. However, no effort is undertaken to identify any specific perforators

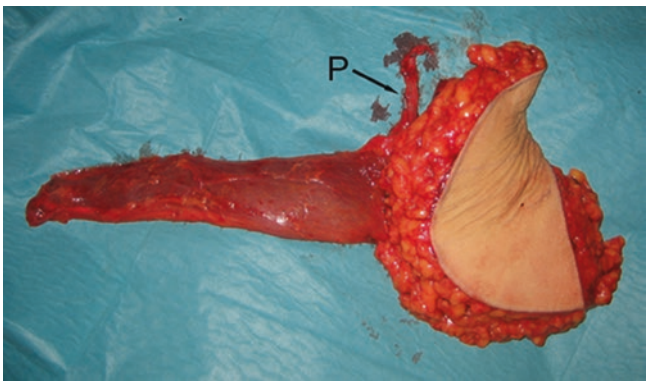

Fig. 26.6 Harvested TMG free flap with its typical chimeric appearance, consisting of the gracilis muscle and the adipocutaneous portion. P pedicle

Technical Variations

For breast reconstruction, there are several options to modify the TMG flap in order to achieve an excellent aesthetic result.

After skin-sparing mastectomy or nipple-sparing mastectomy, full skin removal is possible (musculoadipose flap). Nevertheless, we prefer simple deepithelialization with conservation of the dermis and positioning of the flap with the deepithelialized portion directly underneath the breast skin. This is a preventive procedure in order to have more options in cases of wound-healing disturbances or skin necrosis (e.g., unmeshed split thickness skin graft).

Due to the fact that in some cases the volume of the TMG flap is not enough, there is a possibility of enhancing it by doing lipofilling of the reconstructed breast in further procedures. We observed excellent results by doing this. We assume that the main mechanism behind this opportunity is the well-vascularized muscle tissue, which integrates the injected lipoaspirate by almost 100% [11].

Vascular anastomoses are done primarily under microscope to the internal mammary vessels (one artery, one vein). The artery is anastomosed end to end by using nonabsorbable 8.0–9.0 monofil sutures. The vein is anastomosed by using the Coupler® system (Synovis, Minneapolis, MN, USA). If the internal mammary vessels are not available, there is the possibility to use the lateral thoracic vessels or the thoracodorsal vessels. Perforator vessels from the pectoralis major are usually not recommended as a recipient vessel because the arterial inflow is not strong enough for the flap. Microvascular complications like arterial and venous thrombosis have been observed as a result.

Postoperative Care

Flap monitoring at the recipient site should be done exclusively clinically. In cases where the flap itself is not visible (skin-sparing mastectomy), flap evaluation using a pO_2-probe is possible; nevertheless in these cases we recommend to leave a small monitoring island in the area of the lateral inframammary fold (zone 4 of free flap), which can be removed easily later under local anesthesia.

Placed drainages in the donor-site area as well as at the recipient site should be removed if there is less than 20 ml/24 h of fluid collection. Mobilization starts at day 2. During hospital stay, the patients receive low molecular weight heparin with a simple dosage of 20 mg/s.c. in the morning and 40 mg/s.c. in the evening in the absence of any contraindications (e.g., kidney disease), either for optimization of flap perfusion or for thromboembolic prophylaxis. Oral antibiotics for infection prophylaxis are administered for 1 week in the absence of contraindications.

Clinical Cases

Case 1: Breast Reconstruction with a Bilateral TMG Flap After Simple Mastectomy

A 46-year-old woman presented with a history of bilateral breast cancer, bilateral simple mastectomy, and radiation therapy on her right side. In this patient, the fat distribution also appeared in favor of the thighs, whereas abdominal tissue was not available. The decision was thus made to perform a bilateral transverse gracilis musculocutaneous flap breast reconstruction. The flaps were anastomosed to the right respective left internal mammary vessels. In further procedures, the patient also received fat grafting, nipple-areolar reconstruction, and lipofilling (Figs. 26.7 and 26.8).

Case 2: Breast Reconstruction with a TMG Flap After Nipple- and Skin-Sparing Mastectomy

A 45-year-old woman with a multicentric carcinoma of the left breast. The patient received a nipple-sparing mastectomy with immediate reconstruction with a TMG flap from the right side (Figs. 26.9 and 26.10).

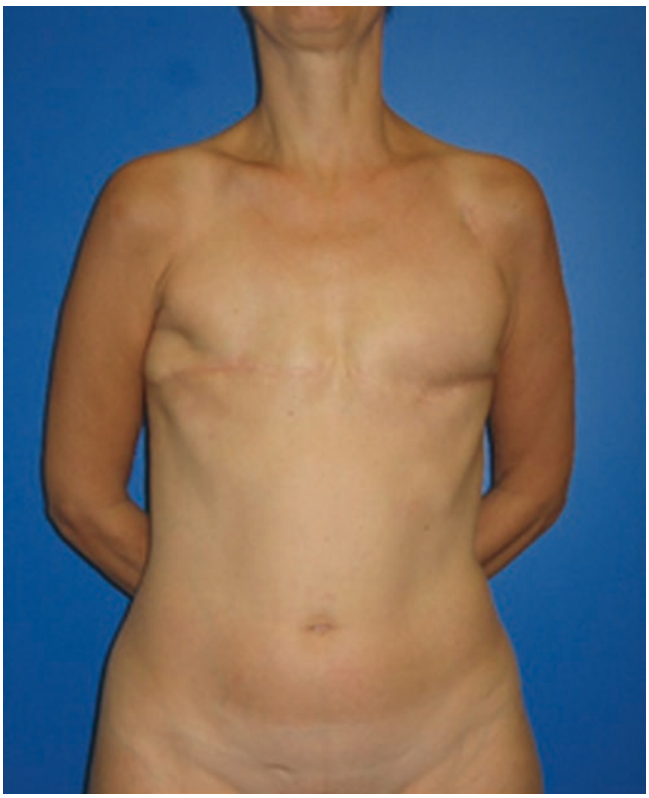

Fig. 26.7 Preoperative view, patient after bilateral mastectomy

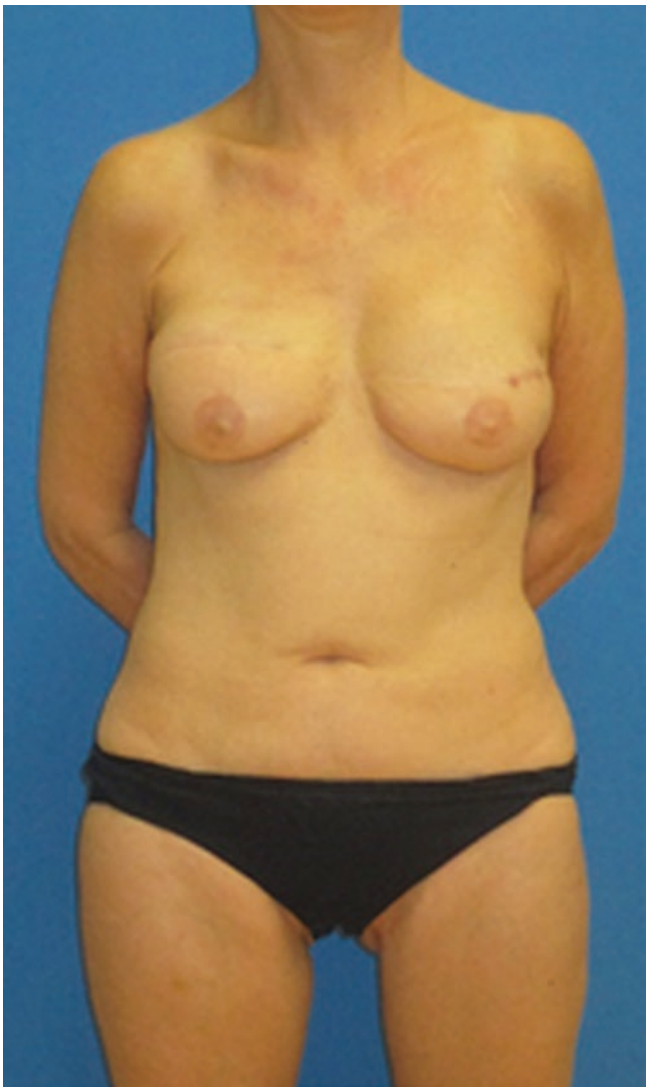

Fig. 26.8 Postoperative view, excellent aesthetic result and low donor-site morbidity, with almost invisible scars in the groin region

Case 3: Breast Reconstruction, Partial Breast Defect Reconstruction After Tumor Excision

A 40-year-old woman presented with a history of right-sided breast cancer – tumor excision and adjuvant radiotherapy. She suffered from a severe contour deformity with absence of the two lower quadrants of the right breast. Decision was made to reconstruct the two lower quadrants by using

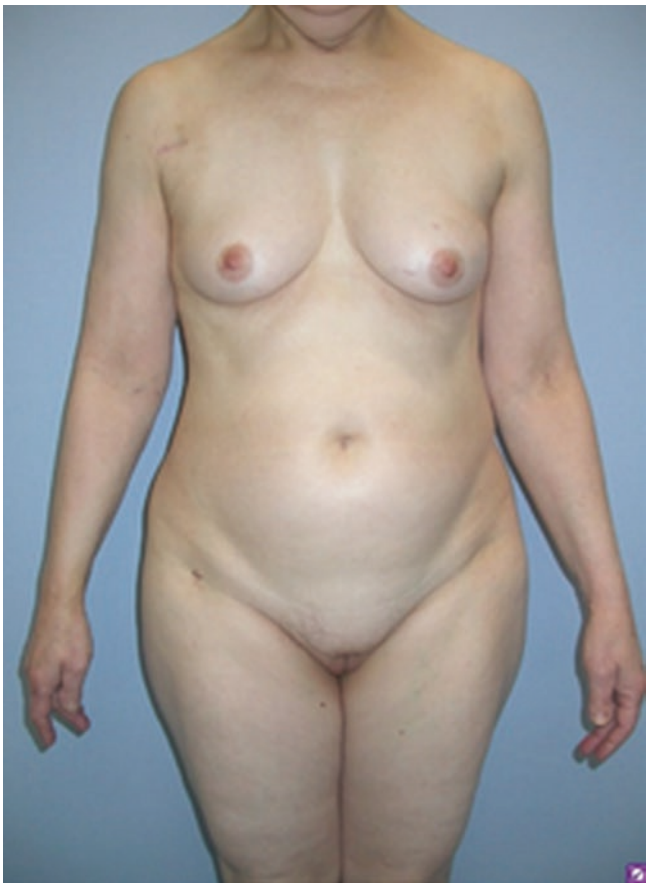

Fig. 26.9 Preoperative view

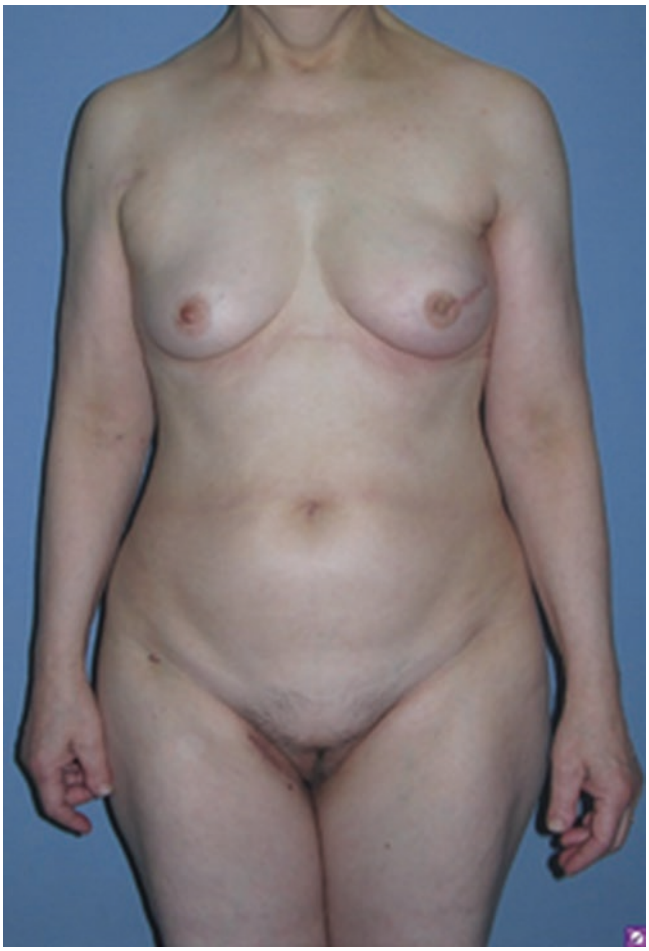

Fig. 26.10 Postoperative view after 6 months without further procedures

a TMG free flap from the contralateral side. Additionally, she received a slight mastopexy on the contralateral side and minor lipofilling in the medial aspect of the flap in a further operation (Figs. 26.11 and 26.12).

Case 4: Breast Reconstruction After Implant Removal due to Painful Capsular Fibrosis

A 53-year-old woman presented with a history of bilateral nipple-sparing mastectomy due to breast cancer on the left side and BRCA gene positivity. Additionally, she received chemotherapy, local radiotherapy, and axillary lymph-node dissection. The breast was reconstructed with 400-cc expander implant. The patient suffered a severe and painful capsular fibrosis Baker IV especially on the left side with additional obvious skin redness. Decision was made to remove the implants, perform a capsulectomy, and reconstruct the breast with a bilateral TMG flap. The result was very satisfying, the patient was free of pain postoperatively, and even the skin redness disappeared (Figs. 26.13 and 26.14).

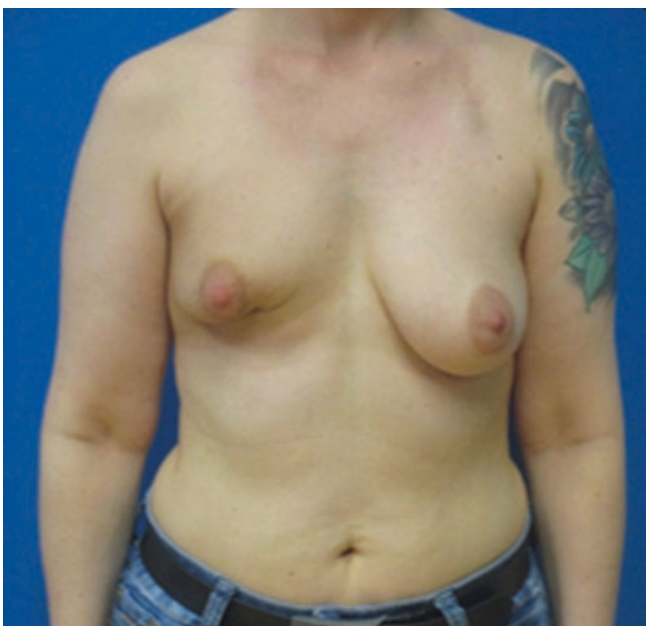

Fig. 26.11 Preoperative view

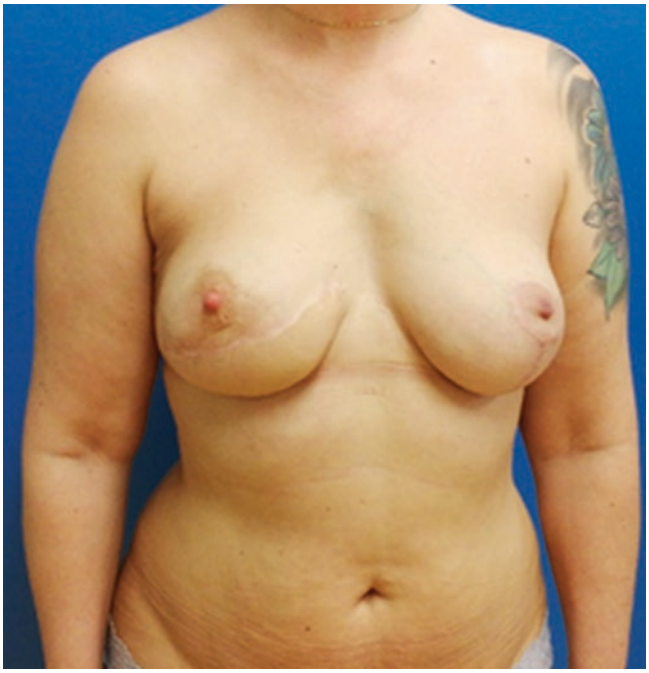

Fig. 26.12 Postoperative view after 12 months

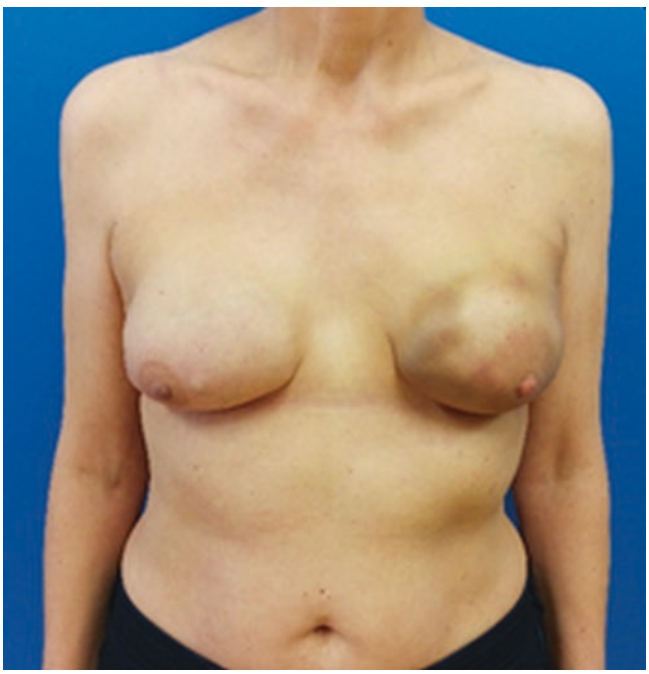

Fig. 26.13 Preoperative view

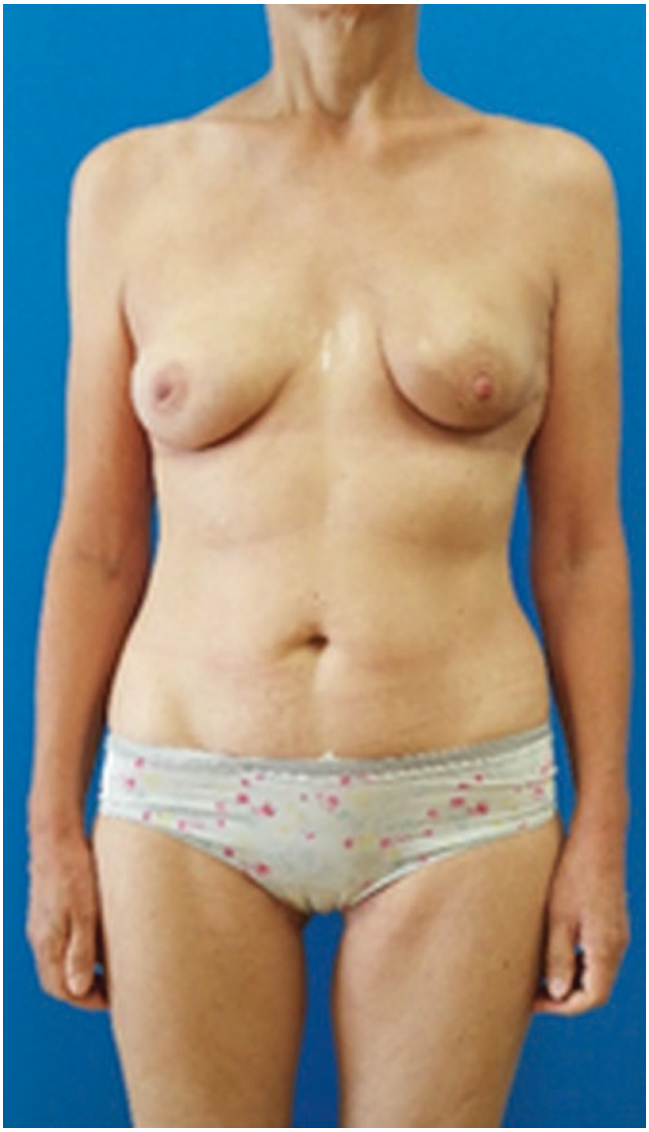

Fig. 26.14 Postoperative view 6 months later, skin redness and tenderness disappeared, and the patient was pain-free

Conclusions

The TMG free flap is an excellent option for breast reconstruction. The flap harvest is a straightforward procedure due to constant anatomy. An easy two-team approach is possible, and the donor-site morbidity is low compared to other options. Strong indications for using the TMG flap are

small- to medium-sized breasts and the absence of enough abdominal tissue for performing a DIEP flap.

Supplemental Digital Content

A Video 26.1 is available as supplemental digital content, showing the preoperative marking and the flap harvest.

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Profunda Artery Perforator Flaps for Breast Reconstruction

27

Jamie Zampell, Hugo St-Hilaire, Jourdain Artz, and Robert J. Allen Sr.

Introduction

With refinement of microsurgical techniques and perforator flap design, autologous breast reconstruction has evolved to utilize donor tissues from the lower abdomen as well as from the hips, buttock, and thighs. While use of the lower abdomen is a clear first choice for donor-site tissues, it may not be available in all cases. Use of medial and posterior thigh tissue is ideal in situations where abdominal tissue is insufficient, unavailable due to previous surgery, or body fat distribution is centered below the waist.

The profunda artery perforator (PAP) flap evolved from initial descriptions of the transverse upper gracilis flap, utilizing tissue based on the medial circumflex femoral artery and requiring muscle sacrifice. Hurwitz et al. later described the posterior thigh myocutaneous flap based on the inferior gluteal artery [1]. Agrigiani et al. subsequently described the posterior thigh perforator flap based on the profunda femoris artery [2]. The profunda artery perforator free flap finally was described for use as a free flap for burn and pressure sores [3] and later for breast reconstruction in 2010 as a viable second choice if abdominal tissue is not available [4]. The flap is based on perforating branches of the profunda femoris artery which are known to provide the dominant blood supply to the posterior thigh [5]. While initially designed as a transverse flap camouflaged in the gluteal crease, recent studies demonstrate multiple variations of aesthetic flap design based on anatomic location of the dominant perforator [6, 7].

Electronic Supplementary Material The online version of this chapter (https://doi.org/10.1007/978-3-030-34603-4_27) contains supplementary material, which is available to authorized users.

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Anatomy

The PAP flap is based on perforators off the profunda femoris artery which provide the dominant blood supply to the posterior thigh. The profunda femoris artery branches from the common femoral artery approximately 3.5 cm distal to the inguinal ligament and spirals to reach the medial aspect of the femur. The profunda splits into medial and lateral branches before giving off perforating arteries. The medial branch gives off three perforators on average, providing a segmental blood supply to the posterior thigh. The first perforator supplies the adductor magnus and gracilis, and the second and third perforators supply the semimembranosus, biceps femoris, and vastus lateralis [5]. Perforators share a common origin in 37.5% of male patients and 18.2% of female patients [8]. For traditional transverse PAP flap design, the first perforator is the preferred pedicle to the flap.

While traditional flap design centered the skin island on proximal perforators, recent anatomic studies show that the dominant profunda artery perforator is located more distally. In studies of transversely oriented PAP flaps, Allen et al. reported that average perforator distance distal to the gluteal crease was 3.5 cm, average pedicle length was 10.6 cm, distance to midline was 6.2 cm, artery diameter range was 2.3–2.8 mm, and average flap weight was 385 g [9, 10]. Subsequent analysis of the entire posterior thigh has demonstrated the mean distance of larger, dominant perforators to be more distal. Computed tomography angiogram analysis of 100 thighs demonstrates that 85% of thighs have three or more profunda perforators, with mean perforator location 6.2 cm distal to the gluteal crease and evenly distributed between the medial and lateral thigh. Average perforator diameter at the takeoff of the profunda was 2.7 mm and average perforator length was 100.7 mm [8]. Cadaveric perfusion studies of 29 posterior thigh flaps demonstrate hot spots for dominant perforator location within 5–10 cm from the inferior gluteal crease with smaller hot spots in the upper lateral and distal posterior midline. Importantly, there were no differences in perforasome territories of proximal and distal perforators [7].

H. F. Mayer (ed.), *Breast Reconstruction*, https://doi.org/10.1007/978-3-030-34603-4_27

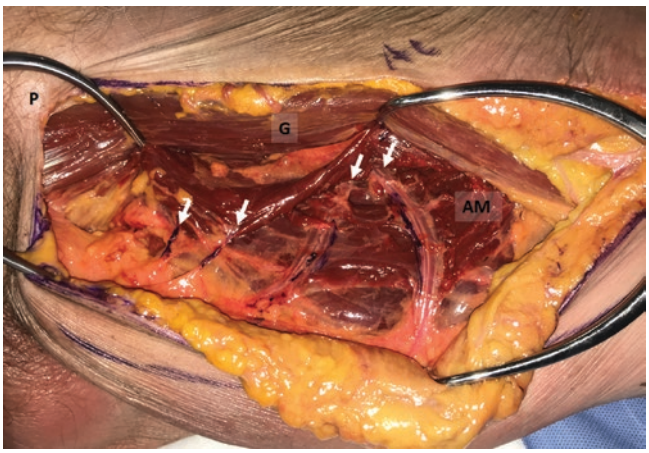

Fig. 27.1 Cadaveric dissection demonstrating four perforators exiting the adductor longus muscle. The pubic tubercle (P), adductor longus, and gracilis muscle (G) are identified, and dissection carried out subfascially over the adductor magnus (AM), where fascial exit of four perforators (white arrows) was identified. The most distal perforator is seen joining the third perforator and exits approximately 11 cm from the gluteal fold

Based on these and our own anatomic (Fig. 27.1) and imaging studies, our current flap design is centered on the location of the dominant perforator, which influences the choice for transverse, vertical, S-shaped, or oblique design. Vertically or obliquely shaped flaps additionally may allow for incorporation of more than one perforator if additional perfusion is desired for larger flaps. Adoption of the vertically oriented PAP flap has been used by St. Hilaire et al. for applications including not only breast reconstruction but also head and neck and lower extremity reconstruction [11].

Perfusion of the flap should be considered based on its perforator angiosome given the segmental nature of blood supply to the posterior thigh. Perfusion studies of circumferential thigh flaps harvested from 10 cadavers demonstrated perfusion zones of 16.7 cm × 16.5 cm (8812 cm^2) in horizontal and vertical dimension, respectively, suggesting perfusion extends lower than traditional transverse flap design [12].

Patient Selection

Indications for PAP flap use in autologous breast reconstruction are broad. Ideal candidates have body fat predominantly centered below the waist and in the upper medial thigh. Women with this body type may have a pear-shaped figure. Women who do not have abdominal tissue available due to lack of body fat, previous abdominal surgery, or abdominal liposuction may be better candidates for thigh or buttock-based flaps. Patient preference is an important additional consideration in terms of donor-site scars.

The nature and location of transverse, vertical, or oblique medial thigh scars can be designed along traditional approaches of aesthetic vertical or transverse medial thigh lift techniques with slight modifications. The planned donor-site scar should be discussed with the patient as part of the preoperative consultation. Finally, all patients should undergo preoperative imaging by magnetic resonance angiography (MRA) or computed tomography angiography (CTA) to identify the presence and location of suitable perforators.

Preoperative Planning

Once a patient is selected to undergo breast reconstruction with the PAP flap, preoperative planning begins with imaging to identify dominant perforators for flap harvest. Our preferred imaging technique is MRA, due to superior image quality and ease of mapping intramuscular perforator course; CTA alternatively may be used if MRA is unavailable or otherwise contraindicated (Fig. 27.2). Perforators off the profunda femoris are mapped in reference to the distance distal to the gluteal fold and posterior to the posterior border of the gracilis muscle. For a transverse PAP flap, proximal perforators are chosen, generally within 3–6 cm of the gluteal crease. For a vertical or oblique PAP flap, more distal perforators are generally chosen and the flap oriented accordingly.

Transverse PAP Design

Preoperative markings are performed the day before surgery in the office (Fig. 27.3a). Markings begin with the patient standing and the inferior gluteal crease is marked. The superior flap border is marked 1 cm inferior to the gluteal crease. A pinch test is performed to determine the width of the flap, generally 6–7 cm, and a second mark is made distal to the first line, denoting the inferior border of the flap. The patient is then moved to a supine position with the thigh abducted. The anterior extent of the flap is then marked, medial to the femoral triangle and just posterior to the adductor longus muscle. A crescent-shaped design is then marked approximately 26 cm × 7 cm. The perforator location is then identified and marked based on preoperative mapping of its predicted location and confirmed with a handheld Doppler. The medial perforator has been favored traditionally based on its location and ease of harvest [4]. Perforator location can be confirmed also in the prone position. The key perforator for a transverse flap is generally 3–6 cm below the gluteal crease and within 4 cm of the posterior border of the gracilis.

Vertical PAP Design

When key perforators are predicted to be more inferiorly located or a patient demonstrates medial thigh laxity in the transverse plane, a vertical or oblique flap design may be preferred. Design of a vertical flap generally results in a scar slightly posterior to the standard location of an aesthetic vertical thigh lift incision (Fig. 27.3b). Markings start again with demarcation of the gluteal crease. With the thigh in

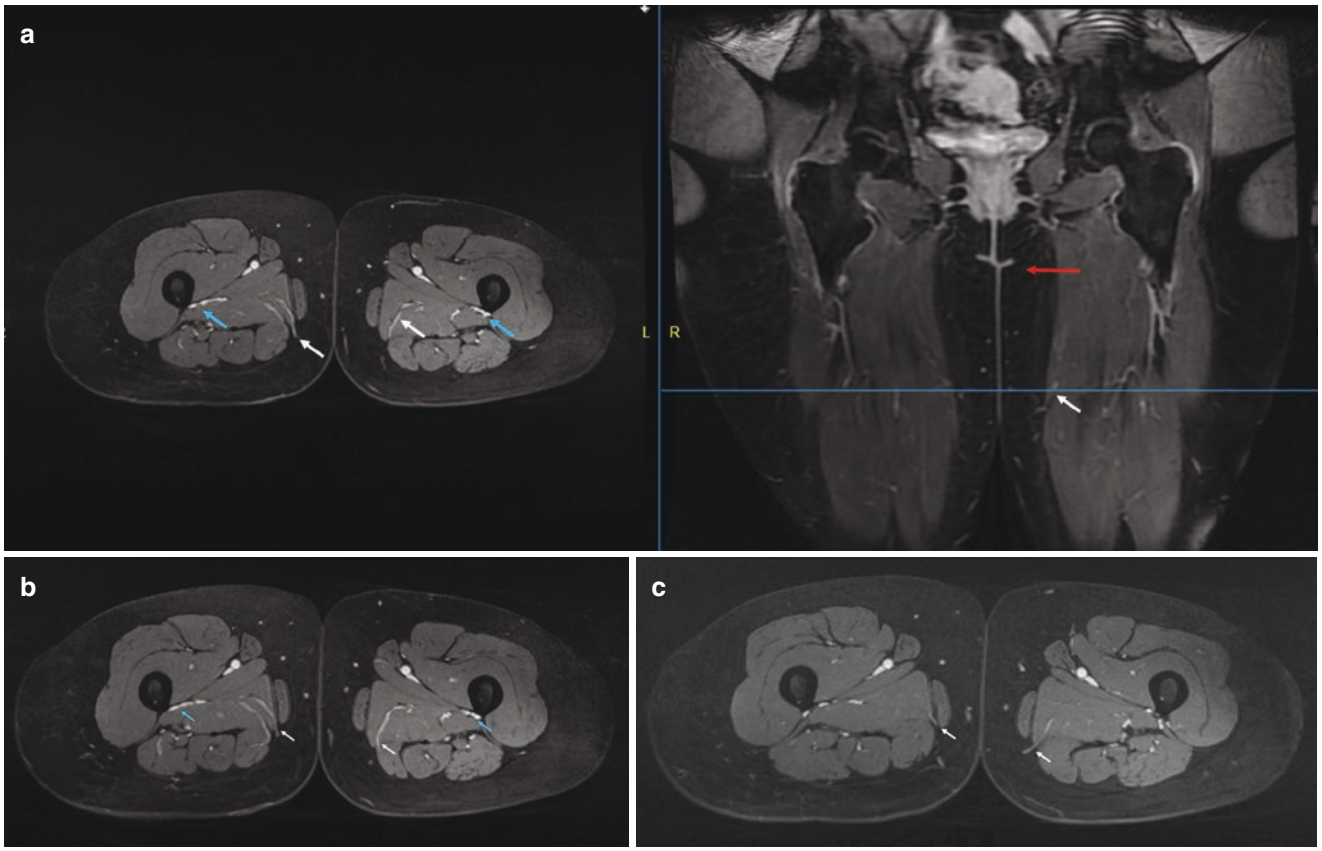

Fig. 27.2 Magnetic resonance angiography (MRA) for preoperative identification of profunda artery perforators. Perforators (white arrows) can be seen branching off the profunda artery (blue arrows), traversing adductor magnus muscle, and exiting adductor fascia posterior to the gracilis muscle. Axial images are used for perforator selection and can be correlated to coronal slices (**a**) to determine the location of perforator exit relative to the gluteal crease (red arrow). Axial images can be used to identify additional more distal perforators entering the posterior thigh (**b**, **c**)

abduction, the tendon of the adductor longus muscle is identified at its insertion on the pubic tubercle. The gracilis borders are identified medial to the adductor longus. The key perforator is then identified based on predicted location from preoperative imaging and confirmed by handheld Doppler. A series of perforators may be identified posterior to the gracilis, defining the axis of the flap. The anterior border of the flap follows the posterior gracilis border. The posterior border is then estimated based on a pinch test to estimate the maximal amount of tissue that can be safely taken, generally a maximum of 6–7 cm. It is important to avoid making the anterior border of the flap too anterior, resulting in missing the perforators or requiring a prohibitively wide flap and resultant tight skin closure.

Surgical Technique

The patient is placed in the lithotomy position, and the lower extremities are prepped into the field. Alternatively, the patient may be placed supine with thighs abducted in a "frog-leg" position; our team has adopted the lithotomy position to allow for easier donor-site closure. A two-team approach is then used throughout the case for simultaneous exposure of recipient vessels with flap harvest.

A video showing the preoperative marking and flap harvest is available as supplemental digital content (Video 27.1).

Transverse PAP Harvest

For the transverse PAP flap, the anterior incision is made and deepened down to deep thigh fascia (Fig. 27.4). Beveling is avoided along the superior incision to prevent hollowing of ischial fat pads and interfering with normal gluteal contour; inferiorly, slight beveling may be performed depending on desired flap volume and perforator location. Anteriorly, the femoral triangle is avoided. The flap is then elevated anterior to posterior superficial to fascia until reaching the posterior border of the gracilis muscle, at which point the fascia is incised. Dissection is then carried out deep to fascia of the gracilis and adductor magnus. Subfascial dissection is continued until the key perforator is identified at which point intramuscular dissection is performed until reaching the origin of the perforator off of the profunda femoris artery. Average pedicle length is 8–12 cm. Once the perforator is

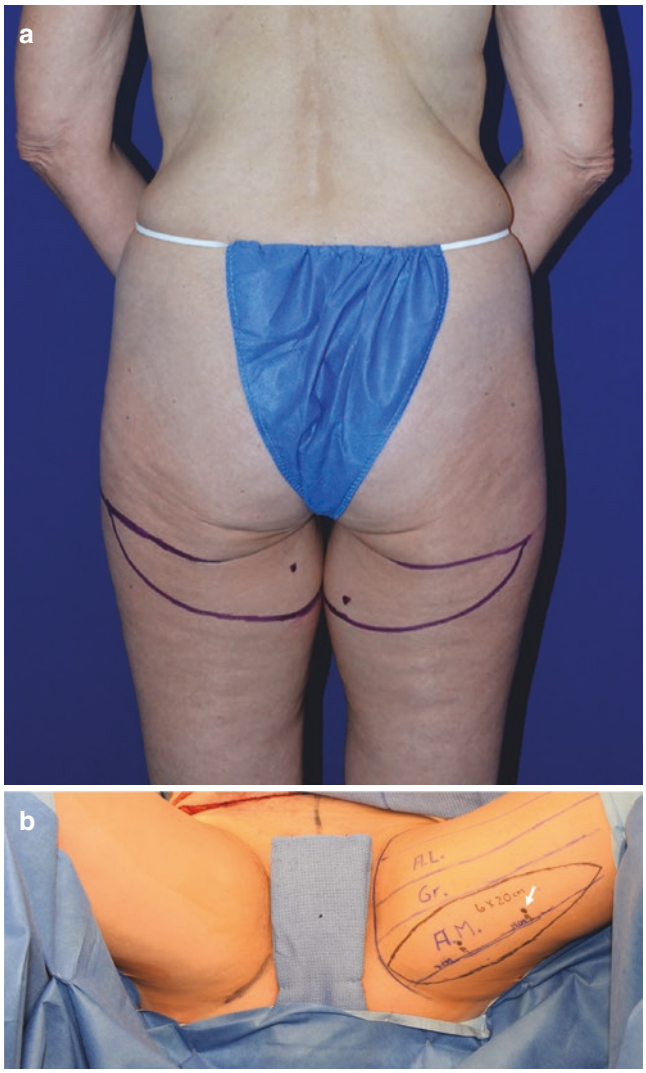

Fig. 27.3 Flap markings for transverse PAP flap (**a**) and vertical PAP flap (**b**) design. Transverse PAP flap markings are marked with superior border within 1 cm of the gluteal crease, lower border 6–7 cm inferior to the superior border, extending laterally to the border of the crease and medially to the medial aspect of the femoral triangle. The vertical PAP flap can be marked pre- or intraoperatively. Shown in **b** is intraoperative flap markings, with the anterior border of the flap centered along the posterior border of the gracilis muscle (G) and flap centered along a vertical axis of perforator exit from the adductor muscle (AM). The most distal perforator is 14 cm distal to the gluteal fold (white arrow)

captured, posterior incisions are completed and the flap is isolated. The thigh is then closed in layers over a closed suction drain. The flap may be coned for creation of one breast or stacked with the contralateral PAP or another flap such as the DIEP for volume enhancement [13]. The internal mammary vessels are the most common recipient vessel.

Vertical PAP Harvest

For the vertical, oblique, or S-shaped design, the anterior incision is made along the posterior edge of the gracilis muscle (Fig. 27.5). The incision is deepened to fascia and beveled anteriorly to capture additional fat if desired. The saphenous vein lies anteriorly and should be preserved. Once the posterior border of the gracilis muscle is identified, the fascia is vertically incised and dissection is carried deep to fascia of the adductor magnus. The key perforator is identified in addition to proximal and distal perforators. If more than one perforator is maintained with the flap, intra-flap perforator anastomosis may be performed to a side branch of the dominant perforator. Intramuscular dissection is performed, and the perforator is dissected back to the source vessel. The posterior incision is made and flap isolated. Because the profunda gives a segmental blood supply to the posteromedial thigh, ICG angiography may be used at this point to confirm the angiosome territory. Similar as for the transverse design, the thigh is then closed in layers over a closed suction drain. The flap may be coned for creation of one breast or stacked with another flap for volume enhancement. The internal mammary vessels are the most common recipient vessel. The flap may be sensitized based on branches of the posterior femoral cutaneous nerve found in the subfascial plane of the posterior mid-thigh.

Technical Variations

Skin paddle design may vary based on the nature and location of the patient's fat distribution, skin laxity, and key perforator location. For women with horizontal laxity, a vertical pattern may be desirable. For patients with upper medial thigh fat predominance with vertical laxity or desire for scar following the gluteal fold, a transverse pattern may be chosen. After massive weight loss or to capture more volume, a fleur-de-lis pattern may be chosen.

Postoperative Care

Standard postoperative free flap monitoring is performed. The patient is able to ambulate by the first postoperative day. Compressive garments may be applied to help with postoperative swelling to the thigh. The drains may be removed after they put out less than 30 cc a day for 2 consecutive days. Strenuous exercise may be started at week 6.

Postoperative complications with flap vascularity are rare. Occasionally fat necrosis may be seen in distal tips of the flap furthest from the perforator angiosome. The segmental nature of posteromedial thigh vascularity should be respected during flap harvest, and perfusion can be studied intraoperatively with ICG angiography to avoid potential fat necrosis. Unfavorable donor-site complications may occur as a result of tension or tight closure, resulting in dehiscence and secondary intention healing. Complications reported by Allen et al. in a report of 164 consecutive PAP

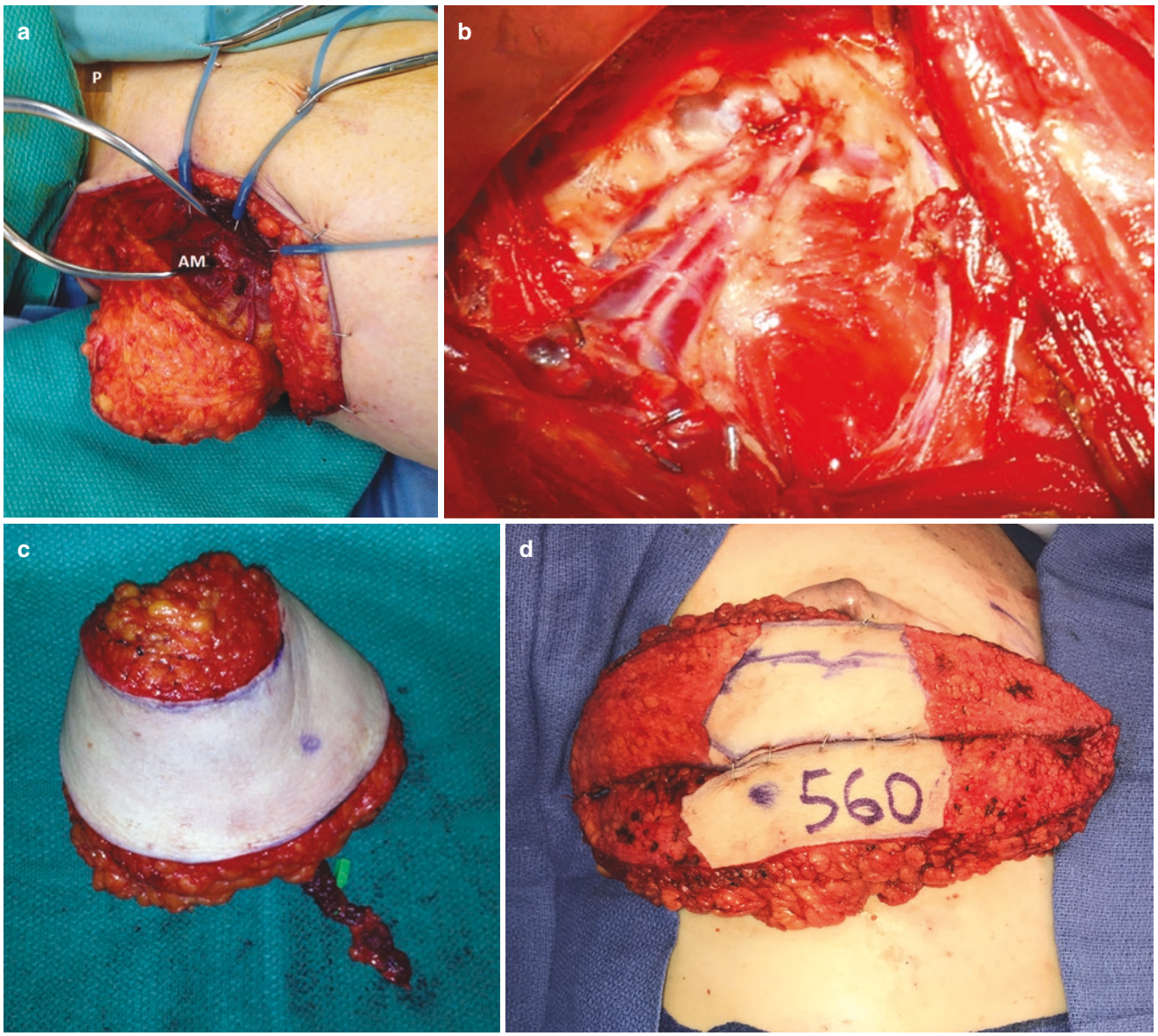

Fig. 27.4 Transverse PAP flap harvest. The pubic tubercle (P) and adductor magnus (AM) muscle is marked. The flap is harvested anteriorly to posteriorly along a crescent centered just below the gluteal crease, capturing proximal perforators. The anterior incision is made medial to the femoral triangle and dissection carried subfascial once reaching the posterior border of the gracilis muscle. The perforator is identified exiting the fascia of the adductor magnus muscle (**a**, **b**). Intramuscular dissection is performed and the posterior incisions completed. Once harvested, the flap may be coned to re-create the projection and appearance of the breast (**c**). The flap also may be stacked for volume augmentation and shape. (**d**) Stacked PAP flap with anastomosis to antegrade and retrograde internal mammary vessels in unilateral breast reconstruction. (**e**) Stacked DIEP-PAP flap with intra-flap anastomosis

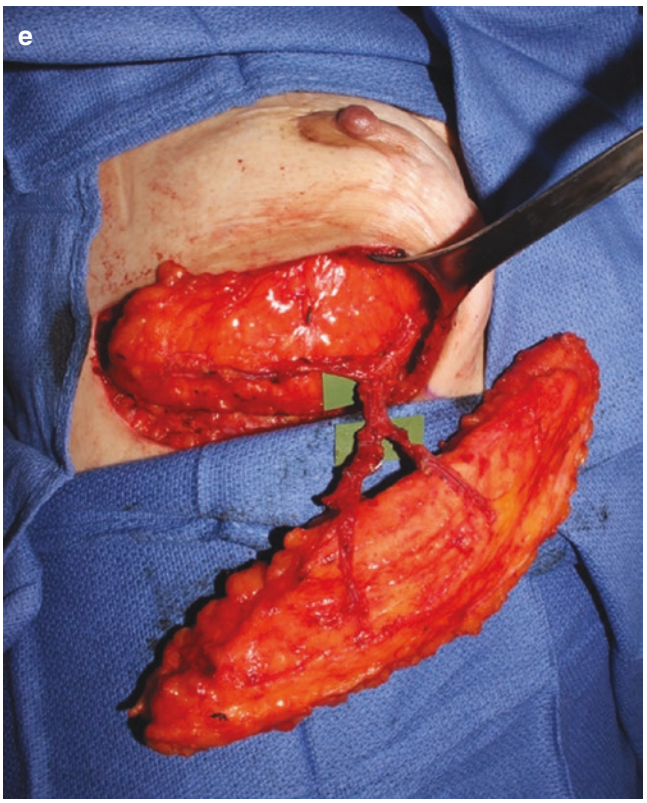

Fig. 27.4 (continued)

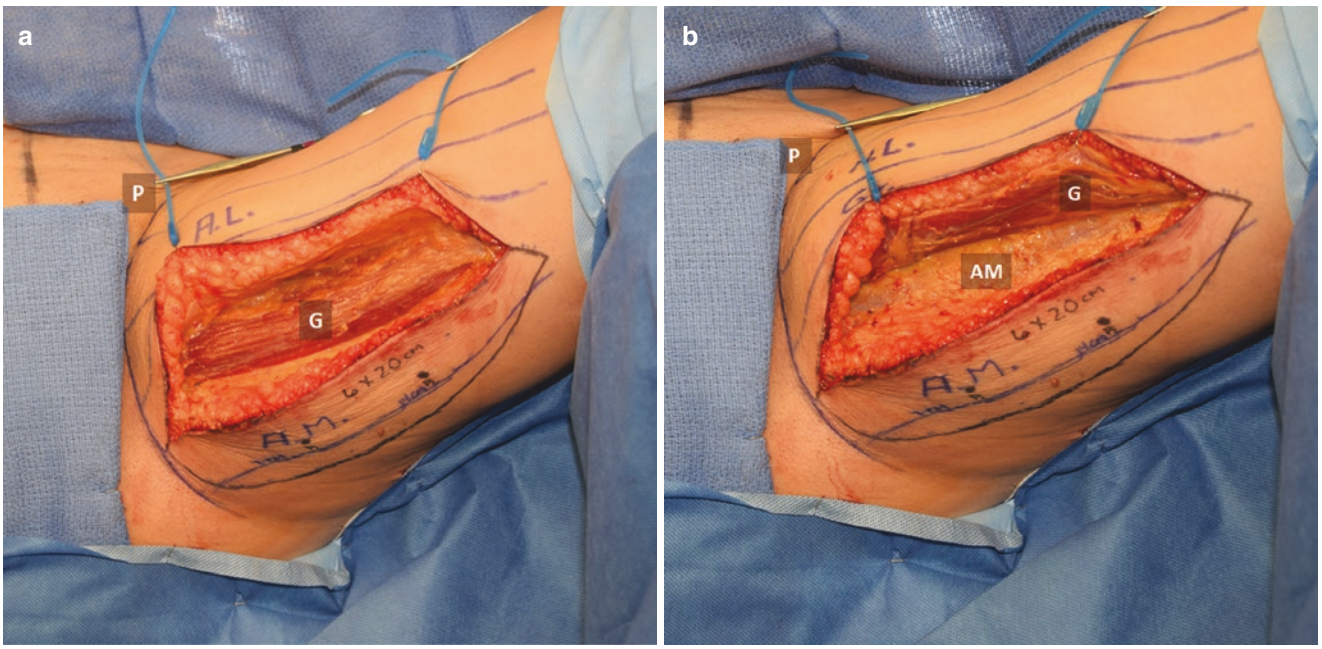

Fig. 27.5 Vertical PAP flap harvest. The pubic tubercle (P), adductor longus (AL), and gracilis (G) muscle borders are marked. Incision is made along the posterior border of gracilis (G) and carried down to the deep fascia (**a**). The gracilis muscle is elevated and adductor magnus (AM) identified (**b**). Dissection is carried out in the subfascial plane over adductor magnus and perforating vessels identified. Intramuscular dissection is carried out back to the takeoff of the perforator from the profunda femoris (**c**). The thigh is closed in layers over a closed suction drain (**d**). Dimensions of the vertical flap are 20 × 6 cm (**e**)

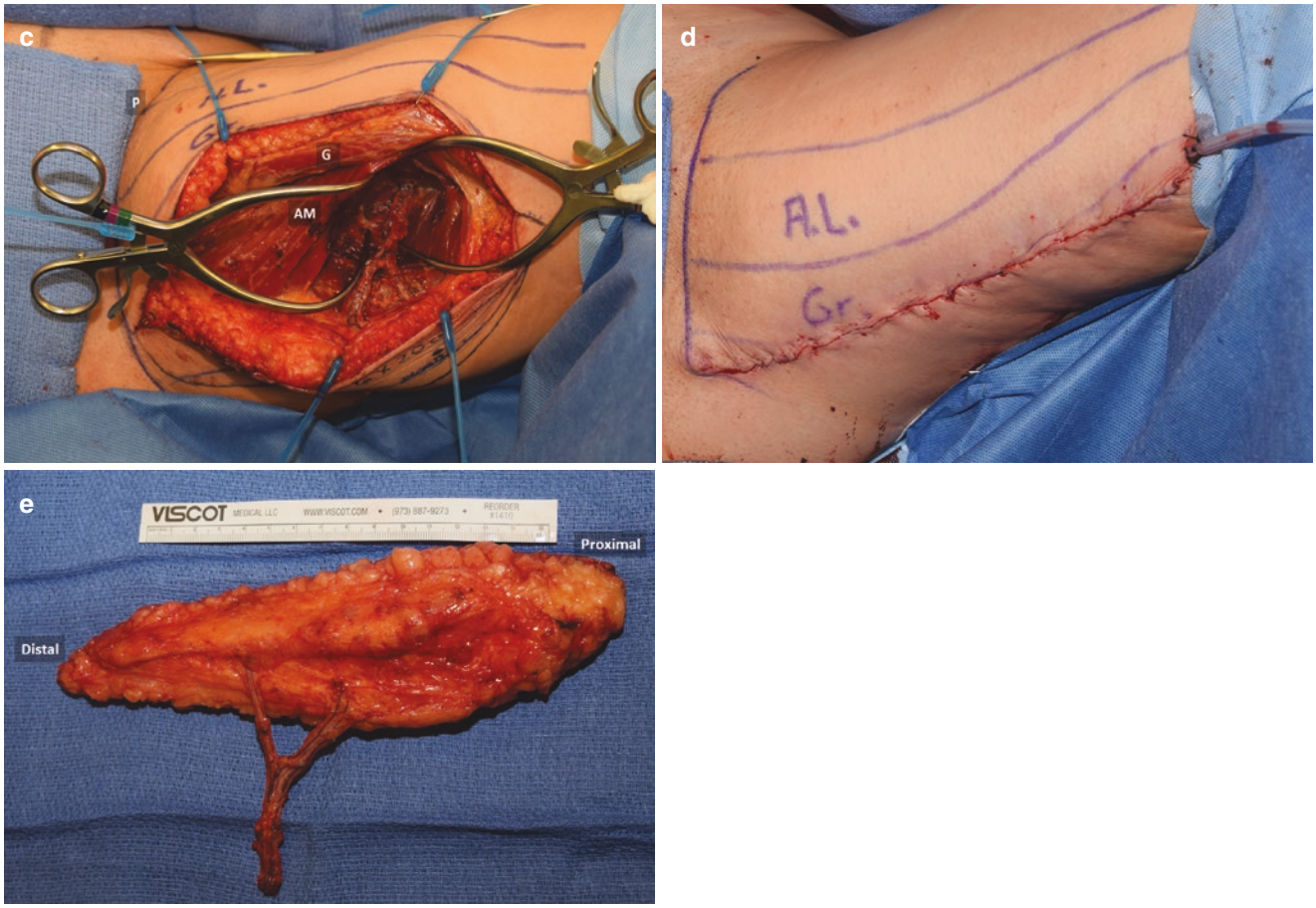

Fig. 27.5 (continued)

flaps include fate necrosis (7%), flap loss (<1%), seroma (6%), hematoma (1.9%), and hematoma (1.9%) [14–16]. There were no secondary operations performed for thigh contouring [4]. The possibility of injury to the posterior femoral cutaneous nerve is present and avoided by supra-fascial dissection in the mid-thigh once the key perforator is identified.

Clinical Cases

Case 1

A patient with BRCA1 gene mutation who underwent bilateral nipple-sparing mastectomy and immediate reconstruction with bilateral transverse PAP flap (Fig. 27.6).

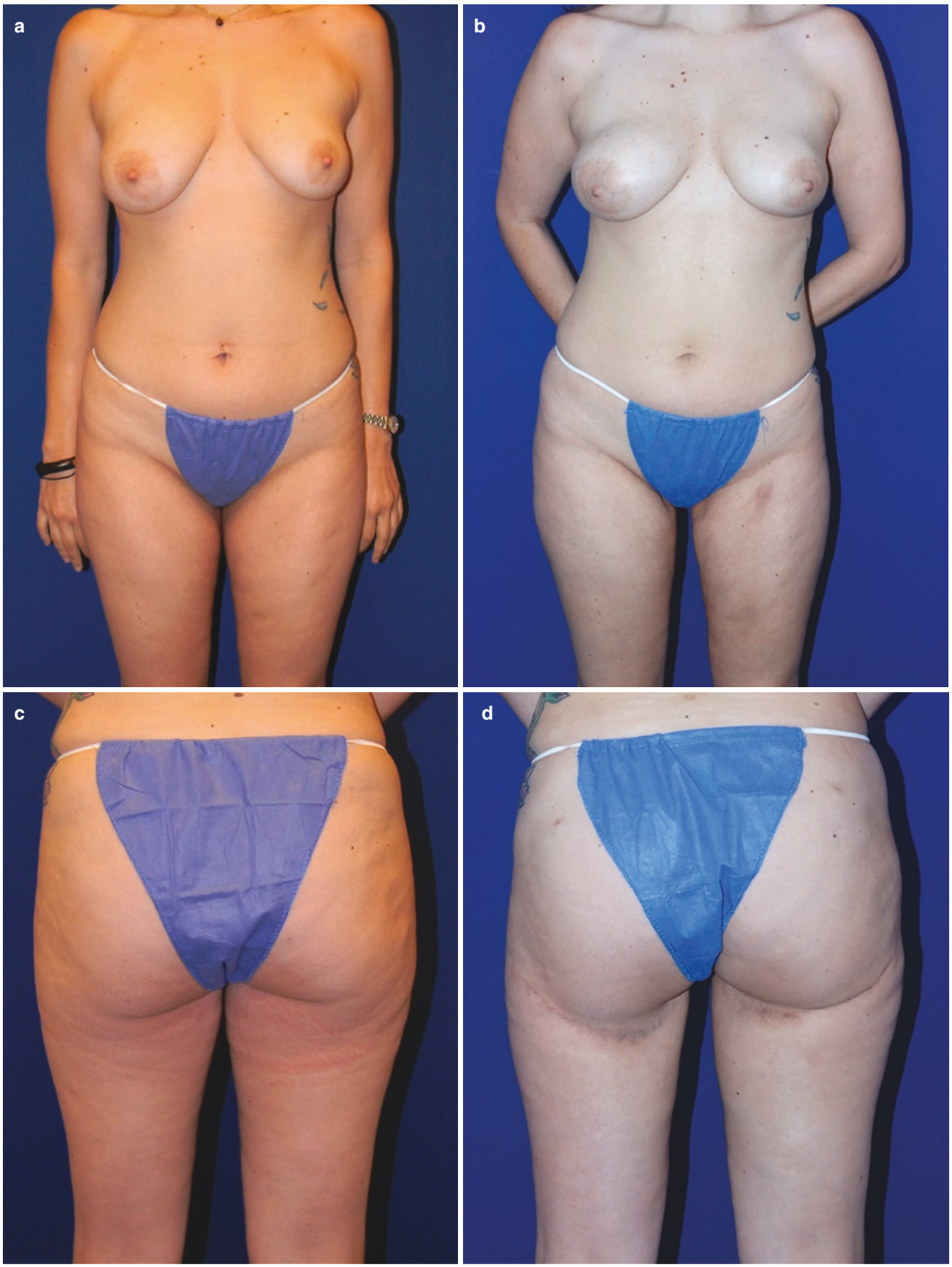

Fig. 27.6 A patient with BRCA1 treated with nipple-sparing mastectomy and transverse PAP flap reconstruction. (**a**, **c**) Preoperative. (**b**, **d**) Postoperative

Case 2

A patient with history of right partial mastectomy and radiation for breast cancer presenting several years later with a second right breast cancer. She additionally had been previously treated for endocervical cancer with hysterectomy, lymphadenectomy, and adjuvant radiation therapy. She was treated with bilateral nipple-sparing mastectomy and immediate transverse PAP flap reconstruction (Fig. 27.7).

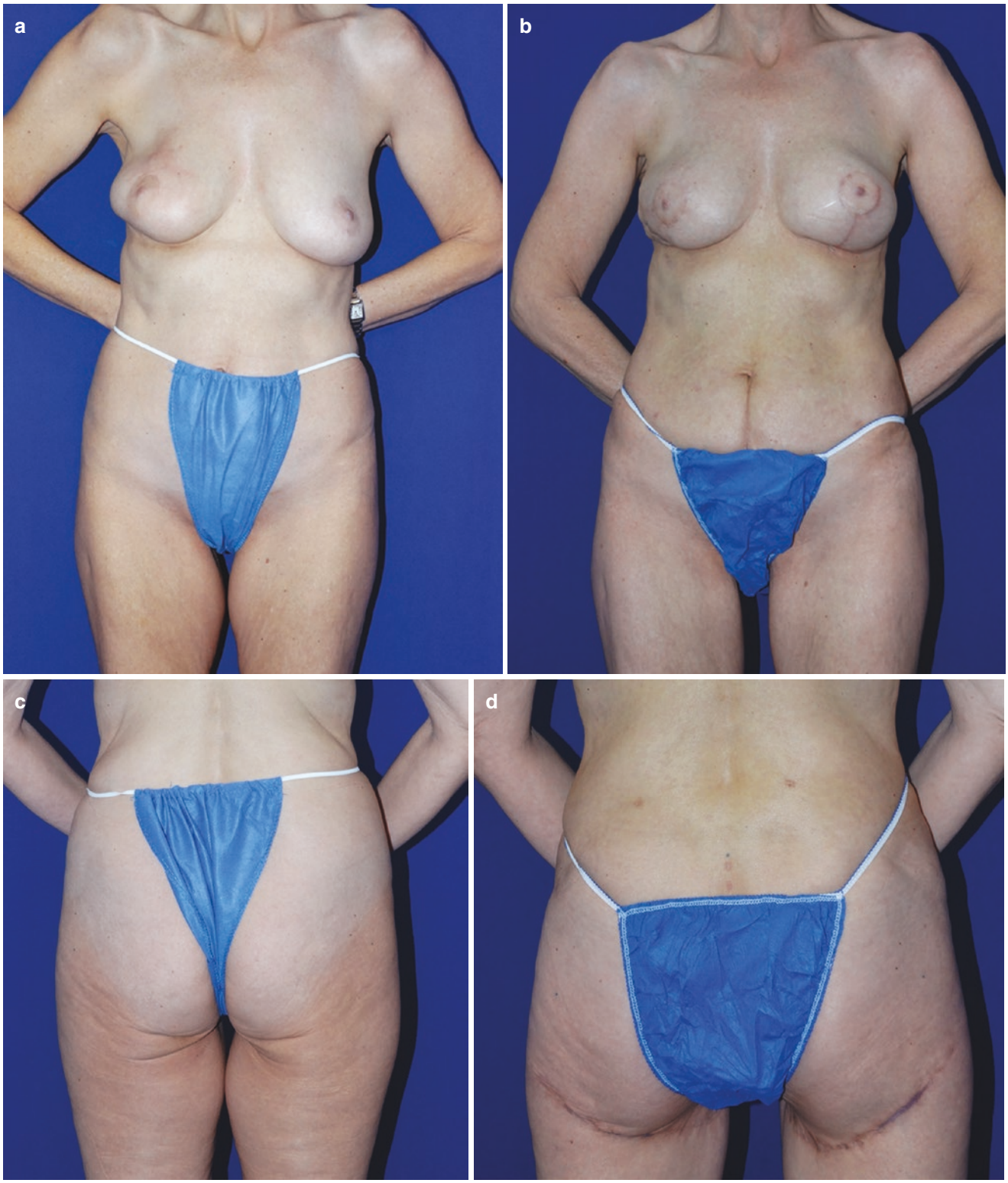

Fig. 27.7 A patient with history of right partial mastectomy and radiation and new right breast cancer treated with bilateral mastectomy and transverse PAP flap reconstruction. (**a**, **c**) Preoperative. (**b**, **d**) Postoperative

Case 3

A patient with history of left breast cancer for which she was treated with mastectomy and DIEP flap reconstruction. Several years later, she presented with a high-risk gene mutation for which she underwent nipple-sparing prophylactic mastectomy and immediate stacked vertical PAP reconstruction (Fig. 27.8).

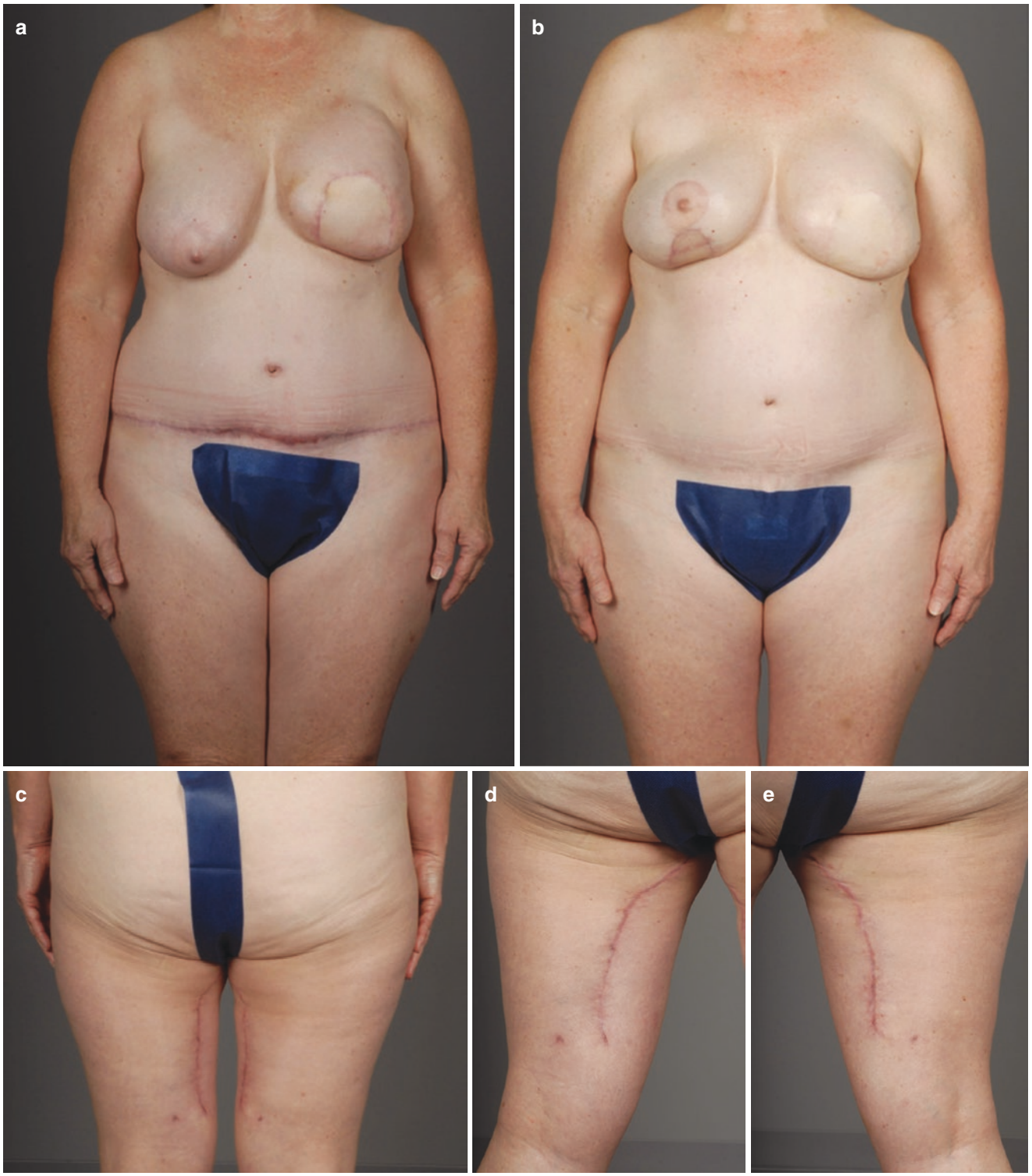

Fig. 27.8 A patient with history of left mastectomy and stacked DIEP reconstruction now treated for genetic high risk with prophylactic mastectomy and stacked PAP vertical flap reconstruction. (**a**) Preoperative photo; note history of left DIEP flap. (**b**) Postoperative. (**c**–**e**) Postoperative posterior thigh views

Case 4

A patient with left breast cancer treated with bilateral mastectomy and stacked bilateral DIEP-PAP flap reconstruction. The pedicle for the PAP flap was anastomosed to a branch of DIEP and the entire flap inset to allow the DIEP flap to reconstruct the superior pole and the PAP flap to fill out the lower pole (Fig. 27.9).

Conclusions

The PAP flap has become an accepted secondary option for autologous breast reconstruction when the abdomen is not available for use. The flap provides a long pedicle, excellent vessel diameter and match to common recipient sites. Preoperative imaging should be used to guide perforator selection and flap design. The dominant perforator is vari-

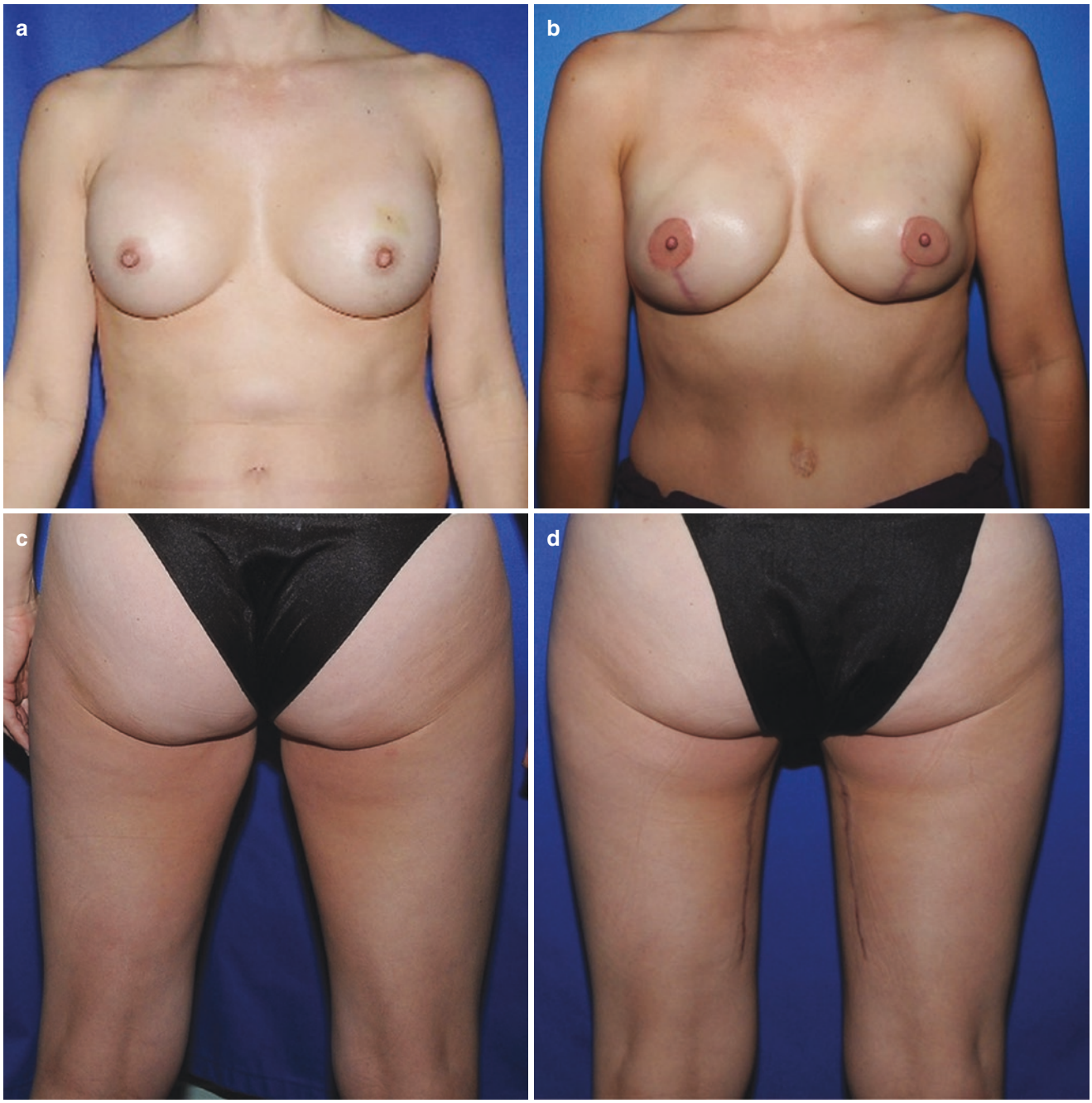

Fig. 27.9 A patient with left breast cancer treated with mastectomy and bilateral stacked DIEP-vertical PAP flap reconstruction. (**a**, **c**) Preoperative. (**b**, **d**) Postoperative

able and patient-specific. Flap design can be tailored to volume requirements and aesthetic principles to guide optimal outcomes. Donor-site morbidity is low, and scarring is well concealed in the gluteal fold or medial thigh. Given its reliable blood supply and ability to cone or stack flaps for creation of a natural-appearing breast, the PAP flap is an excellent choice for breast reconstruction in selected patients.

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Breast Reconstruction with Perforator Flap Transplants from Identical Twins

28

Thais O. Polanco, Robert J. Allen Jr., and Robert J. Allen Sr.

Introduction

Many technical advances in the field of microvascular surgery have surfaced since the advent of the first successful kidney transplantation, performed by the plastic surgeon Dr. Joseph Murray in 1954 [1]. Identical twin transplantation, also known as syngeneic isotransplantation, has the advantage of transferring tissue without immunologic barriers, thus not subjecting patients to the adverse events secondary to immunosuppressive drugs and of rejection [2]. Numerous organs and tissues have been effectively transplanted among identical twins. Examples include the small bowel, hematopoietic cells, ovarian cortical tissue, liver, pancreas, full thickness skin grafts, bladder mucosa, and perforator breast flaps [3–9].

Over the last few decades, autogenous breast reconstruction techniques have evolved to achieve goals of acceptable morbidity and superior aesthetic outcomes. Autologous tissue for breast reconstruction can be transferred either on a pedicle or as a perforator free flap from various donor sites. Koshima and Soeda first reported the clinical use of perforator flaps in 1989 [10–11]. The flap was based on a single paraumbilical perforator from the deep inferior epigastric artery – only harvesting skin and fatty tissue, without sacrificing rectus muscle [10]. The use of superficial inferior epigastric artery (SIEA) and deep inferior epigastric artery perforator (DIEP) flaps for autologous breast reconstruction was then reported by Allen in 1989 and 1992, respectively [11–12].

Perforator free flaps, specifically the DIEP flap, have become the gold standard for autologous breast reconstruction, as it results in less donor-site morbidity and excellent aesthetic results compared to the traditional transverse rectus abdominis musculocutaneous (TRAM) flap [13–15]. Unlike TRAM flaps, perforator flaps leave the abdominal musculature intact, resulting in decreased donor-site morbidity [16]. Other advantages include decreased pain, quicker recovery, preservation of abdominal wall function, lower incidence of hernia, shorter hospital stay, and decreased cost [16–18].

Challenges in some patients include failed implant reconstruction, history of previous abdominal surgeries, and thin body habitus. When situations such as these arise, it is feasible to perform a perforator free flap transplantation in monozygotic twins. In 2008, Allen Jr. et al. reported for the very first time the use of free flap transplantation as a new option for breast reconstruction including cases of DIEP and SIEA flaps [9]. More recently, Hazani et al. described a case of the simultaneous transplantation of both autogenous and syngeneic DIEP flaps for bilateral breast reconstruction in a patient with an identical twin [19].

In this chapter, we review our unique clinical experience in breast reconstruction with transplantation of perforator flaps from one identical twin to another [9].

Anatomy

The skin and fat of the lower abdominal wall is lax with zones of adherence at the linea alba and at the umbilicus. The soft consistency of the fat is ideal for breast reconstruction, as it gives a soft, natural reconstruction. The blood supply to the lower abdominal wall arises from the deep inferior epigastric arteries which branch from the external iliac arteries. The DIEP flap is based on the perforating vessels that originate from the deep inferior epigastric system.

Accurate knowledge of the perforator topography was obtained via preoperative imaging. The largest perforator vessels were chosen preoperatively and then mapped on an *X–Y* axis. These perforators travel through or around the rectus abdominis muscle, pierce the anterior rectus sheath, and

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supply the overlying skin and fat. During DIEP flap surgery, the lower abdominal soft tissue is mobilized on one or more perforators in preparation for free tissue transfer.

Patient Selection

First, it is essential to determine that the twins are monozygotic and, second, to discuss the potential of the donor twin to develop breast cancer in the future. To ensure that these twins are monozygotic, genetic testing is performed for all cases. Twinning incidence has increased by 76% over the last three decades, [20–21] with additional increase in monozygotic twins [22]. Additionally, twin pregnancies after in vitro fertilization have also increased from 2 to 12 times the population incidence of 0.4% [23–25].

Patients are also genetically tested for BRCA1 and BRCA2 mutations, and donor twins are counseled on breast reconstruction options if they subsequently developed breast cancer requiring post-mastectomy reconstruction. In a study by Mack and Peto, monozygotic twins of breast cancer patients were found to have an annual risk of developing breast cancer of 1.31%, with the 20-year risk of developing breast cancer for twin to be 24% [26]. Furthermore, a study from 2016 reported the lifetime cumulative incidence of 8.1% for a monozygotic twin of a breast cancer patient to develop breast cancer [27].

The additional reconstructive options that patients are informed about in the event they needed post-mastectomy breast reconstruction are gluteal artery perforator flaps (when available), anterolateral thigh flaps, lateral thigh perforator flaps, latissimus dorsi flaps, and implant/expander reconstruction. Of the options presented, the patients presented in this chapter chose DIEP/SIEA transplants from their sisters.

Preoperative Planning

All patient underwent an extended preoperative consultation to delineate goals, explain alternatives, discuss expectations, review potential complications, and additionally DNA testing. Various methods of autologous breast reconstruction were described and offered to all the patients. Of the variety of options, the patients chose to undergo DIEP/SIEA transplants from their sisters. After election of type of flap, routine presurgical testing including appropriate laboratory and diagnostic studies and anesthesia consultation were obtained. Due to the highly variable anatomy of the deep inferior epigastric artery with regard to location, course, and caliber, a computed tomographic angiography or magnetic resonance angiogram was used to provide a roadmap of vessels prior to surgery for all cases.

Surgical Technique

Patients were marked preoperatively in the standing position for the anatomic landmarks on the breast and abdomen. The key perforators are then also marked according to the findings of the CTA or MRA in the donor twin with the patient in the supine position.

Both sisters were taken to separate operating rooms for the procedure. Simultaneous abdominal flap harvesting and preparation of the recipient twin chest wall vasculature were performed in a two-team approach.

Harvesting of the DIEP flap begins with an incision at the upper marked line. Dissection proceeds down to the anterior fascia before elevation of a superior abdominal wall flap to the costal margins and xyphoid process. Next, the inferior incision is made. The superficial system is investigated and, if adequate, an SIEA flap is chosen for reconstruction. If the superficial system is inadequate, a DIEP flap is chosen and dissection proceeds in the suprafacial plane to identify the best perforator as seen on preoperative imaging. Once the largest perforator has been identified, the fascia is opened around this perforator and a standard perforator dissection proceeds with sparing of the rectus muscle and accompanying motor nerves. Dissection continues until adequate length of the pedicle is obtained and/or until adequate caliber vessels are encountered.

The harvested flap is then transferred to the recipient twins anterior chest wall and temporarily secured in position. The internal mammary system is our first choice for recipient vessels in the chest; however, the thoracodorsal vessels may also be used. The internal mammary vessels are usually approached at the second interspace between the second and third costal cartilages. An end-to-end venous anastomosis is performed with a venous-coupling device. The end-to-end arterial anastomosis is hand-sewn with 9-0 nylon sutures. The flap is then debulked as needed, contoured, and inset to achieve the desired breast size and shape. A closed suction drain is placed and brought out through the lateral edge of the skin closure or through a separate stab incision. We routinely leave a skin paddle for postoperative monitoring.

The closure of the donor twin abdomen begins as soon as the flap is harvested. The anterior rectus sheath is closed with two-layer running barbed suture. The remainder of the abdominal closure is in layered fashion. Abdominal plication is performed as needed. Two closed suction drains are placed in the abdomen and brought out through the lateral incision. The umbilicus is exteriorized and inset in the midline with absorbable sutures.

Postoperative Care

Standard, postoperative care and monitoring were done on all patients. No immunosuppressive drugs were required during any period of care for all patients. The patients were

monitored in the recovery room for 4 hours postoperatively. Flap checks are performed every 15–30 minutes during this time and consist of assessments of skin paddle color, temperature, capillary refill, and Doppler signals for the recipient twin. The recipient twin is then moved to a regular room, where flap checks are performed every 1 hour overnight and then every 4 hours while the patient remains hospitalized. Deep venous thrombosis prophylaxis and sequential compression devices are continued during hospitalization. The recipient twin is then discharged on postoperative days 3–4. After 4 weeks, patients are encouraged to resume their preoperative levels of activity. Moreover, the donor twins have a short hospital course and are discharged to home on postoperative day 2.

Clinical Cases

Case 1

The first transplantation for breast reconstruction was between a set of 46-year-old identical twin sisters. The recipient twin had undergone a right mastectomy in 1998 for stage II breast cancer. Immediate reconstruction at an outside hospital involved tissue expansion with subsequent silicone implant reconstruction and contralateral silicone breast augmentation for symmetry. After postoperative radiation therapy, the right silicone prosthesis became exposed, infected, and subsequently removed. The patient was an avid runner and had little excess abdominal or gluteal tissue, thus not making her a candidate for autologous breast reconstruction. Her identical twin sister was multiparous, 10 pounds heavier, and willing to offer her excess abdominal tissue for the reconstruction of her sister's breast.

On February 29, 2000, a team of two surgeons harvested abdominal tissue from the donor twin, and another team of surgeons prepared the breast pocket and the internal mammary vessels on the recipient twin. The flap was based on lateral row perforators. There, a sensory nerve was dissected for coaptation to make this a sensate flap. Once harvested, the flap was transferred to the adjacent operating room for reconstruction of her twin sister's right breast. The abdominal donor site was closed using a standard abdominoplasty closure. The DIEP flap was anastomosed microscopically to the recipient internal mammary vessels and the fourth intercostal nerve of the recipient twin. The breast flap was contoured and inset with a final weight of 505 g.

The donor twin tolerated the procedure well and was discharged to home from the hospital on postoperative day 2. The recipient twin had an uncomplicated postoperative course and was discharged to home on postoperative day 4.

Case 2

A second pair of identical twin sisters underwent a similar procedure for breast reconstruction in 2001. The recipient twin had a history of invasive carcinoma of the left breast treated with mastectomy and specifically desired autogenous breast reconstruction. However, the patient had previously undergone an abdominoplasty, making this donor site unavailable for breast reconstruction. Reconstruction with a gluteal artery perforator flap was discussed with the patient, but she wanted to avoid the morbidity involved in harvesting gluteal tissue and the potential for buttock asymmetry following unilateral reconstruction. Her identical twin sister was eager to donate her lower excess abdominal tissue for breast reconstruction.

On September 5, 2001, both sisters were taken to adjacent operating rooms for the operation. A sensate superficial inferior epigastric artery flap (1350 g) was harvested from the donor twin based on these vessels. Using an operative microscope, the superficial inferior artery and vein of the transplant flap were anastomosed end-to-end to the recipient internal mammary vessels. The sensory nerve from the flap was approximated to the fourth intercostal nerve to provide sensibility to the new breast. After contouring, the final flap weight of 855 g appeared symmetric to the right breast, which underwent a mastopexy at the time of flap insetting.

By postoperative day 5, the distal inferior lateral aspect of the flap showed signs of ischemia, at which time the patient was taken back to the operating room for debridement of 183 g of the flap. After this revision, the patient did very well and was discharged home the next day. The donor twin sister had an uncomplicated stay in the hospital and was discharged home on postoperative day 2.

Case 3

The final transplant procedure for breast reconstruction were between a set of 44-year-old identical twins. The recipient patient had a history of stage III ductal carcinoma of the left breast treated with modified radical mastectomy with immediate tissue expander placement followed by chemotherapy and radiation therapy. She later underwent a right prophylactic mastectomy with tissue expander reconstruction. After radiation therapy, the left expander became exposed, infected, and subsequently removed (Fig. 28.1). Additionally, the reconstructed right breast developed a symptomatic capsular contracture. The patient desired autogenous breast reconstruction; however, she was not a candidate due to a previous abdominoplasty. Discussing further surgical options, the patient expressed great concern over having any other area of her body subjected to surgical manipulation. Her identical

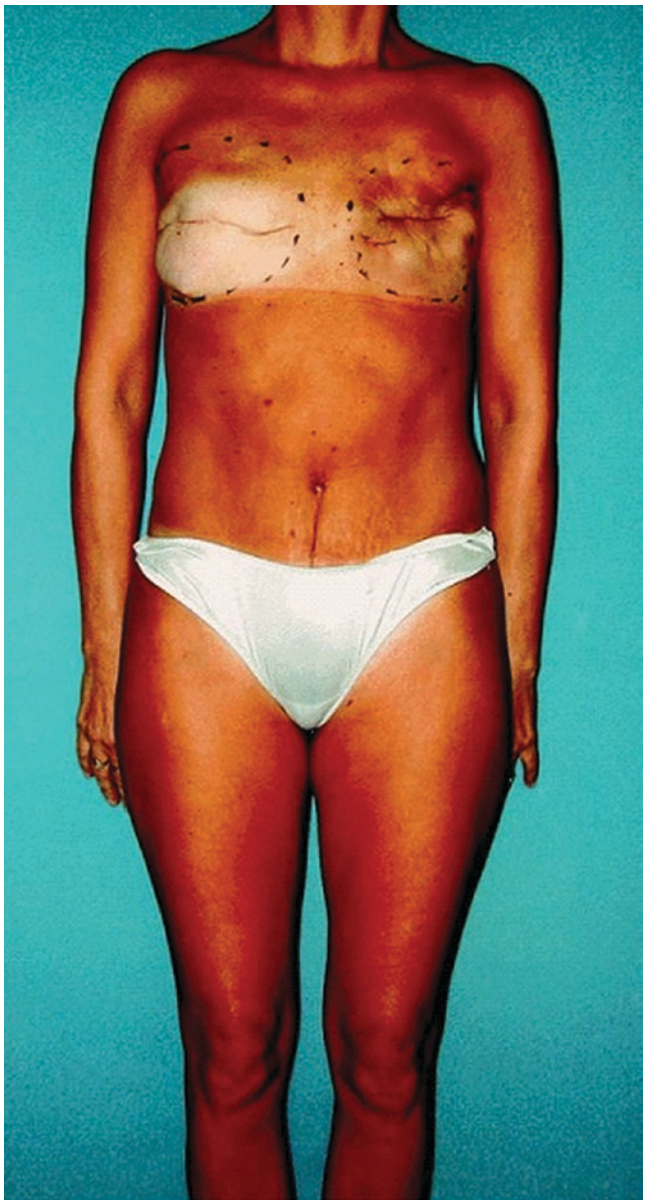

Fig. 28.1 Preoperative view of the recipient twin after bilateral mastectomy for left breast carcinoma. (Reprinted with permission from Allen et al. [9])

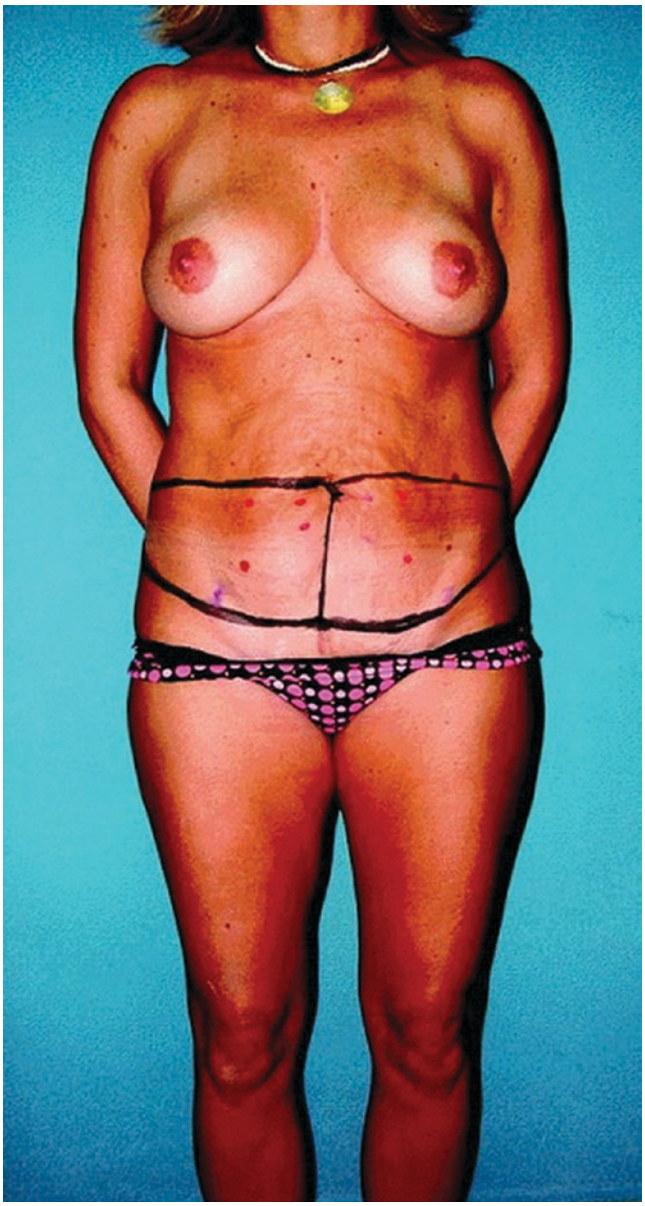

Fig. 28.2 Preoperative view of the donor twin before bilateral DIEP flap harvest. Incision lines are marked in black. Doppler signals of DIEP flap perforators are marked in red. (Reprinted with permission from Allen et al. [9])

twin sister was willing to donate her extra abdominal tissue for her sister's bilateral breast reconstruction (Fig. 28.2).

On October 17, 2006, both sisters were taken to separate operating rooms for transplantation. The donor twin underwent harvest of bilateral DIEP flaps for reconstruction of her sister's breasts. Both flaps were based on two medial row perforators. The initial flap weights were 460 and 408 g. A standard abdominoplasty closure was performed on the donor. Once the right breast expander was removed, the breast pockets and internal mammary vessels were prepared in the recipient twin. The left and right DIEP flaps from the donor twin were used to reconstruct the recipient twin sister's right and left breasts, respectively.

Both patients were discharged home on postoperative day 4 without complication. Of note, the recipient of the bilateral DIEP flap transplants had essentially no postoperative pain. The donor patient had the usual abdominoplasty postoperative pain.

Three months after the transplants, the twins returned for second-stage procedures (Fig. 28.3). The recipient twin required bilateral nipple reconstruction and left breast flap

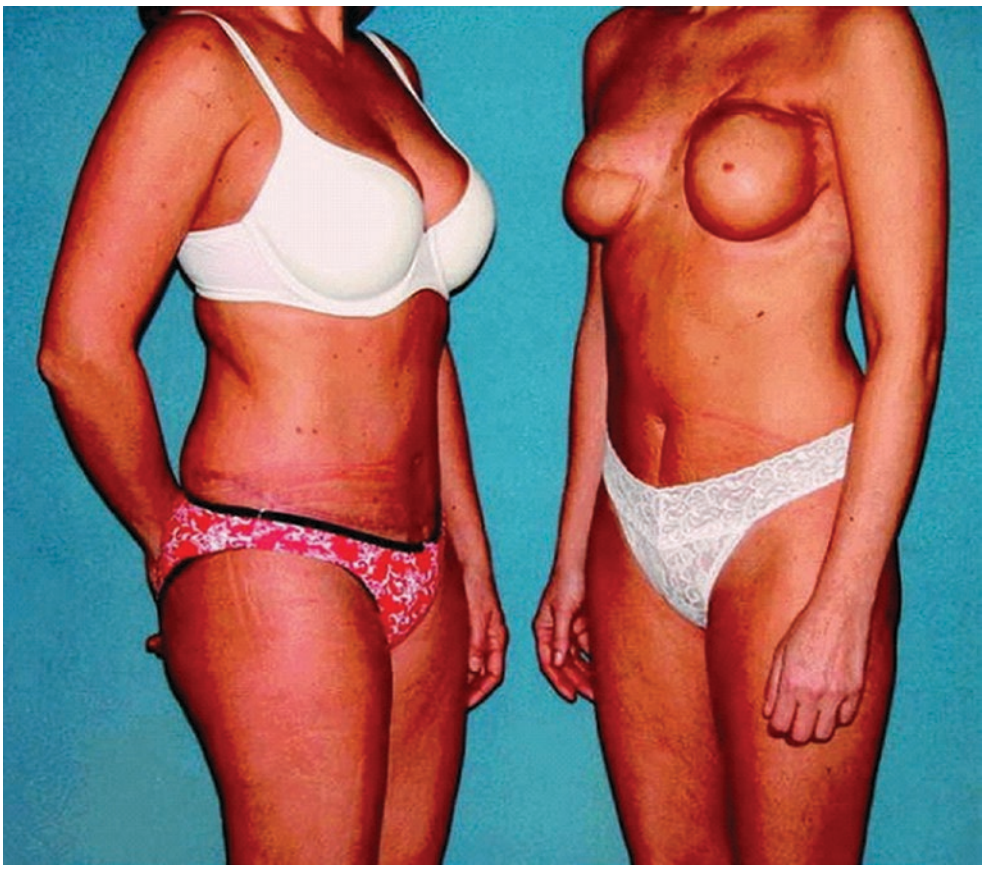

Fig. 28.3 View of the donor twin (left) and the recipient twin (right) 3 months after DIEP flap transplant for bilateral breast reconstruction. (Reprinted with permission from Allen et al. [9])

revisions because of contracture of the irradiated skin superiorly. The donor twin had mild dog-ear deformities bilaterally from her abdominoplasty. The decision was made to first harvest fat from the donor twin's lateral abdomen to correct for the dog-ear deformities and then to use this fat for lipoinfiltration of the recipient twin's contour defect of the left breast flap. Fat was harvested from the donor twin and processed with centrifugation, and 52 cc of processed lipoaspirate was injected around the superior and lateral borders of the recipient twin's left reconstructed breast. Both twins tolerated the procedures well and were discharged to home the same day. To our knowledge, this was the first-ever documented case of the transplant of fat cells between two humans for lipoinfiltration.

The recipient twin returned 1 year postoperatively for nipple–areola tattooing. Although we are unable to objectively determine the quantity of fat that has persisted from grafting to the recipient twin's left breast flap/chest wall, we estimate a 40% take at 11 months. Fourteen months after the initial procedures, both twins are very happy with their results (Fig. 28.4).

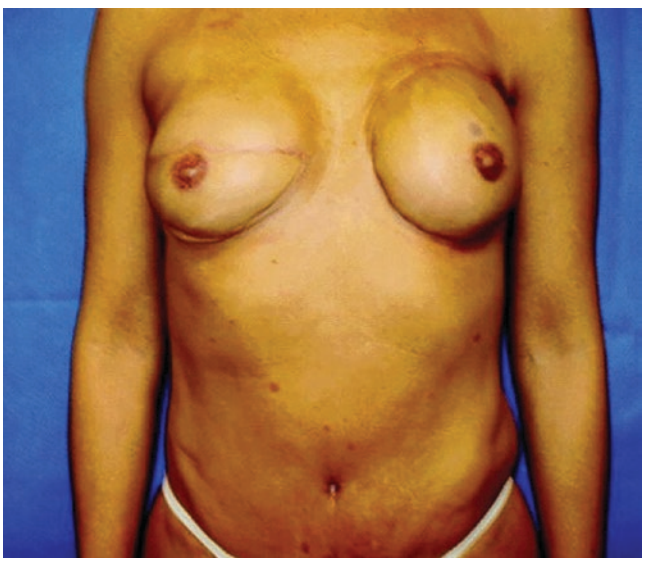

Fig. 28.4 Anteroposterior view of the recipient twin 14 months after DIEP transplant for bilateral breast reconstruction. (Reprinted with permission from Allen et al. [9])

Conclusions

For the reconstructive surgeon, the chance of encountering an identical twin is small; however, it remains an option to keep in mind. Transplantation of free flaps can become a realistic option in the future when the challenge of immune incompatibility is resolved and immunosuppression does not put the recipient in danger. The success of our cases demonstrates the potential for expanding the options of donor sites when the possibility of transplantation among monozygotic twins is available. This should be considered as a practical option in these complicated cases.

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Breast Reconstruction Using Scaffold-Based Tissue Engineering

29

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Introduction

Regenerative medicine is thought of to be transformative in scope. It can add value and expand the scope of current models of care by capitalizing on a growing comprehension of the innate mechanisms of not only repair but true regeneration. The emergent model of regenerative health care encompasses the discovery, development and delivery of next-generation holistic and evidence-based treatment concepts. Central from a translational point of view is that patient-centric regenerative paradigms aspire to not just repair damaged tissue, but to restore normal structure and function [1].

Under the scaffold-based tissue engineering (TE) paradigm, a scaffold is used to support cellular growth in much the same way that the extra-cellular matrix does in normal physiological conditions. In order to achieve this, mechanical, biological and architectural factors must be optimized. Given the generalized and ambitious nature of these goals, a number of different approaches have been taken in attempting to achieve them.

This may be addressed in TE with the use of biodegradable scaffolds (Fig. 29.1) that can support growth until a stable tissue has formed and subsequently resorb leaving only the host cells [2]. Progress in TE has been aided by the rise of additive manufacturing (3D printing), which allows the production of scaffolds with customizable micro- and macro-architecture in a number of different biocompatible materials.

A small number of teams around the world are investigating TE concepts in breast reconstruction and augmentation. This is done by means of seeding a scaffold with the patient's own or allogeneic cells in order to provide structural support for tissue regeneration. However, the scientific validity is often compromised by a neglect of the required biology, as cell seeding efficiency, attachment, proliferation and ultimately tissue growth depend on the surface-to-volume ratio of the scaffold. Most importantly, clinical viability of many of these approaches is limited by their costs to manufacture an in vitro grown scaffold/ECM/cell construct. Contrary to statements in many review articles, it is by no means clear what defines 'the ideal scaffold/cell or scaffold/neo-tissue construct' – even for a specific tissue type. Since some tissues perform multiple functional roles, it is unlikely that a single scaffold would serve as a universal foundation for the regeneration of even a single tissue. In many ways, remodelling of a scaffold/cell construct after implantation can be considered as 'guided wound healing', and it is notable that most constructs become extensively remodelled as part of normal tissue repair/regeneration and subsequent natural remodelling processes. Future work has to prove that TE concepts developed for breast reconstruction offer the right balance of capability and practicality to be suitable for fabrication of scaffolds in sufficient quantity and quality to move holistic TE technology platforms into clinical application.

The considerations for scaffold design are numerous and complex. They include, but are not limited to, material composition, structural mechanics, surface properties, degradation properties and degradation products [2]. This is further compounded by the addition of any biological components. All of these factors must be considered in the context of time and the tissue in which they are embedded. For each envisioned clinical application, successful scaffold-guided tissue engineering (SGTE) will have certain minimum requirements for physical, chemical and biochemical properties.

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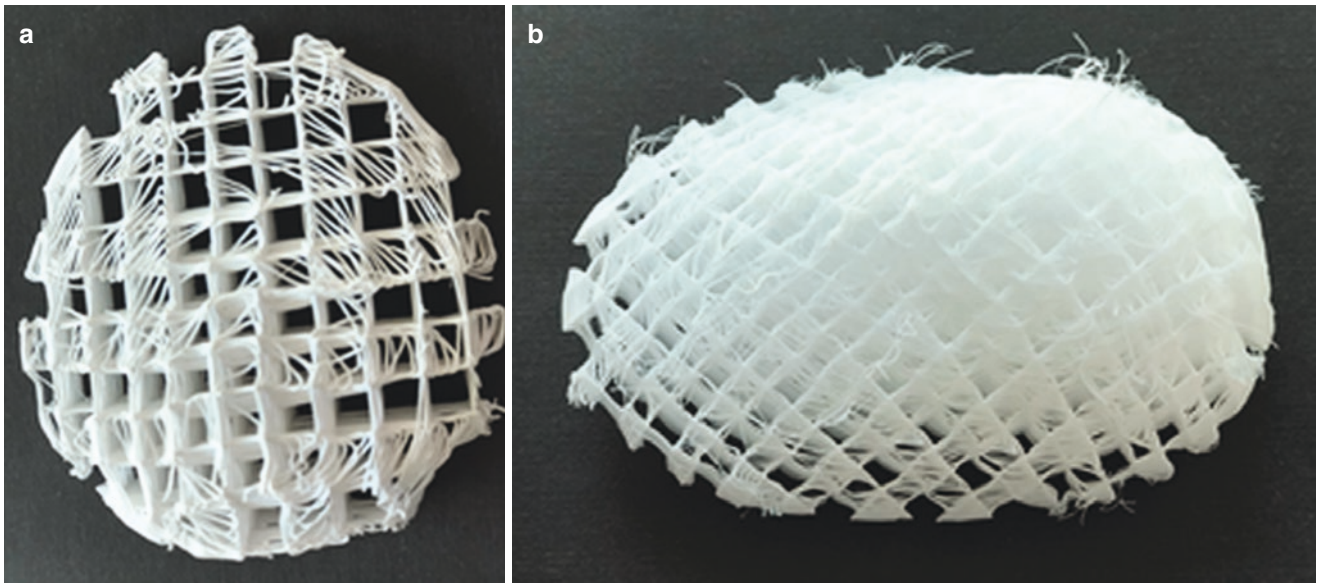

Fig. 29.1 Biodegradable scaffolds of different design additively manufactured from medical grade polycaprolactone (mPCL). (**a**) overhead view, (**b**) lateral view of scaffold architecture

Any biomaterial to be used in breast regeneration must be biocompatible, sterilizable and possess breast tissue-specific biomechanical properties so as to provide a natural feel to the patient, but also be robust enough to maintain its shape and support tissue growth. The table below shows the mechanical properties of the major components of the breast tissues compared to some of the clinically used biodegradable and bioresorbable polymers already approved in many medical devices and implants (Table 29.1). The use of a biomaterial that is already used in Food and Drug Administration (FDA)-approved medical devices and implants would also fast-track translation towards commercialization and clinical use.

Scaffolds should be fabricated from materials that do not have the potential to elicit immunological or clinically evident primary or secondary foreign body reactions which would lead to revision surgery [5]. Parallel to the formation of new tissue in vivo, the scaffold does undergo degradation via the release of by-products which can be eliminated through natural pathways from the body, either by simple filtration of by-products or after their metabolization (bioresorbable scaffolds) [6]. Due to poor vascularization or low metabolic activity, the capacity of the surrounding tissue to eliminate the by-products may be low, leading to a buildup of by-products [6]. A massive in vivo release of acidic degradation by-products leading to inflammatory reactions has been reported for several bioresorbable devices made from polylactides [7–9]. Another example is the increase of osmotic pressure or pH caused by local fluid accumulation or transient sinus formation from fibre-reinforced polyglycolide pin degradation used in orthopaedic applications [7].

Scaffold structure is expected to guide the development of new tissue formation by promoting attachment, migration, proliferation and differentiation of cells at the host site.

Table 29.1 The mechanical properties of major components of the breast and common biopolymers

Component of breast tissue	*Elastic moduli (GPa)*
Adipose tissue	$0.5–25 \times 10^{-6}$
Glandular tissue	$2–66 \times 10^{-6}$
Suspensory ligaments	0.04–0.4 (40% decrease with age)
Biomaterial	*Elastic moduli (GPa)*
Poly-D,L-lactide (PDLA)	1.5–1.9
Poly-L-lactide (PLLA)	1.4–2
Poly-caprolactone (PCL)	0.31

Adapted from Gefen et al. [3] and Chhaya et al. [4]

Furthermore, the scaffold is also responsible for importantly only temporary mechanical support and stability at the TE site until the new tissue is fully matured – after undergoing remodelling 2–3 times. As a general rule, the scaffold material should be sufficiently robust to resist changes in shape resulting from the introduction of cells into the scaffold (each of which should be capable of exerting tractional forces) and from wound contraction forces that would be evoked during tissue healing in vivo [10]. In order to achieve optimal results, it is therefore necessary to carefully balance the biomechanical properties of a scaffold with its degradation kinetics. Figure 29.2b depicts the interdependence of molecular weight loss and mass loss of a slow degrading composite scaffold and also shows the corresponding stages of tissue regeneration [12]. At the time of implantation and throughout the tissue regeneration process, the biomechanical properties of a scaffold used in breast reconstruction should match the structural properties of the host tissue it is implanted into as closely as possible [13]. In SGBT, the degradation and resorption kinetics of the scaffold have to be controlled in such a way that the scaffold retains its physi-

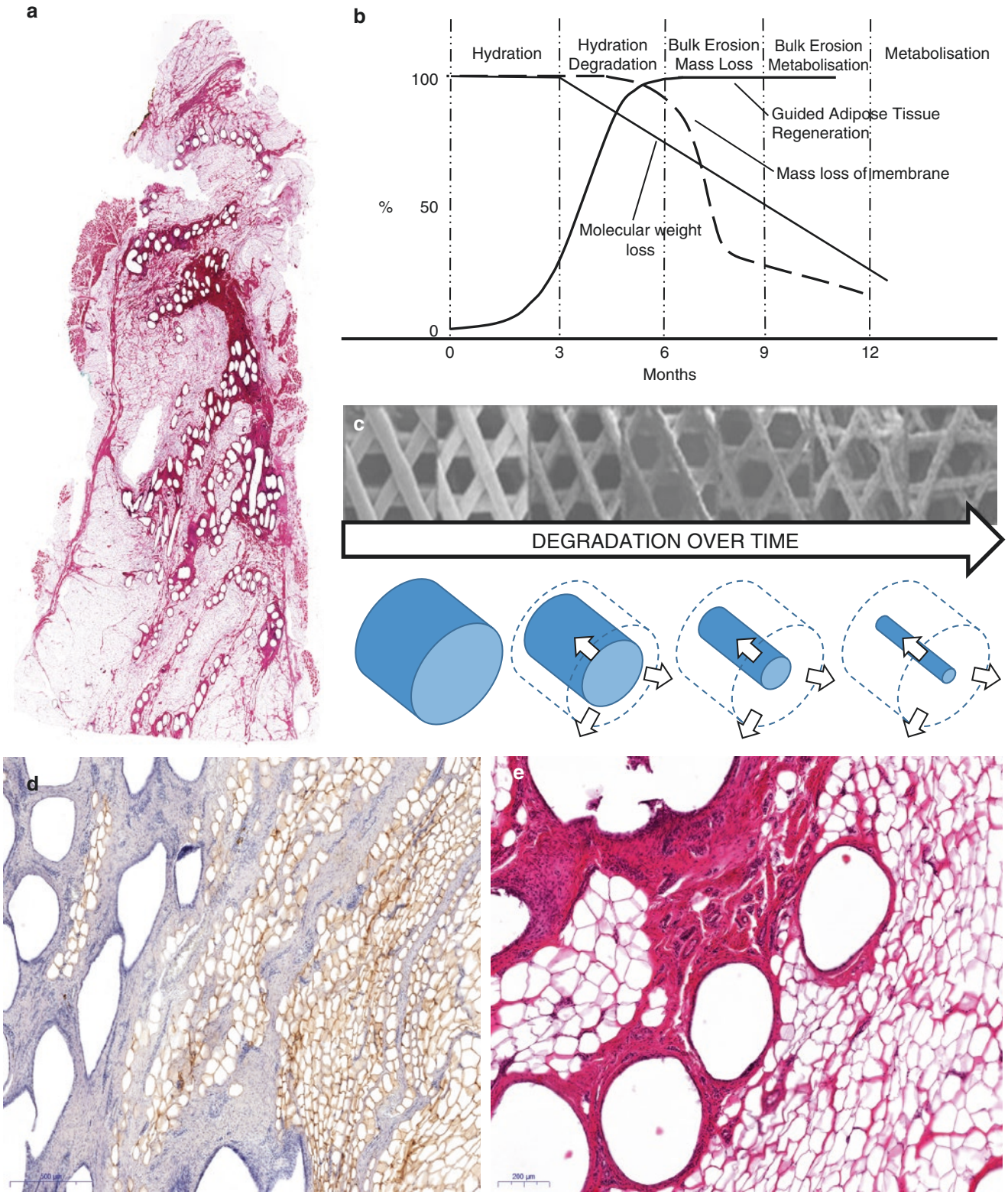

Fig. 29.2 Overview of complex interplay of mechanical properties and scaffold degradation mechanism. (**a**) Haematoxylin and eosin (H&E) staining of scaffold architecture 1 year post implantation in a pig. Graphic (**b**) and pictorial (**c**) overview of degradation kinetics and mechanisms. (**d**) shows viable adipose tissue surrounding a medical grade polycaprolactone (mPCL) scaffold 1 year after implantation using immunohistochemistry staining for perilipin. (**e**) magnified H&E views of scaffold and surrounding regenerated adipose tissue. (Adapted from Henkel et al. 2013 [11])

Table 29.2 Summary of advantages to tissue-engineered breast reconstruction

Advantages of scaffolds designed and fabricated via additive manufacturing
Higher variability of designing a targeted degradability and resorbability as well as improved biocompatibility
Can be processed into various shapes, volumes and macro & microstructures
Easily mass-produced or properties can be tailored for patient-specific applications (addressing the scheme of Personalised Medicine)
Control over chemical and physically structural properties, crystallinity, hydrophobicity, degradation rate and mechanical properties
Engineering of porous morphology, satisfying the biophysical limitations of mass transfer and mechanical properties
Flexibility to manipulate the configuration of matrix to vary the surface area available for cell attachments, also to optimize the exposure of attached cells to nutrients and allow transport of waste products
The potential to deliver antibiotics and chemotherapy drugs that can be incorporated into the scaffold structure
The ratio of surface area to mass can be altered or the porosity, pore size and pore size distribution of the differing configurations can be altered so as to increase or decrease the mechanical properties of the scaffold

cal properties for at least 6 months to enable cell and tissue remodelling to achieve stable biomechanical conditions and vascularization at the defect site [6].

Scaffold porosity and pore size relate to the volume area available for the potential for host tissue ingrowth, including vasculature, to penetrate ideally into the central regions of the scaffold architecture. In vivo, larger pore sizes and higher porosity lead to a faster rate of neovascularization, thereby promoting greater amounts of new breast tissue formation. It is important to find a balance between these pros and cons in order to tailor the scaffold properties to the demands of the TE approach used (Table 29.2). For comprehensive reviews on the role of scaffold morphology and architecture (porosity and pore size, interconnectivity, surface-to-volume ratio), the reader is referred to two recently published reviews [14, 15].

This chapter aims to introduce the concepts of SGTE as a whole and how its concepts can be applied in breast reconstruction. Whilst still in its early phases, we present a number of both clinical and pre-clinical advancements in the field. Furthermore, we discuss future directions and how they can combine with established breast reconstruction methods to improve overall patient outcomes.

Anatomy

Strong consideration must be given to the anatomy of the breast in order to achieve successful reconstruction. The functional components of the breast – glandular and ductal tissue – make up the minority of total breast composition [16]. The size, profile and tactile properties of the breast are most greatly contributed to by the skin that envelopes it, interconnecting fascial network and adipose tissue [17]. Given the oncologic risk and minimal functionality of breast tissue, regeneration in all current methods mainly focuses on the restoration of contour and tactile properties of the breast through controlled adipose tissue regeneration.

Adipose tissue is dispersed in varying degrees and proportions among glandular and fibrous tissue. Deep to the breast lies the pectoralis major muscle, which is separated from the breast by deep fascia and a loose layer of connective tissue – retromammary space – more superficially. Stemming from the deep fascia underlying the breast are the suspensory ligaments of Cooper, which are attached to the dermis of the overlying skin.

The breast naturally changes in composition with age, leading to important changes in physical characteristics. This process is completely dependent on the individual, highlighting the importance of a patient-specific approach which would allow for eventual regeneration, as opposed to permanent implantation to match characteristics at the time of surgery. Changes occur in adipose volume, skin thickness, elasticity and ligament laxity [17].

The preferred site of scaffold implantation is yet to be determined. Both submuscular and subglandular pockets offer a unique set of dynamics which must be considered when making the choice of implantation site. In the setting of total mastectomy, a submuscular pocket is favoured due to the paucity of soft tissue coverage, whilst both submuscular or subglandular pockets may be used in skin-sparing/nipple-areolar complex-sparing (NAC) mastectomy and breast-conserving surgery.

Pockets for implantation of scaffold-guided breast tissue engineering (SGBTE) constructs would be created in the same fashion to that done for other implants – current scaffolds are compressible such that they can be manipulated to allow for insertion through small incisions. As of yet, no surgical factors have been identified specific to the implantation of the scaffold. The main difference is that a scaffold may obviate the need for tissue expanders and definitive second-stage reconstruction as it would provide the adequate mechanical protection to allow for adipogenesis and angiogenesis.

Patient Selection

Reconstruction Following Mastectomy

Despite increasing clinical evidence to support the safety of breast-conserving surgery in breast cancer, mastectomy plays a significant role in select patient groups [18]. Following mastectomy, there are three approaches to reconstruction of the breast – implant-based, autologous tissue transfer or a

Table 29.3 Current approaches to breast reconstruction following mastectomy

	Advantages	Disadvantages
Breast implants	No donor site morbidity Comparatively simple procedure Cost-effective	Risk of Capsular Contracture Risk of Implant rupture Risk of Seroma formation Inferior cosmetic result in some patients High rates of revision surgery over time
Autologous tissue transfer	Best cosmetic outcome Use of the patient's own tissue Superior patient satisfaction	Requires higher level of surgical expertise Only suitable in certain patients Donor site morbidity

combination of the two [19]. The table below (Table 29.3) broadly summarizes the considerations in deciding the optimal approach in each patient. There is yet to be a consensus gold-standard approach; however, autologous tissue transfer is favoured. It has been shown to lead to greater satisfaction in patients who meet the indications and have access to the procedure [19].

SGTE may offer an alternative. The concept of generating new autologous adipose tissue may be appealing to the patient over implantation of a foreign object and may negate some common disadvantages of other reconstructive techniques.

As discussed earlier, the role of a biodegradable scaffold is to facilitate sustained, large volume regeneration of native tissue. The current approach to this is to enhance established lipofilling techniques to overcome some of their shortcomings.

The central issues facing lipofilling in breast reconstruction are volume loss due to internal space limitations and compromised vascular supply. These mainly arise from excessive tension under the remaining skin and large volume of defect to be corrected. For TE, upscaling current approaches is not practical.

Although it is well established that isolated stem cells and growth factors will promote tissue regeneration [20], it has recently been recognized that mature lipoaspirate may contain the adequate growth-promoting factors to allow for angiogenesis and adipogenesis [21]. A common TE approach is to isolate stem cells and culture them prior to reimplantation – the idea being that they are able to proliferate unlike mature adipocytes. However, the relative success of lipofilling suggests that this may be an unnecessary step. The lipoaspirate following simple on-site concentration protocols may be rich enough in these stem cells to promote adipose regeneration, and this is a more cost-effective approach. Although stem cells are more resistant to reduced vascular supply, mature adipocytes too may be able to survive when sufficient vascularization is maintained. Additionally, the risk of injecting a cocktail of stem cell-enriched cells into a breast environment might trigger or activate the dormant cancer cells in a breast cancer patient.

Khouri (2014) suggests that with advances in lipoaspirate harvesting protocols, the current limiting factor in graft survival is the recipient site rather than the graft material, with cell survival dependent on distribution [22]. This is consistent with the observation that smaller grafts have higher survival rates due to a higher surface-to-volume ratio to the vascular bed. He advocates the use of BRAVA (Brava Breast Enhancement and Shaping System)to aid fat grafting, whereby a pump attached to polyurethane domes applies negative pressure to the breast to encourage microangiogenesis and volume expansion with stretching of the skin envelope [23]. Breast reconstruction using injected lipoaspirate is technically possible even without BRAVA technology through multiple lipotransfer sessions. However, the result is sometimes difficult to predict and resorption rate of fat is different in specific anatomic compartments of the breast.

A more practical concept to increase available internal space and vascular supply is the implantation of a patient-specific scaffold prior to adipose tissue transfer. This allows the body to act as a bioreactor, allowing tissue ingrowth and establishment of a vascular supply prior to injection of the lipoaspirate. This ensures that angiogenesis precedes adipogenesis, which is a critical step in adipose tissue regeneration. The scaffold also provides mechanical support encouraging adipose proliferation. This approach combines aspects of TE and lipofilling, with each accounting for disadvantages in the other.

It is important to distinguish between augmentation/skin sparing mastectomy and radical mastectomy with resection of the skin envelope. In the latter procedure, there is very little volume of tissue remaining under the skin, and expandable implants are required to expand the skin envelope. This requires substantial mechanical pressure which cannot be achieved by lipofilling alone. It is possible that implantation of a scaffold could provide the required mechanical support for tissue growth after expansion. Clearly, the primary breast pathology will determine what manufacturing protocol and TE construct will be necessary for a given breast defect.

In the development of a new treatment concept in medicine, patient safety must be paramount. In breast reconstruction, it is important to consider factors that might impede detection of recurrence or promote survival of residual malignant cells.

Despite correct harvesting and injection technique combined with the introduction of specialized devices, there is still a risk of fat necrosis, oil cyst formation and calcification [24]. These may lead to false-positives on breast imaging or delayed detection of recurrent disease. In 2009, the American Society of Plastic Surgeons (ASPS) Fat Graft Taskforce found no evidence that these changes interfere

with cancer imaging; however, they suggested that more studies were needed to confirm these findings. Since then, it has been shown that changes from lipofilling and fat transfer can be reliably distinguished from recurrent disease on imaging by experienced clinicians [25, 26].

The addition of a TEC could impede the detection of new malignant growth. Like silicone implants, these scaffolds could compress tissue, cause scar formation and increase the radio-density, thus interfering with identifying lesions. Silicone implants have been shown to obscure mammographic imaging of the breast, but this has not translated into any change in morbidity or mortality, with patients presenting at similar stages of breast cancer [27]. Specific imaging techniques have been developed to overcome these potential problems. Also, silicone implants – especially those placed in a subpectoral pocket – may cause atrophy of the breast parenchyma facilitating palpation of new lesions [28, 29]. It is important to recognize key differences between a silicone implant and a scaffold – which will have significant implications on risk. A porous scaffold would be less radiopaque than a silicone implant and produce less scar tissue allowing better visualization of surrounding tissue. It is likely that after degradation, the scaffold would cease to interfere with imaging entirely. However, a scaffold might also conceal new lesions arising within its substance, both at clinical examination and radiologically. Whilst this potential risk must be noted, the scaffold is designed to regenerate adipose tissue as opposed to functional breast tissue so that chance of new or recurring malignancy within its substance is theoretically minimal. There are no studies specifically examining this risk, and this is an issue that needs consideration in the future.

There are theoretical concerns that lipofilling may encourage cancerous recurrence or new growth because its regenerative effects are based on the same hormones, growth factors and stem cells that have been shown to promote cancer progression and neoplastic angiogenesis in laboratory research. This has been reviewed in animal models which found that there is no increase in tumour recurrence or increase in size of residual tumour with the use of fat grafting [30]. Their conclusions delineate a difference between dormant cancer cells and high-grade tumours, suggesting that only the growth of these high-grade cells is encouraged by regenerative efforts. They conclude that attempted TE reconstruction should be delayed until cancer remission is firmly established [31]. The possible correlation between their cancer cell types and breast cancer clinical staging or histological grading is uncertain and so its clinical relevance is unclear.

Since the rise in popularity of lipofilling in breast reconstruction, a large number of studies have been performed. A comprehensive meta-analysis assessing the oncologic safety of fat transfer in breast cancer patients has been carried out by Krastev et al. and found no significant differences in locoregional recurrence in either mastectomy or breast-conserving surgery when reconstructed with autologous fat transfer. A total of 59 trials were analysed with 4292 breast cancer patients receiving autologous fat grafting and 4499 controls. Average follow-up was 3 years after lipofilling procedure [32].

Whilst the theoretical risks of lipofilling encouraging malignant growth are concerning, there is increasingly strong evidence to support its oncologic safety. However, the absence of randomized control trials due to practical and ethical reasons means that this is likely the highest level of evidence that is able to be achieved.

Regarding SGBTE, the risks of encouraging cancer recurrence and hindering detection would change depending on placement of the construct. Subglandular placement may distort breast anatomy in the same way that an implant does and also pose the same aforementioned concerns that lipofilling has due to direct interaction with breast parenchyma.

Due to its degradation properties, a TE construct would have reduced incidence of capsular contracture and would allow for safe and effective subglandular or subpectoral placement. Subpectoral placement would provide better blood supply due to the dense vasculature of muscle tissue. However, this may be more uncomfortable for the patient and will place increased mechanical stress on the construct which would likely not be conducive to long-term adipose tissue retention. As is the case with implants in current clinical use, deciding where to place the TE construct will necessitate balancing risks and benefits by open discussion between surgeons and patients. In contradistinction to the implants in current use, the use of TE constructs will necessarily involve bioengineers in the discussion.

Breast-Conserving Surgery

Due to a combination of increased awareness, early detection, improvement in adjuvant therapies and surgical advances, an increasing proportion of women are undergoing breast-conserving surgery (BCS) for carcinoma of the breast. In support of this trend, recent trials suggest that up to 80% of breast cancers can safely be managed with BCS [33]. Although the actual number of women who have BCS varies due to clinician and patient preference, the need for optimization of established techniques is clear, as clinical practice begins to reflect up-to-date evidence.

Among women who have BCS, up to 25% will have an unfavourable cosmetic result from their initial surgery [34, 35], with up to one in five undergoing reoperation for cosmetic or oncologic reasons [14]. In addition, issues such as chronic pain and psychosocial comorbidity have been described. In the initial stages of BCS, it was established that retaining original breast is superior when compared to mastectomy [36]. However, there is now increasing emphasis on achieving symmetry and resolving any residual

deformity, which cannot be achieved simply by retaining native breast tissue. The concept of autologous fat grafting to lumpectomy defects has been recognized as an exciting approach, as the majority of excised/oncologic tissue mostly comprises of adipose tissue. As previously described, the combination of a TE approach and lipofilling is especially appealing – as a construct of any size can be designed, and the scaffold can provide support to the adipose cells maintaining the desired shape.

Adjuvant therapy is usually necessary as part of BCS to optimize oncologic outcomes. It is widely recognized that adjuvant therapies generally – and radiotherapy specifically – will compromise the conditions for reconstruction of the residual defect. These women face the difficult decision of whether or not to undergo additional treatment. Deciding on the best course of treatment involves complex judgements about the individual patient's tolerance for the potential risk of recurrence balanced against the patient's tolerance for the potential risk of complications associated with adding radiation treatment, hormonal therapy or chemotherapy.

The detrimental effect of radiation therapy is well described and has been associated with increased rates of implant removal following implant-based reconstruction [37]. Pre-/post-surgery radiation is commonly recommended in patients with locally advanced breast cancer, with large tumours or with significant lymphovascular/lymph node involvement. However, it is associated with increased complication rates and reconstructive failure in all current methods [38]. The radiation targets the rapidly dividing cancer cells disrupting replication and cellular architecture but results in unavoidable damage to the surrounding normal local tissue causing significant dermatitis, subcutaneous fibrosis, skin hyperpigmentation and impaired healing. This can lead to a self-maintaining pathological condition that can last for years; its pathogenesis is thought to a vicious cycle of vessel injury, hyperpermeability, altered blood flow and ischaemia. The use of lipoaspirate shows promise not only for breast reconstruction but also could concomitantly act as a therapy for treating the side effects of radiation therapy [39]. Rigotti et al. showed that the transplantation of lipoaspirate into chronic radiotherapy-induced tissue injury can lead to both clinical and microscopic improvement, with revascularization and restoration of function [39]. This was thought to be due to the presence of the adipose-derived stem cells in the lipoaspirate, which are known to induce neovascularization. They are theorized to improve the capillary: adipocyte ratio breaking the cycle of damage.

Chemotherapy also causes dysfunction of cellular functions necessary for recovery. This theoretical mechanism has not been clearly defined in clinical practice; however, neo-adjuvant chemotherapy may increase complications such as fat necrosis, wound-healing problems and tissue expander-related complications [40]. Hormonal therapy has also been postulated to impair wound healing. Although clinical evidence is limited, oestrogen-modulating therapies may increase the rates of fibrosis, especially in the elderly and when used in the perioperative setting [40]. Interestingly, others have shown that adipose-derived stem cells continue to have regenerative potential after chemotherapeutic treatments [41].

Clough et al. suggest that in many cases of poor outcomes in breast reconstruction following BCS, revision options are limited and the best approach is prevention of complications [42]. Immediate reconstruction after excision may be beneficial. A range of techniques have been reported including lipofilling, tissue expanders, implants and acellular dermal matrices, but a clearly superior approach has not yet been identified [33, 34, 43, 44].

Breast reconstruction – whether partial or total – can involve the nipple-areolar complex (NAC). Patients with centrally located tumours involving the NAC who undergo BCS are at high risk for breast deformity and asymmetry, and immediate reconstruction of the breast mound has a favourable impact on surgical outcome. However, current methods of NAC reconstruction are less predictable and this is exacerbated in the irradiated breast. TE using a scaffold-based approach may present a solution. To date, only animal-based experiments using TE NAC reconstruction have been reported. Promising results in these studies and lack of a consensus approach in humans with current methods highlight the fact that NAC reconstruction may benefit from a SGTE approach [45].

There are numerous potential advantages that could be incorporated into this approach in the future. Another group claims to be developing technology with both therapeutic and diagnostic capacities, with the delivery of chemotherapeutic drugs and/or tumour-detecting chemicals on breast prosthesis [46, 47]. This has the potential not only to reduce cancer recurrence but also aid early detection and treatment. Whilst incredibly effective at reducing tumour recurrence and metastatic disease, chemotherapy is often complicated by systemic side effects due its poor bioavailability, high-dose requirements and low therapeutic indices. The potential use of scaffolds as a chemotherapy-delivering agent in situations where adjuvant therapy is indicated could revolutionize breast cancer treatment in much the same way that antibiotic-impregnated materials are used in deep implant infections. By providing local treatment, this would reduce the total amount of agent used, allow for a more target approach and potentially reduce systemic side effects.

Revision Surgery Following Augmentation

Breast implants are foreign bodies and inherently carry the risk of infection, contracture, displacement and, in some

cases, rupture. The risk of these complications increases with radiation and ageing [38]. The risk of complications in the former has been reported to be as high as 40%. Even in the absence of radiation and the complications mentioned above, patients may be dissatisfied with their cosmetic outcome and seek revision. Some patients describe an 'unnatural feeling' associated with implants and cite this as a source of concern [15]. They described a desire for a more nature feeling breast which will change as they age and with fluctuations in weight. Clearly, where a patient seeks a more natural feel, revision implant surgery may not address the problem. Revisions using autologous tissues confer donor site morbidity and substantial risk, as outlined in Table 29.3 [15, 48].

A scaffold-based approach has the potential to limit many of these problems. Using a scaffold with lipoaspirate, donor site morbidity from autologous tissue transfer is greatly reduced, as is the operating time, complexity and therefore the risk of serious complications. Whilst SGTE in breast reconstruction does often involve some donor site morbidity through harvest of lipoaspirate or adipose-derived stem cells, this pales in comparison to the technical factors and morbidity of microsurgical autologous free flaps. This improved risk profile may broaden the indications for autologous reconstruction and a shorter, cheaper reconstructive procedure may improve access to breast reconstruction services [49, 50].

The management of an infected breast implant is the subject of some controversy. The conservative surgical strategy is explantation of the infected implant with appropriate antibiotic cover, followed by a variable period of settling and delayed replacement with an appropriately sized implant in whatever pocket is most suitable under the circumstances. Alternative techniques are reported [51]. Despite the best efforts of the surgeon and the treating team to clear the infection and restore an optimal cosmetic outcome, an infected breast implant can lead to scarring, distortion of the breast envelope, capsular contracture and compromise of the aesthetic outcome.

As outlined above, the capacity for biodegradable scaffolds to be a vehicle for drug delivery may also have a role to play in the infected breast implant. This concept has shown great potential in deep infections of the bone and could be translated to clinical or subclinical infection of breast prostheses [52]. An antibiotic-impregnated scaffold could deliver higher doses of antibiotics locally and, at the same time, reduce systemic side effects [47]. In addition, current antibiotic-impregnated devices such as polymethylmethacrylate (PMMA)-based devices often need to be removed at a subsequent procedure. Due to the biodegradable nature of scaffolds, the need for a secondary procedure could be avoided.

It is likely that patients with infected breast implants or concerns regarding the feel of existing silicone breast implants would present the best target cohort for clinical trials of SGBTE. This is because many of the confounders seen in oncologic breast reconstruction surgery can be avoided as the skin envelope and surrounding tissues are often free of the effects of radiation and carry substantially lower oncologic risk. In this situation, the use of lipoaspriate can be regarded as much safer from an oncologic point of view and in terms of offering an environment free of mechanical and microvascular hostility.

Surgical Technique

We are currently developing a technique for the use of a tissue-engineered scaffold for breast reconstruction; to date, this has been trialled in a pig model with promising results. In order to assess the performance of the scaffold under different circumstances, lipoaspirate and/or platelet-rich plasma (PRP) was injected into the scaffolds at two different time points. Outlined below is a summary of the surgical protocol for both implantation and harvest of lipoaspirate and PRP.

For acquiring lipoaspirate, a Body-jet Eco liposuction machine (Human med AG, Schwerin, Germany) was used following standard protocol and set-up recommended by the manufacturer. The harvest sites varied but were kept separate from the intended implant site. A small stab incision was created to allow access to subcutaneous fat and subsequently closed primarily. PRP was harvested from a central venous line (CVL) in the internal jugular vein at the time of implantation surgery.

Due to the unique anatomy of the pig, the sub-panniculus carnosus plane was used as a surrogate for the subpectoral region in humans. 4 cm incisions were made adjacent to the nipple line, and dissection was performed deep to the panniculus carnosus and superficial to deep fascia. Specific effort was made to keep pocket size to a minimum. Incisions were closed primarily.

Two weeks following implantation, lipoaspirate and/or PRP was injected into the scaffold. This was done under sterile conditions, using an ultrasound-guided technique to confirm injection into the scaffold. 25 ml of lipoaspirate in total was injected into each breast receiving this treatment – dispersed evenly across the scaffold in five different injection sites.

There were no immediate or delayed complications observed in any of the animals. Upon explantation for analysis 12 months later, scaffolds showed good volume retention and integration with adjacent tissues. Furthermore, no capsule formation was seen in any treatment group, along with some macroscopically visible, patent vasculature ingrowth into the scaffold. Histological analysis is still underway to confirm these initial observations.

Technical Variations

A microsurgery-driven concept to vascularization is the use of an arteriovenous (AV) loop. This has been used by the Morrison group to produce a clinically relevant volume of adipose tissue [53]. In results published in Plastic and Reconstructive Surgery (2011), they demonstrated the production of 80 ml of soft tissue by encasing an AV loop (alone, with a muscle flap, with a fat autograft or with a fat flap) and a sponge scaffold in a perforated hard plastic chamber, and implanting it subcutaneously in a pig model. The pedicled fat flap (starting volume 5 ml) was the only group to produce significant adipose volumes with 8 samples filling the 80 ml hard chambers with an average volume of approximately 25 ml fat tissue (1/3) and the other 2/3 of the volume consisting of fibrovascular tissue. A single sample was left in situ for 22 weeks, and after removing the hard casing at week 12, there seemed to have been fibrovascular regression leaving a volume of ~60 ml consisting almost entirely of adipose tissue. The authors noted that the reason for poor adipogenesis in the fat autograft group was likely due to the autograft being placed on a two-dimensional vascular pedicle rather than a vascularized three-dimensional space. In a reply in the same journal, Yuan suggests that the success of this approach with fat pedicles was due to the modulation of physical forces promoting adipogenesis [54]. In other work, Yuan has shown that adipogenesis is inhibited by mechanical forces in contrast to musculoskeletal tissues that are known to proliferate in response to physical stress – this is consistent with the observation of volume loss in lipofilling [55]. Whilst the work of the Morrison group is significant as they are the first to engineer clinically relevant volumes of adipose tissue, its widespread clinical application is questionable.

Animal Models

The ability to regenerate soft tissue through SGTE is widely thought to have the potential to transform the field of breast reconstructive surgery. However, progress to scale up to clinically relevant volumes has been slow. Since the first in vivo adipose TE study in 1998, multiple small animal studies have been conducted (reviewed by Visscher et al) [56]. However, the inadequate volumes for regeneration in small animal models have hindered progression of the field from a translational point of view. Many of these small animal studies have utilized cell-based approaches, which have been useful to validate the breast TE approach, although their ability to be scaled up to clinically relevant volumes is limited. This is due to difficulties in mass tissue culture, costs and external regulation on stem cells. Only recently, a handful of large animal studies and one human trial have been conducted. Some of these large animal studies have circumvented these issues by developing approaches which use the body as a bioreactor and therefore avoiding cell culture [56].

Pigs are largely seen by the leaders in the field as appropriate large animal models owing to their shared similarities in anatomy, biology and physiology to humans, especially in soft tissue [57, 58]. The Morrison group has utilized tissue-engineered chambers implanted in the groin of pigs as bioreactors to generate large volumes of soft tissue. Findlay et al. were able to generate 56.5 ml of adipose tissue after 22 weeks from a 5 ml fat flap pedicled on the superficial circumflex iliac vessel to fill a chamber [53]. Morrison et al. progressed this approach conducting a human trial of five patients. They had some limited success where one patient generated 210 ml of soft tissue from a 20 ml fat flap. However, the group was not able to complete the trial, and three failed to develop significant enlargement of the fat flap, which was encased in a thick fibrous capsule [59].

Hutmacher's group uses the body as a bioreactor by implanting well-designed highly porous and biodegradable scaffolds, and filling them with free fat graft. This obviates the need for a fat flap. Chhaya et al. [60] were able to produce a 4.95-fold increase in adipose tissue from 75 ml scaffolds injected with immediate fat graft and a 6.1-fold increase in scaffolds injected with fat graft delayed by 2 weeks. The delay period allowed angiogenesis and vascularization of the scaffold to support the adipogenesis at the time fat graft was injected. This prevascularization period allows adequate vascularization to the scaffold/tissue construct, avoiding the need to import a pedicled fat flap.

Current Barriers to Translation

Since the pioneers of the field first considered the approach in 1994, there have been only a small number of teams investigating a regenerative medicine-based breast TE concept. In contrast, many more teams have conducted mainstream research in adipose TE. In spite of this, little progress has been made from a clinical point of view, with as of yet only one human trial and only one group successfully regenerating clinically relevant volumes of tissue [53, 61].

The key problem facing TE in most tissue types is the regeneration of a functional vascular network to feed into the TEC. The importance of this is heightened in adipose TE, with fat cells being highly metabolically active and undergoing necrosis when not adequately vascularized. A potential way to overcome this is with angiogenesis and growth-promoting factors at sites of tissue regeneration. This, however, may carry increased risks of tumour recurrence. It is well established that the use of adipose-derived stem cells enhances the efficacy of autologous fat grafting in soft tissue reconstruction – likely due to its potent stimulatory effects within the host microenvironment. This may

prove to be a key factor in broadening the utility of SGTE; however, the issue of oncologic safety must be addressed.

In a comprehensive review in 2004, the lack of clinical translation in TE was acknowledged and the published studies were categorized into two main approaches: first, those isolating and culturing preadipocytes for implantation and, second, those using tissue growth factors to recruit resident preadipocytes [17]. In the last 10 years, these methods have remained similar, and unfortunately, the adipose and breast TE field has not produced results from a clinical translational point of view. Many groups have traditional concepts, commonly utilizing growth factors like fibroblast growth factor (FGF), insulin-like growth factor (IGF-1) and vascular endothelial growth factor (VEGF), matrigel (a combination of extracellular matrix and growth factors), preadipocytes and HUVECs (human endothelial stem cells), as well as the use of bioreactors to promote angiogenesis and adipogenesis. Whilst many of these studies have demonstrated the possibility of producing a vascularized adipose construct, they have been limited to constructs of small volume – predominantly <2 cc, which is clearly not clinically relevant to breast constructs which would require at least 150–200 cc to match the smallest commercially available implants. One of the major limitations in scaling up experiments is cost of these growth factors and particularly of culturing the stem cells which require complex good manufacturing practice (GMP)-certified laboratories. This poses serious concerns for the commercial viability of such approaches on a larger scale. Such techniques would also require extensive investigation prior to FDA approval for human use to prove that the use of such growth factors and stem cells did not encourage malignant growth.

A proof-of-concept pilot study in human volunteers has been conducted using the same approach of vascularized fat pedicles inside hard plastic casing (without sponge) of various volumes in five patients with unilateral mastectomies [59]. In one of the patients, the fat flap grew from 30 ml to fill the 210 ml encasing, which remained stable for 12 months inside the encasing and retained some volume for 6 months following removal. In surgery, the tissue was reported to resemble partly fat and partly fibrous tissue. In the other subjects, three showed no adipose growth and one patient withdrew from the trial due to pain from the implant at week seven. Importantly, there were some major demographic differences between the one successful patient and the others, the former being the only one with her mastectomy over a decade prior (14 years vs 0.5–2 years), the only diabetic patient (evidence that diabetics have higher circulating growth factors) and the only one with a tissue expander for almost a year (cf. 2 months). They suggest that these disappointing results compared with their animal work may be due to the fact that pigs continue to grow throughout life, whereas humans do not. In closer inspection of their original results, they noted that fat growth to week six (1/3 adipose, 2/3 fibrous) was significantly greater than growth of the animal, but that adipose growth past that point (after chamber removal) occurred at a rate similar to total growth of the animal. Other inherent problems in this approach include the formation of thick fibrous capsules in three of the four patients and the need for reoperation to remove the hard implants. This two-stage approach seems to offer little benefit over the use of a tissue expander followed by definitive implant at a subsequent procedure. In addition, the implantation of a hard casing may not be comfortable, as demonstrated by the patient who withdrew from the study, and is contrary to the ideal that an implant should share the biomechanical properties of the tissue it aims to replace. By addressing these issues, a biodegradable scaffold with sufficient strength to resist shearing forces may confer distinct advantages.

Conclusions

The concept of scaffold-guided breast reconstruction (SGBR) utilizing the combination of scaffold-based tissue engineering principles and lipofilling offers a promising alternative to silicone implants and to current reconstructive techniques. The clinical application of SGBR may seem to be a generation away; however, human clinical experiments and sustained clinically significant adipose tissue volume regeneration suggest that it may become a reality much sooner than expected. The main problems this approach will address are to reduce technical requirements, donor site morbidity and expansion of patient eligibility compared to autologous transfer and to reduce complications and produce a more natural, patient-specific outcome than what is offered by implant- and flap-based approaches.

The Hutmacher laboratories' Scaffold-guided breast reconstruction technology platform (SGBTP) brings together additive biomanufacturing, surgical oncology, reconstructive surgery and drug delivery to change the current implant paradigm in breast conservation and reconstruction surgery. It has the potential to redefine the native tissue restoration for the breast cancer patient; first, by providing a holistic therapy concept that restores breast shape and volume and second, by obviating limitations associated with other contemporary reconstructive options. Recently, our interdisciplinary group has demonstrated the regeneration of larger-volume adipose tissue by using additively biomanufactured scaffolds with an implant volume of 150 ml without complications clinically detected with silicone implants or LPAG-only procedures. SGBR combined with local drug delivery offers tailorable and adaptable treatment for the breast defect (Fig. 29.3). Local delivery of antibiotics can provide more control over the dose that reaches the target tissue and limits systemic circulation to decrease side effects. The therapeutic effect on the

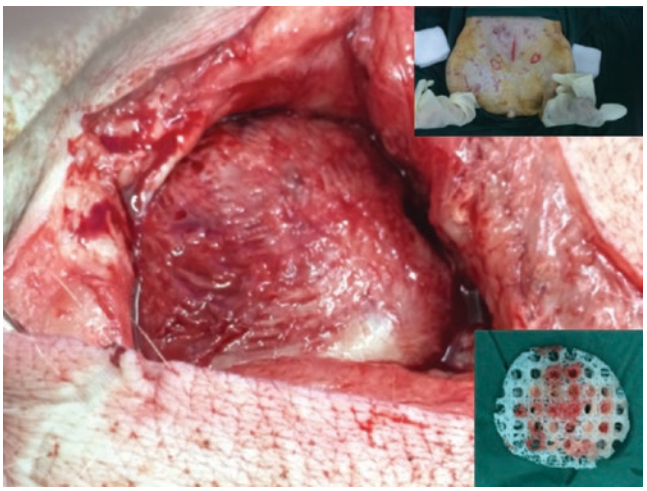

Fig. 29.3 Additively biomanufactured scaffold loaded with a small volume of lipoaspirated adipose tissue shows after 6 months of implantation highly vascularized and well-structured stroma/adipose tissue without signs of capsule contraction

tumour or implant site becomes dose dependent; therefore, the pharmacokinetic release profiles can be controlled and customized. Hence, an eminent SGBTE research programme will be a catalyst in advancing and translating an innovative, holistic regenerative medicine therapy concept into routine clinical practice. Regenerative principles are poised to leverage understanding of a multitude of parameters, defining therapeutic outcomes in the context of patient-specific disease management. This SGBTE research programme in conjunction with current precision medicine paradigms will deliver in the years to come predictive and personalized health care, a patient-specific solution for patients who suffer with breast cancer.

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