Contemporary Microsurgical Breast Reconstruction: Abdominally Based Flaps

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Learning Objectives: After studying this article, the participant should be able to: 1. Understand the types of abdominally based flaps, their anatomy, and their drawbacks. 2. Understand important aspects of the history and physical examination of patients wishing to undergo these procedures. 3. Understand the benefits of preoperative planning and its role in avoiding complication. 4. Understand the operative steps of the procedures and tips to increase efficiency. 5. Understand the postoperative care of these patients and the role of enhanced recovery pathways.

Summary: In this article, the authors review the history, current state, and future directions related to abdominally based microsurgical breast reconstruction. This article covers preoperative, intraoperative, and postoperative considerations intended to improve patient outcomes and prevent complications. Evidence-based findings are reported when available to comprehensively review important aspects of these procedures. *(Plast. Reconstr. Surg.* 154: 199e, 2024.)

Postmastectomy breast reconstruction is an important part of breast cancer management that can offer significant physical and psychological benefits for patients.[1] In general, breast reconstruction following mastectomy can be performed with prosthetic devices, such as tissue expanders and implants, and with autologous tissues. Abdominally based microsurgical techniques are the most common of the autologous flap–based methods and include the transverse rectus abdominis myocutaneous (TRAM) flap, the deep inferior epigastric artery perforator (DIEP) flap, and the superficial inferior epigastric artery (SIEA) flap. Microsurgical reconstruction techniques with alternative donor sites (ie, thigh, lower back, and gluteal regions) serve as viable options for those patients who are not suitable candidates for abdominally based breast reconstruction; however, this article focuses on the techniques used in abdominally based microsurgical breast reconstructions.

TYPES OF ABDOMINALLY BASED AUTOLOGOUS BREAST RECONSTRUCTION

The pedicled TRAM flap was initially described in the early 1980s and was popularized because of its ease of harvest and ability to provide natural and aesthetically pleasing outcomes.[2–4] The free TRAM flap is similar to the pedicled TRAM flap based on its adipocutaneous elements; however, its principal vascularity is derived from the deep inferior epigastric system, whereas the pedicled TRAM is derived from the superior epigastric vessels. These flaps have been criticized because they require total or subtotal harvest of the rectus abdominis muscle with resulting abdominal donor-site morbidity that includes bulge, hernia, pain, and functional weakness. These concerns have been a driving force behind the development

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Received for publication August 13, 2023; accepted February 20, 2024.

DOI: 10.1097/PRS.0000000000011373

Disclosure statements are at the end of this article, following the correspondence information.

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of perforator flap-based breast reconstruction in which more of the integrity of the rectus abdominis muscle is preserved.[5,6]

The types of abdominal perforator flaps primarily include the DIEP and the SIEA flaps. In a DIEP flap reconstruction, a myotomy is created and one or more deep inferior epigastric artery perforators are dissected through the rectus abdominis muscle down to the main pedicle, thus preserving as much of the integrity, continuity, and innervation of the muscle as possible.[3,5] Depending on the number and orientation of perforators harvested, motor nerves may be disrupted during flap elevation, although attempts can be made to preserve these nerves and/or to repair them, as discussed further in this article. In time, the DIEP became the accepted standard in autologous reconstruction, and deviations were developed where necessary.[7–9] The SIEA flap is another abdominally based flap that spares the rectus abdominis muscle and fascia, as no myotomy is created.[3] However, this technique requires that the superficial inferior epigastric artery and vein be present and of suitable caliber. There may still be donor-site morbidity related to flap elevation and closure of the donor site in the form of wound dehiscence, unsightly scarring, tissue necrosis, infection, and seroma. Because of vascular uncertainties, the SIEA flap is associated with higher rates of flap loss and other flap-related complications when compared with the DIEP flap.[10,11]

AUTOLOGOUS VERSUS IMPLANT-BASED RECONSTRUCTION

Despite the proposed benefits of flap-based breast reconstructions, between 63.2% and 92.5% of postmastectomy breast reconstructions conducted in the United States are nonautologous.[12,13] Abdominally based breast reconstructions require microsurgical expertise and may not be as easily accessible in certain geographic regions. Because of the complexity of the operation and the involvement of two surgical sites, the length of the operation and recovery time is longer for flap-based reconstructions compared with implant-based reconstructions. Finally, there are donor-site considerations that patients may find undesirable. Financial reimbursement appears to affect the choice of reconstruction where privately insured patients were 1.93 times as likely as publicly insured patients to receive DIEP flaps.[13] Although the insurance landscape continues to shift, it is understood that there may be regional differences in rates of microsurgical breast reconstruction. However, the choice of reconstruction offered should always be in the best interests of the patient and not motivated by external gain.

There are notable benefits to the use of autologous tissue to reconstruct like with like. Because the flap is composed of the patient's own tissue, the procedure eliminates the long-term risks with implants, such as rupture or capsular contracture. The flap also adapts as the patient ages, or gains or loses weight, based on changes in the patient's body habitus, and rarely requires additional surgical interventions once it has stabilized. As such, this method can have significant physical and psychological benefit for patients.[14–16] These advantages may explain the higher rates of patient satisfaction associated with microvascular autologous breast reconstruction.[14,16,17]

ANATOMY

Perfusion of the lower abdominal flap is often described using Hartrampf zones—four vertical sections that span the full width of the adipocutaneous component of the flap. The general idea behind the Hartrampf concept is that the flap is perfused from a central ellipse and that perfusion declines toward the periphery of the flap.[18,19] However, in 2006, Holm et al. argued for a need to rearrange the classic Hartrampf zones.[20] Their study demonstrated that the lower abdominal flap is more accurately described as two halves separated by the midline and that the ipsilateral half shows an axial pattern of perfusion, whereas the contralateral half shows a "random-pattern, individually variable blood supply."[20] In light of this finding, the group stated that zones II and III should be reversed. In 2008, Wong et al. added further complexity to the issue by demonstrating that there are differences in the vascular territory depending on whether the lateral or medial row of perforators are selected and harvested.[21]

Despite these competing classifications, the surgeon can expect that the dominant perforators are usually located in the periumbilical region that typically ranges within 3 to 5 cm of the umbilicus.[22,23] In anatomical studies, medial row perforators tend to exhibit greater branching and robust vascularity across the midline, whereas lateral perforators cannot be expected to reliably provide vascularity across the midline (Figs. 1 and 2).[24,25] There is evidence from retrospective studies of statistically higher rates of fat necrosis when medial versus lateral row perforators are used in hemiflaps, and rates of abdominal

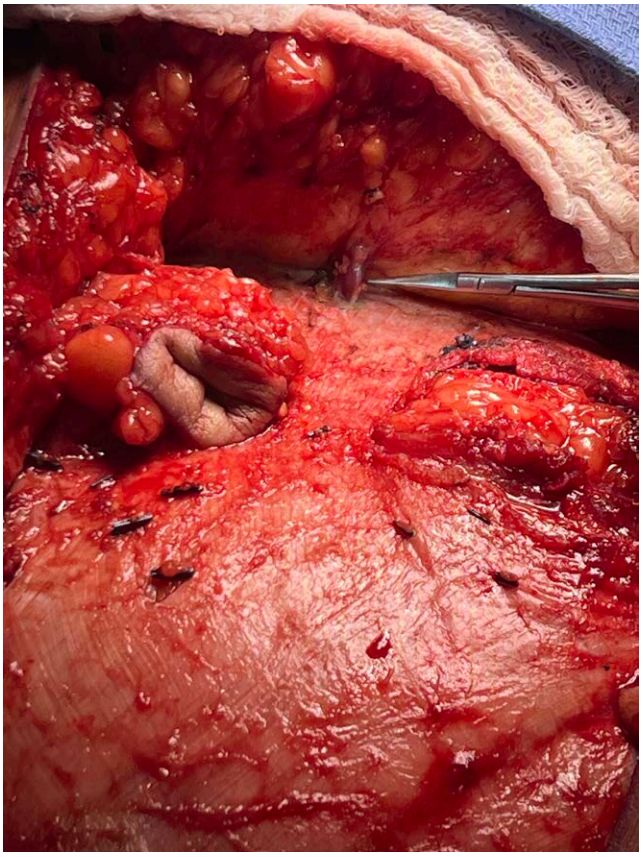

Fig. 1. A single, dominant, medial row perforator is selected for a left hemiabdominal DIEP flap.

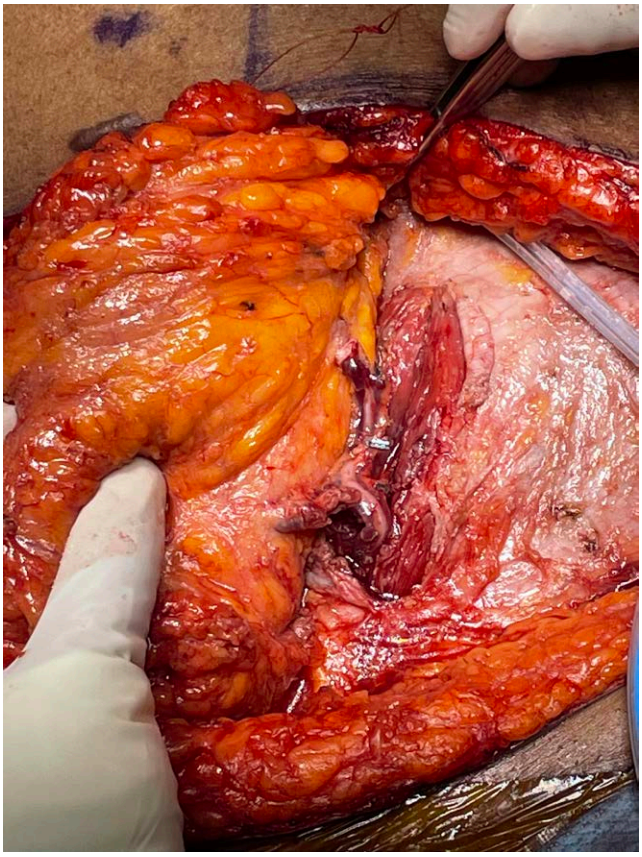

Fig. 2. The left hemiabdominal DIEP flap is based on two lateral row perforators.

bulge are higher in lateral row flaps.[26,27] These considerations are important for the surgeon to consider during perforator selection to optimize outcomes. Appreciating the vascular anatomy and perfusion of abdominal flaps can be assessed preoperatively using computed tomography (CT) or magnetic resonance (MR) angiography and intraoperatively using an image-capture device with or without the injection of dye.

PREOPERATIVE ASSESSMENT

Medical and Surgical History

A thorough medical history is conducted at the beginning of the initial consultation, including prior breast procedures.[28] The surgeon should understand the stage, type, size, and laterality of cancer to inform decisions in the reconstructive process.[29] The following examples help to illustrate the importance of the initial consultation. Patients who have undergone certain types of abdominal surgery in the past, such as abdominoplasty, may not be candidates for abdominally based autologous breast reconstruction.[30] In patients who have had abdominal operations, preoperative imaging using CT or MR angiography should be considered to assess the abdominal perforators. Rozen et al. demonstrated that prior abdominal operations can potentially disrupt the abdominal perforators and DIEA and SIEA vessels.[31] Patients with a heritable susceptibility to breast cancer should be counseled regarding bilateral prophylactic mastectomy and be provided the option of breast reconstruction.[32,33]

Patients noted to have aggressive, large tumors may have positive margins following mastectomy, thereby necessitating postoperative chemotherapy or radiation therapy.[30] Neoadjuvant chemotherapy may be recommended in large tumors with positive biomarkers, and this will impact the timing of extirpation. By contrast, adjuvant chemotherapy initiated after healing is deemed adequate and may need to be delayed if wound complications arise. Radiation therapy can damage the breast tissue and may alter the quality of the skin, influencing the healing process.[30,34] In cases where postoperative radiation therapy is required, the plastic surgeon may also

consider placing a tissue expander and delaying reconstruction until after the radiation therapy is completed.[34] Studies have shown that immediate autologous breast reconstruction can be safe and aesthetically favorable, even for advanced-stage breast cancer in patients who are planning to undergo postoperative radiation therapy.[34–38]

Patients undergoing radiation therapy after mastectomy and implant-based reconstruction can present after failed reconstruction. Alternatively, patients with a prior unsuccessful attempt at autologous reconstruction have expended a possible reconstructive modality. As such, it is important to consider each patient's unique situation. Patients with clinically evident nodal disease may require axillary dissection.[30] In such cases, considerations to combat lymphedema can be incorporated into the reconstructive plan, such as the simultaneous transfer of vascularized nodal tissue with the abdominal flap.

Patients who are candidates for nipple-sparing mastectomy will need to be counseled on the risks of nipple and mastectomy flap necrosis (both recorded at 12.7% in 1 review).[39] Mastectomy flaps can be evaluated intraoperatively with or without the use of imaging, and a decision can be made to resect additional areas of devitalized skin. A thorough discussion of treatment options and alternatives can help to establish preference-concordant care where patients feel that their values are acknowledged. Immediate reconstruction following mastectomy has been demonstrated to provide psychological benefits to patients.[34,40,41] In addition, the aesthetic outcomes are generally improved in immediate reconstruction.[40] Delayed reconstruction is associated with fewer surgical complications, and aesthetically pleasing results are still attainable with high patient satisfaction.[40,41]

Multiple studies have reported that age is not predictive of poor outcomes after microvascular breast reconstruction and is not associated with increased levels of complications or postoperative patient dissatisfaction.[42–44] However, in patients older than 65 years who have coexisting medical conditions such as hypertension, cardiovascular disease, or high body mass index, adequate counseling is necessary so that patients understand the additional risks.[45] Advanced age may work synergistically with these and other risk factors to increase the risk of venous thromboembolism, delayed healing, and the development of an abdominal bulge or hernia after surgery.[10] Surgical risks should be considered on a case-by-case basis.

Physical Examination

During the physical examination, the patient's breasts, abdomen, and overall body habitus are evaluated to determine the options for breast reconstruction. Relevant examination considerations for the surgeon include breast volume, breast shape, symmetry, ptosis, skin or nipple-areola complex (NAC) irregularities, radiation changes, tumor size, tumor location, abdominal skin laxity, hernias, and previous incisions.[30,46] Mastectomy skin flap reduction may be required at the time of mastectomy or performed secondarily at a revision procedure. Following or at the time of unilateral mastectomies, contralateral procedures to achieve symmetry can include doing nothing, mastopexy, augmentation, or reduction.[30,32] In patients with a larger breast volume relative to the availability of abdominal skin and fat, a standard DIEP flap may not be possible; thus, alternative flap donor sites such as the back or thighs may be considered.[47–49] Other variations in flap design to accommodate such mismatches include the extended DIEP flap, stacked flap, or a hybrid reconstruction with a prepectoral implant.[38]

Preoperative Imaging

The vascular anatomy of the perforators can differ significantly from patient to patient. Although it is not a prerequisite, preoperative imaging of the lower abdomen using CT or MR angiography is helpful to assess for vessel patency, map perforator anatomy, and check for incidental scarring or masses. These images can be used to assess a patient's candidacy for an abdominally based flap and are especially useful in patients who have had prior abdominal surgery.

The preoperative scan can be used to map the location and size of perforators that can be traced back to the source pedicle, and the scans reliably predict the dominant perforator that can be harvested within the proposed flap boundaries.[50] The course and length of the perforator within the rectus muscle can be traced as well, thereby helping to determine the ease of dissection of a particular perforator. Knowledge of perforator anatomy and location has been shown to significantly shorten the operative time.[50–53] A desirable perforator has the following characteristics: patency of the artery and vein without stenosis for the length of its course (at least for 6 cm and preferably for 10 cm); a size of 1 mm for the artery alone; a size of 2 mm for the artery and vein combination; and a relatively short, straight intramuscular course.[53] The choice between CT or MR imaging will often

depend on scanner availability and the comfort of radiologic interpretation, but the proposed benefit of the latter is the enhanced contrast for the intramuscular mapping, lack of ionizing radiation, and absence of iodinated contrast material.[53] Additional modalities for preoperative planning include handheld Doppler ultrasound and color Doppler ultrasound, but these modalities are highly operator-dependent and are limited on detail in a thicker pannus.[53]

Additional Preoperative Considerations

Active smoking has been implicated in poor wound healing and in increasing the risk for partial flap necrosis; therefore, surgeons must stress the importance of smoking cessation before surgery.[54–56] Obesity has been associated with increased donor- and recipient-site complication rates including delayed wound healing, infection, and flap failure.[10] Despite an increased risk of postoperative complications, multiple studies highlight both improved outcomes and higher patient satisfaction following microsurgical versus prosthetic-based reconstruction in obese individuals.[14,17] Patients with a personal or family history of venous thromboembolism and/or multiple spontaneous abortions should be considered for coagulopathy screening before the operation.[30] Diabetes mellitus is associated with increased risks for infection and wound dehiscence, and longer length of stay after surgery.[57] Adequate control of diabetes mellitus is strongly recommended and best assessed by measuring glycated hemoglobin levels.

A key consideration in the choice of pursuing abdominally based reconstruction hinges on the adequacy of lax abdominal pannus to make up for the deficient breast volume following extirpation. In wide-chested patients, the height of the donor flap accounts for the width of the reconstructed breast and may not fully account for the widthwise volume loss in the chest. In cases of significant disparity, it is not possible to devise a simple algorithmic approach, because choices are determined with shared decision-making between patients and surgeons. The following points may help to guide management on disparities in either direction. Flaps can be designed to be smaller and can be safely trimmed of the lateral corners and flap periphery, taking care to leave wide areas around the axial perforators. Where abdominal tissue is insufficient, the patient may elect for a decrease in postoperative breast mound volume, and this is achieved with reduction of the mastectomy skin envelope, as discussed. In unilateral reconstructions, stacked abdominal or other flaps can be safely used to account for the mismatch.[9] The use of implants placed beneath abdominally based flaps is discussed later. Although beyond the scope of the current review, alternative donor sites may be pursued, and these are reviewed briefly. The lumbar artery flap can provide on average approximately 500 g of soft tissue in patients of normal body habitus, but drawbacks are the need for changes in patient positioning and higher rates of flap failure.[7] The transverse upper gracilis flap produces a smaller breast (approximately 350 g) with a relatively short dissection but at the tradeoff of donor-site delayed healing and sensory disturbances in the thigh.[10] The gluteal-based flaps require patient repositioning, are associated with painful sitting, and result in the harvest of fat that is less soft and conforming than abdominal adipose tissue.[7,10] The profunda artery perforator flap can be harvested with a relatively wide skin paddle and with somewhat discreet scar locations. Although profunda artery perforator flaps are newer by comparison, they may allow for successful reconstruction in thin patients.[10,49]

Preoperative Marking

A standardized approach to markings using commonly referenced landmarks can be used to ensure symmetry and consistency.[58] If preoperative imaging has been obtained, the perforators are mapped out with knowledge of the pedicle and perforator course. Some surgeons will use a printed grid template that can be laid on the patient's abdomen while lying supine to allow for accurate markings.[59] Other surgeons will measure and mark out the perforator points in reference to the umbilicus, based on preoperative imaging. In cases where preoperative imaging has not been obtained, the flap outline is delineated, and the perforator location is determined intraoperatively while raising the flap. Nipple-sparing mastectomy can be completed through an inframammary crease incision, a lateral radial incision, an inverted-T configuration, or one along the vertical limb between the nipple-areola complex and the inframammary fold.[60,61] Factors associated with mastectomy flap necrosis include increasing mastectomy weight, tobacco use, and poorly controlled diabetes mellitus.[62]

The transverse scar height is often determined based on perforator height in cases where there is limited laxity of the tissues and there is a need to capture a perforator at or above the level of the umbilicus. The lower incision will need to be raised to meet a higher superior incision. This can be determined preoperatively if imaging is

obtained or intraoperatively before committing to a superior transverse incision. In addition, it is possible and recommended in these circumstances to bevel the incision superiorly beneath the Scarpa fascia to include soft tissue and perforators beyond the skin boundaries of the flap. Where sufficient laxity exists, it is preferable to keep the lower incision low enough to hide the scar beneath the underwear line. Where there is a cesarean section scar, this can be included within the boundaries of the flap so that the patient is not left with multiple transverse scars and to avoid vascular compromise of the intervening skin. In the event that it is not possible to capture a high perforator and to close the abdomen at the level of an existing transverse scar, one can consider a delay procedure for the proposed inferior incision before the flap surgery. This will result in two transverse scars in the initial period, and if laxity exists at 6 months to 1 year after the reconstruction, the donor site can be safely revised at that later time.

OPTIMIZING INTRAOPERATIVE WORKFLOW

In cases of immediate reconstruction, it is helpful to have two separate surgical teams to optimize surgical efficiency. A proposed layout has the breast team including the surgical scrub at one side of the chest and off to the side of the chest, whereas the microsurgery team starts below, at the abdomen, for simultaneous flap harvest.[63] The addition of a co-surgeon for the reconstructive team has been shown to decrease operative time and improve patient outcomes.[64] It is worth noting these benefits in light of recent measures to withdraw or limit reimbursement for co-surgeons.

Perforator Selection

The choice of a single perforator or multiple perforators reflects a balance between the risk of flap complications and the risk of donor-site morbidity. The use of a single, dominant, centrally located perforator is safe and reliable for flap harvest,[65] and the increased caliber of the venous perforator rather than the size of the arterial perforator has been shown to correlate with fewer intraoperative flap concerns.[66–68] The recent advent of robotic dissection for flap harvest has the potential to limit donor-site morbidity through shorter fascial incisions, although patient selection is critical, as only those with perforators with a short intramuscular course stand to benefit.[69–71]

Recipient Vessel Harvest

The options for recipient vessels in the setting of microvascular breast reconstruction include the internal thoracic, thoracodorsal, or circumflex scapular vessels. In an anatomical study, the internal thoracic vessels were found to have adequate diameter matching in reference to the deep inferior epigastric vessels.[72] In addition, studies have demonstrated increased flow rates within the internal mammary vessels (25 cc/min) relative to the thoracodorsal vessels (5 cc/min).[73] Before the preferential use of the internal mammary recipient vessels, the thoracodorsal vessels were commonly used, particularly in the era of routine axillary node dissection. A benefit of exposing the internal mammary vessels is that there is no added risk for lymphedema of the upper extremity and in some patients, an internal mammary lymph node may be visualized and removed for pathologic analysis.[74,75] There is some debate regarding the need for rib resection with its attendant pain and morbidity as part of the vessel dissection. In one retrospective review, a rib-sparing dissection was found to have no increased rate of flap-related complications.[76] In cases where multiple anastomoses are performed with the chest vessels such as with multiple veins or in cases of stacked flaps, it is safe to use contiguous rib spaces while preserving the intervening cartilage.[77]

Microsurgical Anastomosis

The remainder of the recipient vessel dissection including separating the vessels and ligating small branches can be done with use of the operating microscope or continued with loupe magnification based on surgeon preference. For those trained in the latter, evidence indicates that use of loupes only for microsurgery is not inferior to the use of the microscope.[78,79] Benefits of loupes-only microsurgery include time saved on setup (estimated at 20 minutes in one study) and enhanced ergonomics.[79] The benefit of the operating microscope is that the magnification can far exceed the power of loupes in challenging cases. The flap and recipient vessels are oriented with a marker on their anterior surfaces. The flaps can then be rotated and sutured to the chest wall to allow for the anastomosis to be performed. The vascular anastomosis is typically performed with the coupler for the vein and is usually hand sewn for the artery. Although short ischemia time is preferable, only long ischemia times on the order of 1.5 to 2 hours have been shown to increase vascular complications.[80]

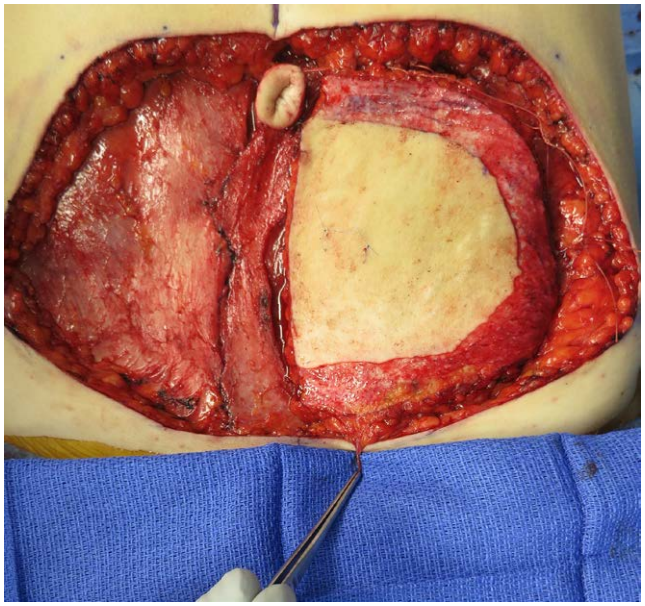

Fig. 3. A small stump of the SIEV is preserved in cases where superficial dominant circulation may be suspected.

In some patients, the superficial inferior epigastric vein (SIEV) rather than the deep inferior epigastric vein is the dominant venous drainage of the DIEP flap. This can be suggested based on preoperative imaging but is better apparent during the operation when a large SIEV is seen along the inferomedial aspect of the flap. Thus, it is common practice to dissect a sufficient stump to the SIEV to allow for additional outflow by performing a secondary venous anastomosis (Fig. 3).[81] When a single internal mammary vein is present, the anastomosis can be retrograde into the internal mammary vein or antegrade into a lateral chest wall vein, but the former option is often preferred to avoid the necessity of a vein graft. Ultimately, the decision to supercharge the flap by means of anastomosing the SIEV is a clinical one when signs of congestion are noted in the monitoring skin island (ie, brisk capillary refill, darker coloration, brisk and purple bleeding on scratch) or by means of intraoperative imaging (eg, with delayed diffusion of injected dye relative to a contralateral flap or normal skin). In cases where no such congestion is noted, there is insufficient evidence in the literature to recommend prophylactic supercharging, and there is no definitive way to predict congestion preoperatively. In cases without congestion and where the internal mammary vein is branched, the larger branch is selected for anastomosis. When the SIEA flap is raised, bilateral harvest of the full length of the SIEV has been associated with an increased rate of abdominal seroma formation (40%) when compared with no-SIEV dissection (11.5%; $P = 0.02$).[82]

Inset and Closure

Following the microsurgical anastomosis, the surgeon can secure the flap with tacking sutures and recreate the contour of the breast mound. The final area and dimensions of the skin paddle are delineated, and the remainder of the flap is deepithelialized. The benefit of completing deepithelialization at this stage is twofold. The pinpoint bleeding demonstrated with the removal of the superficial skin is a good indicator of flap health. In addition, the mastectomy skin edges may need to be trimmed, leaving a greater area of skin deficit than might have been expected. In cases of concern for skin flap viability, intraoperative imaging can be useful in detecting poorly perfused skin and fat that may be at risk for necrosis.[83] In the absence of such technology and with equivocal mastectomy flaps, some surgeons bury large skin paddles and then bring patients back to the operating room after 1 to 2 weeks to débride any necrotic skin and then permanently inset the flap along its new boundaries. The flap can also be preshaped into a conical form before placing it into the chest cavity to provide enhanced appearance.[84]

The abdominal donor site can be closed in the fashion of an abdominoplasty based on surgeon preference but with a few caveats (Fig. 4). There is some debate on the use of mesh for the fascial closure because of the absence of high-quality evidence. One retrospective review of 202 patients showed no statistical difference in abdominal wall morbidity with or without mesh.[85] A retrospective review of 85 patients found that the use of semiabsorbable mesh resulted in a significantly decreased rate of hernias but had no impact on late bulge or abdominal wall strength.[86] Another retrospective review found no difference in donor-site complications with reference to the plane of mesh placement, but this study lacked a control group with no mesh used.[87] Finally, in a review of 644 patients, the only factors associated with significant increases in late abdominal bulge or hernia were the development of an abdominal wound or sacrifice of the laterally based nerves.[88] In the absence of these factors, whether a mesh repair is used or not, it is helpful to reapproximate the muscle and fascia in the orientation in which it is divided. In addition, if motor nerves are identified and divided during the dissection, they can be tagged for repair following flap

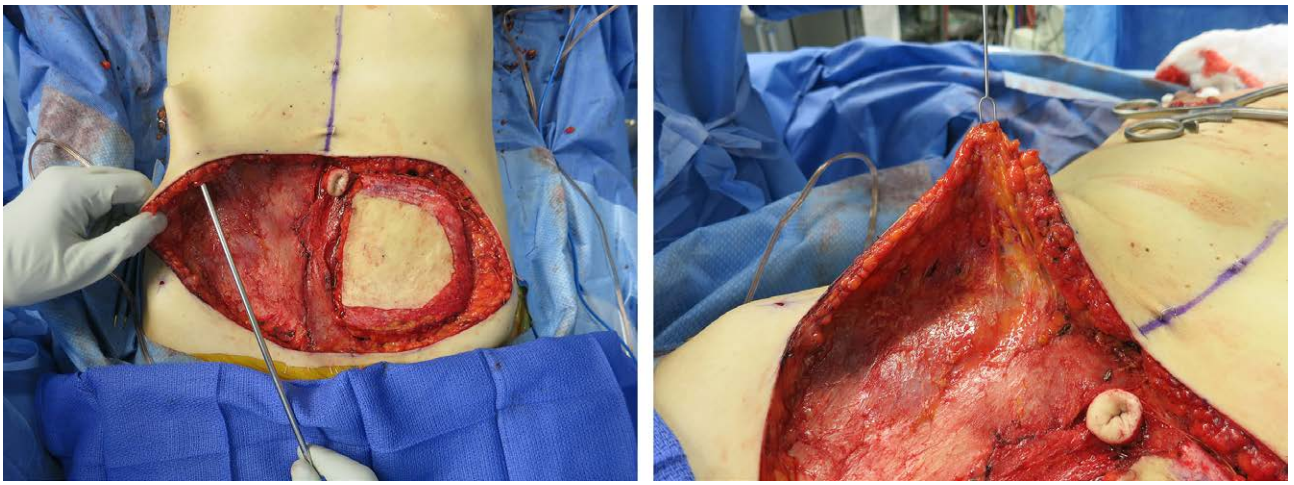

Fig. 4. (*Left*) A liposuction cannula is used to facilitate donor-site closure. (*Right*) Discontinuous undermining creates tunnels without disrupting superolateral blood supply to the donor-site closure.

separation. In cases of concomitant umbilical hernia repair, many opt to sacrifice the umbilical stalk and to reconstruct it at a later point. If the umbilical stalk contains no hernia or if the hernia can be repaired without division of the stalk, it can be preserved; but even then, it is at risk for devascularization because of division of the inferior epigastric vessels.

POSTOPERATIVE COURSE

Studies in the field of breast reconstruction and for DIEP flaps, in particular, have highlighted the importance of enhanced recovery after surgery (ERAS) protocols.[89–91] The measures highlighted by consensus review and previously covered in great detail include preoperative education, medical optimization, optimal weight management, surgical planning, comprehensive multimodal analgesia, and early mobilization, among other measures aimed at risk mitigation.[89] ERAS pathways have been shown to reduce the length of stay without any additional complications.[90–92] Perhaps the greatest driver of early mobilization and discharge is the use of enhanced measures for pain control. Long-acting liposomal bupivacaine when deposited for regional blocks can replace the need for continuous anesthetic infusions and has been shown to further reinforce ERAS goals above the prior baseline.[91] Although the most ideal dosing, technique, and effect duration in the case of transversus abdominis plane blocks is unknown, the benefits of this and other regional nerve blocks (ie, pectoral nerves, thoracic nerves) cannot be overstated.[92] Blocks can be administered by either the surgical team or they can be administered by the anesthesia team based on practitioner comfort. Safe dosing requires adherence to recommended guidelines and avoiding the mixing of liposomal bupivacaine with lidocaine.

There are several modalities for inpatient flap monitoring, including clinical examination, handheld Doppler, implantable Doppler, and near-infrared tissue oximetry monitoring.[93–97] It is worth noting that studies on head-to-head comparisons between monitoring pathways are of limited power, leading to gaps in the literature. In a large head-to-head retrospective study, rates of flap salvage were noted to be statistically equivalent between clinical monitoring, microdialysis, or an implantable Doppler probe, and there were 4 false-positive results (1.0%), which caused unnecessary returns to the operating room.[94] Near-infrared tissue oximetry has high rates of false-positives as well, leading to significant ambiguity in interpreting alerts.[95] With a relatively low rate of flap compromise and with most of these cases occurring within the first day, some recommend similarly short courses for inpatient monitoring.[95,97]

Complications

Rates of total flap loss for DIEP flaps are reportedly low in some reviews, ranging from 0.9% to 2.0%, whereas the rates of partial flap necrosis vary widely between 0.1% and over 10%, depending on the definition used.[98,99] The most commonly identified cause for flap failure is venous congestion.[99,100] However, the rates of total or partial flap necrosis and fat necrosis are not significantly different between DIEP and pedicled TRAM flaps; the rates of hernia are lower for the former.[100]

Comparisons between SIEA flaps and muscle-sparing TRAM or DIEP flaps are limited, although there is a significantly higher rate of anastomotic revision because of arterial compromise with SIEA flaps.[11,101] At 2 years after surgery, the rate of any complication is higher for those undergoing autologous reconstruction than for those undergoing expander-implant–based reconstruction, but reconstructive failure rates are lower with autologous reconstruction.[102] Congruently, infection rates are lower with DIEP flaps when compared with expander-implant reconstruction.[102] Satisfaction is high with microsurgical abdominal flap breast reconstruction, and in a head-to-head comparison with expander-implant reconstruction, respondents reported improved satisfaction and quality of life with the former.[103] Additional procedures can be performed after abdominally based flap surgery, including nipple reconstruction, contour adjustments, and scar revision.[104,105]

Innovations and Future Directions

New directions in the field are emerging to address previous shortcomings. Some patients are deemed to not be candidates for these procedures on account of insufficient abdominal wall subcutaneous tissue. Hybrid breast reconstruction, with the addition of acellular dermal matrix and/or implants, allows for increased flexibility with regard to donor-site volume (Figs. 5 through 7).[106] (**See Video [online]**, which displays that, in hybrid breast reconstruction, microsurgical anastomosis is routinely performed after the prepectoral implant is secured.) In this approach, the implant is placed beneath the flap to allow for immediate correction of the volume imbalance. In cases where the patient is equivocal on the desired volume, implants can be safely placed in revision procedures. Similarly, fat grafting of the flaps in one or more stages can be safely implemented in revision procedures with incremental volume gains and based on patient desire. Late abdominal bulge is a frequent cause of morbidity for many patients undergoing abdominally based flaps. The ability to limit the fascial dissection theoretically minimizes this risk, and the surgical capability for this already exists. Several centers are trialing the use of robotic approaches to abdominal flap dissection whereby the submuscular pedicle dissection is accomplished with robotic assistance (Fig. 8).[69–71] Even without robotic assistance, limited fascial incisions can allow for the harvest of the abdominal flaps with significantly decreased rates of neurogenic deviations for the abdominal wall musculature.[107] This technique involves making separate short (3 to 4 cm) fascial incisions where the vessels course through the muscle and where the pedicle meets the iliac

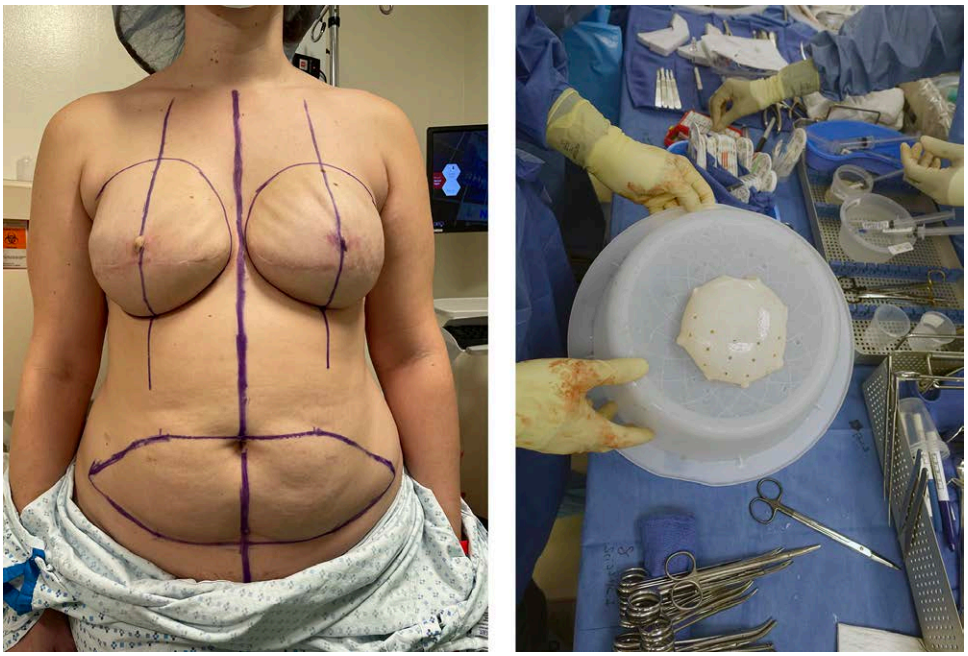

Fig. 5. (*Left*) Frontal view of a patient with previous bilateral prepectoral silicone implant breast reconstruction is shown. The patient reported implant visibility, palpability, and rippling. (*Right*) A smooth round silicone implant is wrapped with acellular dermal matrix.

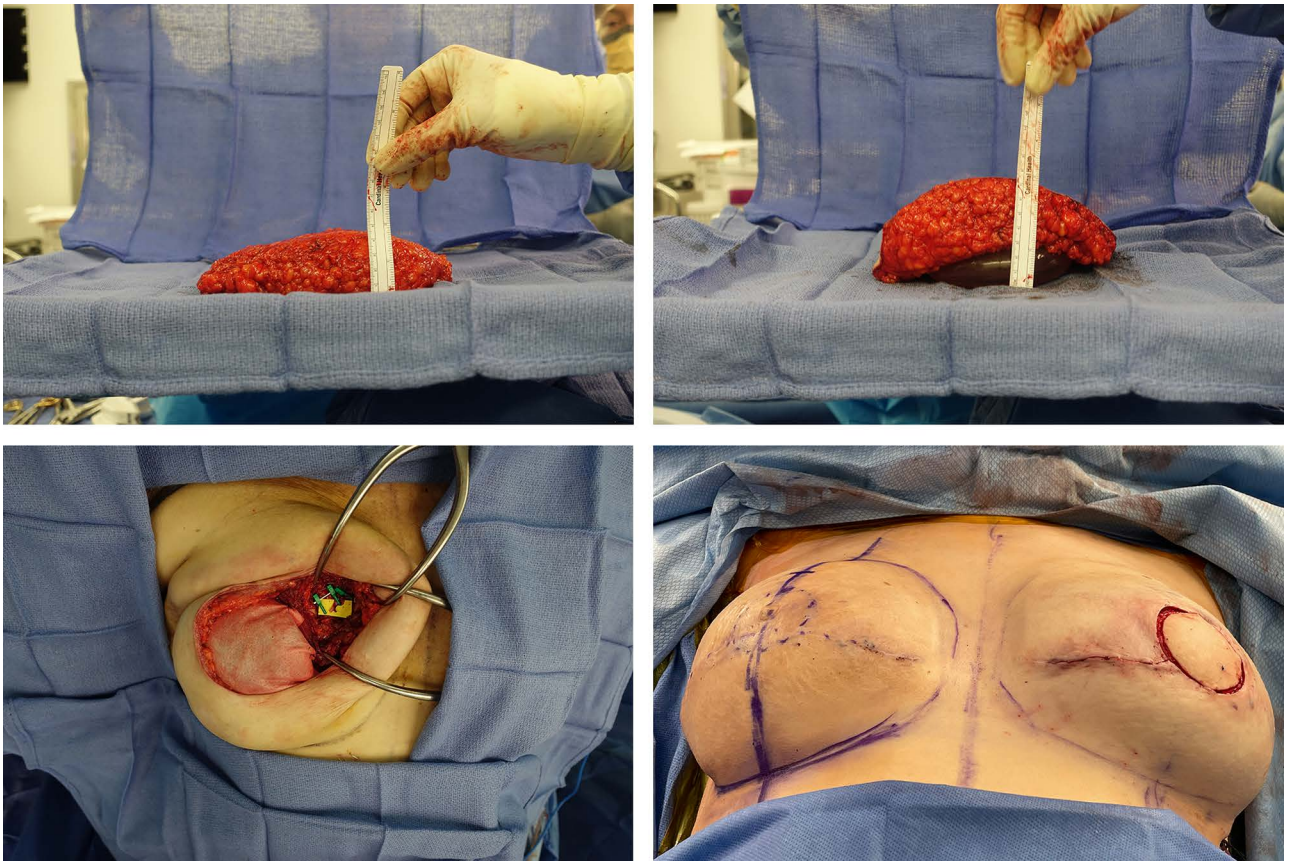

Fig. 6. The projection achieved with (*above*, *left*) DIEP flap alone and (*above*, *right*) DIEP flap and an underlying implant is shown. (*Below*, *left*) The implant (wrapped in acellular dermal matrix) is secured in the prepectoral position before microsurgical anastomosis. (*Below*, *right*) The left breast hybrid breast reconstruction with DIEP flap and prepectoral implant is completed.

vessels and subsequently tunneling the pedicle through the incisions after division.[107]

Lastly, there is some debate on the use of nerve grafts to reestablish sensation to the abdominal flaps (Fig. 9).[108,109] Because of nonstandardized assessments of postoperative sensation (pain versus touch versus temperature) and patient satisfaction, it is difficult to define the true benefit of neurotization. In a recent meta-analysis, data indicate that neurotization enhances the magnitude and rapidity of sensory recovery, and this has been shown to lead to improved patient-reported outcomes.[109] The specifics of the techniques involved and their utility are the subject of ongoing research. To cite some examples, sensory recovery can be expected at 6 months in neurotized DIEP flaps raised with a skin island and at 24 months in buried flaps.[110] The use of a 7-cm nerve allograft can lead to effective sensory recovery, and this allows for easy rotation of the nerve beneath the flap and coaptation of sensory-only donor-recipient targets.[110,111] Sensory-only nerves are identified piercing the rectus fascia and traveling to the subcutaneous tissue of the flap in the abdomen and piercing the muscle fascia of the anterior or lateral chest. There are no known studies directly comparing and investigating the primary repair of targets, use of autograft, acceptable graft length, ideal donor or recipient targets, and sensory recovery in reference to the size of the skin paddle.

The Next Level in Autologous Microsurgical Breast Reconstruction

As expertise continues to evolve in abdominally based autologous breast reconstruction, there is continued refinement of protocols and techniques at every step of the process. Prehabilitation with set exercise programs can improve upper extremity functional recovery and allow patients to feel recovered sooner after surgery.[112] With respect to core strength, there are insufficient data to suggest a benefit, but patients may find subjective gains.[113] The recognition of the importance of preoperative discussion and shared decision-making has allowed patients to feel more

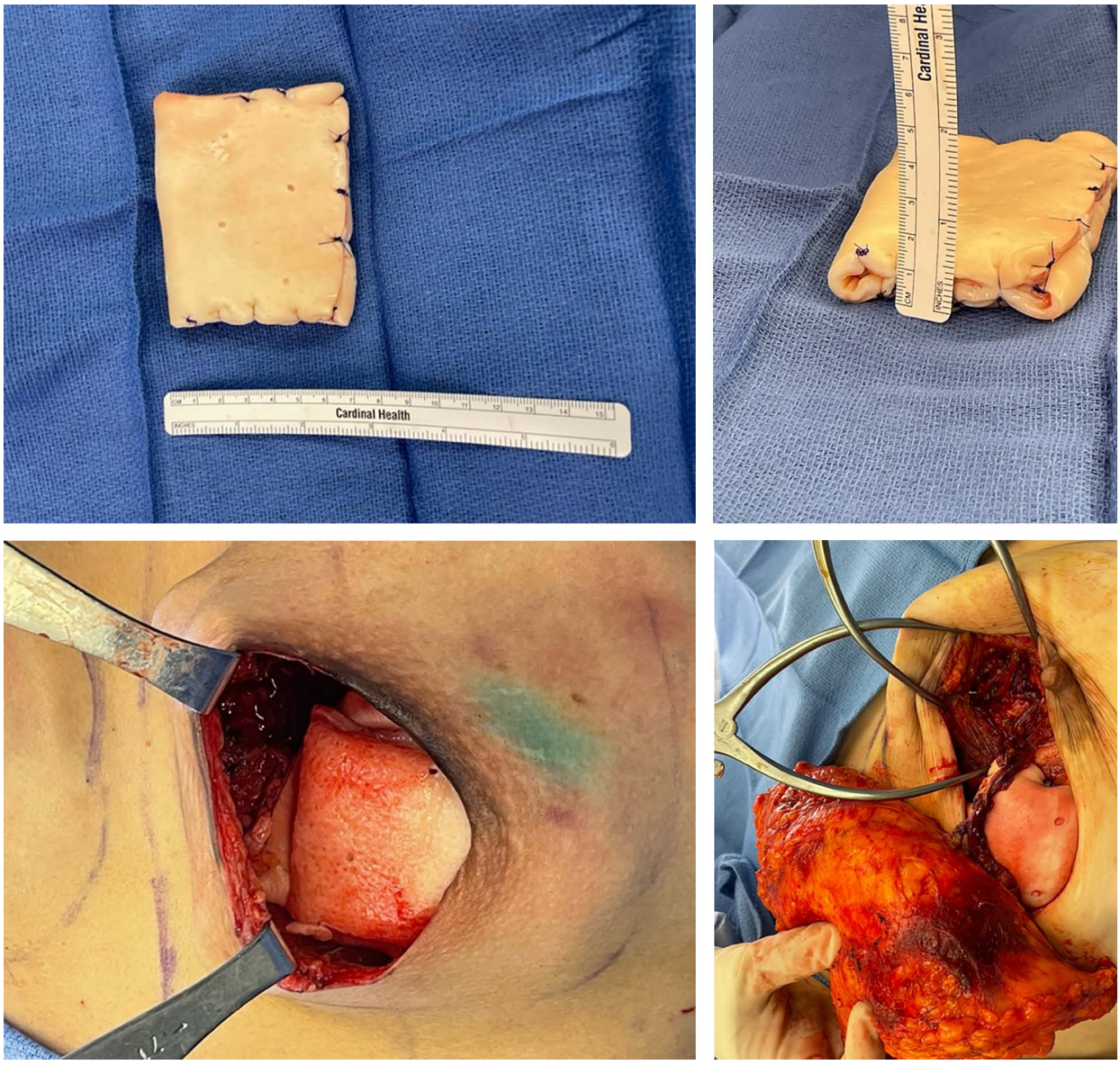

Fig. 7. (*Above*, *left*) In select cases, hybrid breast reconstruction can be completed with just acellular dermal matrix (without the use of an implant). (*Above*, *right*) The acellular dermal matrix provides core projection to the breast reconstruction. (*Below*) The implant (wrapped in acellular dermal matrix) is secured in the prepectoral position before microsurgical anastomosis.

empowered with respect to their choices at a difficult and helpless time in their lives.[114] With respect to the reconstructive approach, enhanced attention to aesthetic goals can push the limits of what can be achieved with breast reconstruction. The approach to aesthetically oriented microsurgical breast reconstruction means not simply restoring a breast mound but attempting to improve the contour and overall appearance of the breast from the preoperative baseline. For example, the surgeon should consider preserving mastectomy skin only where it suits the anticipated final result and not needlessly keeping irradiated skin of poor quality.[114] In a nipple-sparing approach, greater attempts are made at preservation than for skin-sparing approaches. In both cases, one must be able to guide decisions based on planned future revisions such as mastopexy or delayed placement of an implant or fat grafting or both concurrently. The abdominal donor site should be thought of not only as a donor site with inherent morbidity but also as a site for contouring. This means considering the use of plication suturing, trying to lower incisions where possible, addressing tissue excess at the lateral extents, and ensuring good appearance for the umbilicus. For the latter, one

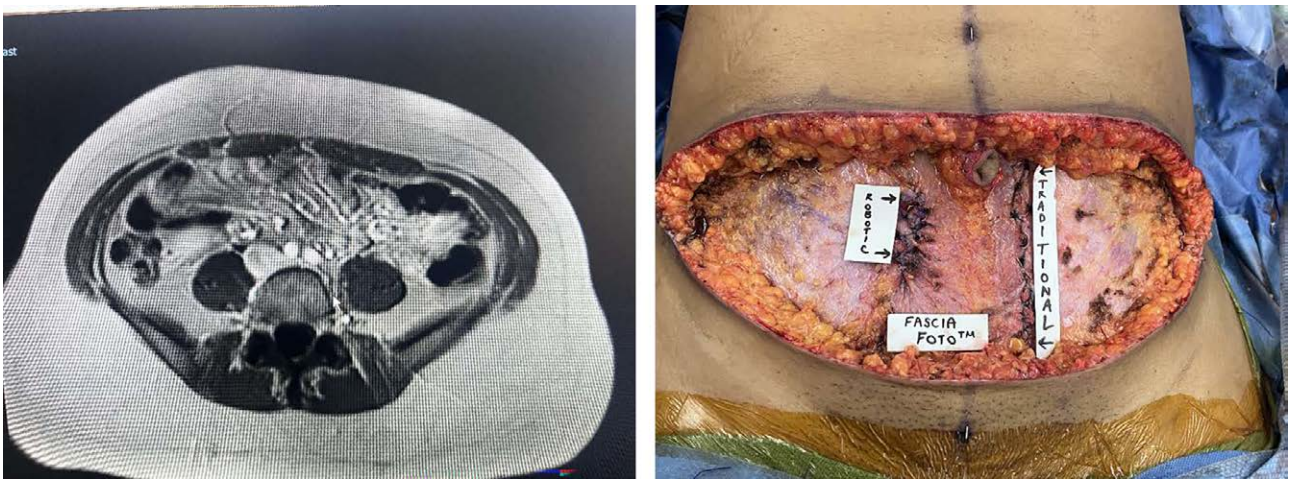

Fig. 8. (*Left*) Axial radiograph demonstrates the vascular anatomy appropriate for robot-assisted right DIEP flap harvest. (*Right*) The fascial defect following robot-assisted right DIEP flap harvest is much shorter than that following traditional left DIEP flap harvest.

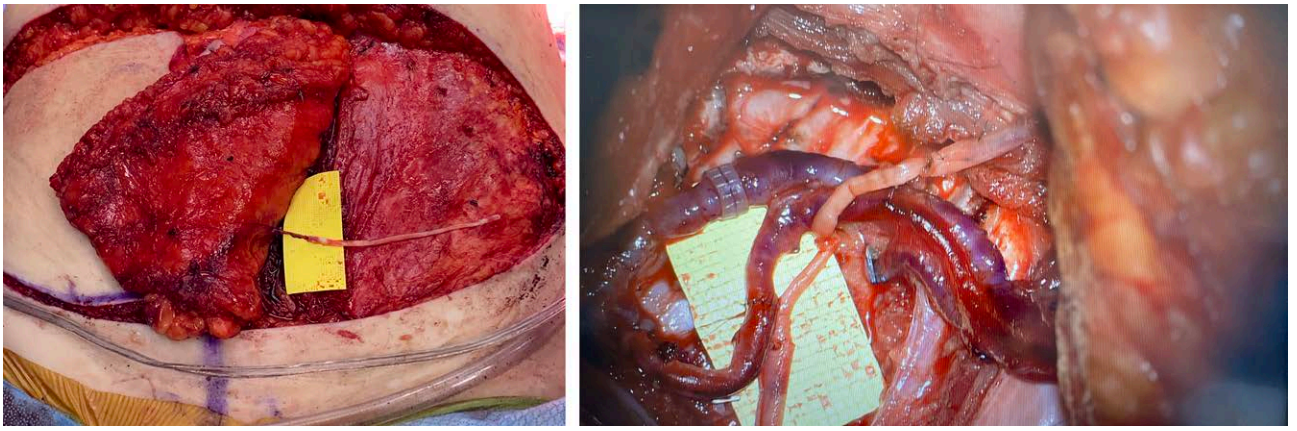

Fig. 9. (*Left*) Sensory nerve coaptation is shown at the flap donor site between the donor nerve and cadaveric nerve allograft. (*Right*) Neurorrhaphy at the recipient site is shown.

may draw from the literature on abdominoplasty where recommendations include a small, noncircular size.[115] In cases of poor umbilicus vascularity where the stalk is sacrificed, neoumbilicoplasty can be performed with excellent aesthetic outcomes.[116]

CONCLUSIONS

Since their original description, abdominally based free flaps have become a reliable and popular tool for postmastectomy reconstruction. Methods to enhance efficiency have allowed this operation to be performed safely and effectively, and years of adaptations have allowed for broad use and optimized outcomes.[117–121] Comprehensive attention to preoperative, intraoperative, and postoperative factors can improve patient care and satisfaction. Future directions aim to build on these gains, limit morbidity, and expand the reach of these procedures to more patients.

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DISCLOSURE

The authors have no financial interests to disclose. No funding was received for this article.

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