Evidence-Based Medicine: Autologous Breast Reconstruction

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Learning Objectives: After studying this article, the participant should be able to: 1. Gain an understanding of the different methods of autologous reconstruction available. 2. Understand the timing of autologous breast reconstruction and the impact of adjuvant and neoadjuvant treatments. 3 Understand the factors necessary for a comprehensive patient assessment. 4. Gain knowledge of patient factors that will affect autologous reconstruction and potential contraindications. 5. Summarize the patient-reported and clinical outcomes of autologous breast reconstruction.

Summary: This article was prepared to accompany practice-based assessment with ongoing surgical education for the Maintenance of Certification for the American Board of Plastic Surgery. It is structured to outline the care of the patient with the postmastectomy breast deformity. (*Plast. Reconstr. Surg.* 139: 204e, 2017.)

Autologous tissue transfer facilitates the primary goals of breast reconstruction. These include creation of a mound that matches preoperative dimensions, position, and contour; has natural consistency; and is long lasting. Refinements in autologous techniques have enhanced the current reconstructive options to a stage where outcomes closely parallel the presurgical form (Fig. 1), establishing it as the gold standard for breast reconstruction.[1] Harvest techniques and flap viability have improved to the point where focus has shifted toward improving breast and donor-site aesthetics mirroring those seen in elective cosmetic surgery. To date, multiple series in the literature have shown no detrimental effect on the detection of cancer recurrence.[2–9] Most importantly, the Halstedian dismissal of breast reconstruction as frivolous has been replaced with an appreciation for the psychological impact of the loss of a breast and the acceptance of reconstruction as an integral part of breast cancer care.[10] This Continuing Medical Education article provides an overview of the current state of autologous breast reconstruction with a focus on influential, evidence-based advancements.

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THE BREAST RECONSTRUCTION PATIENT

Patients seeking breast reconstruction most commonly desire maintenance of their preoperative form (Fig. 2a). A small proportion request moderate cosmetic enhancement (Fig. 2b), and a third group request complete revision of a previous reconstruction (Fig. 2c). Patient expectations play a major role in postoperative satisfaction, and realistic outcomes must be discussed from the outset. Patients deemed to have inadequate preparatory information before embarking on breast reconstruction have been shown to have a higher rate of decisional regret and dissatisfaction.[11,12] A thorough preoperative evaluation of the patient's expectations and suitability for a particular reconstruction is therefore essential.

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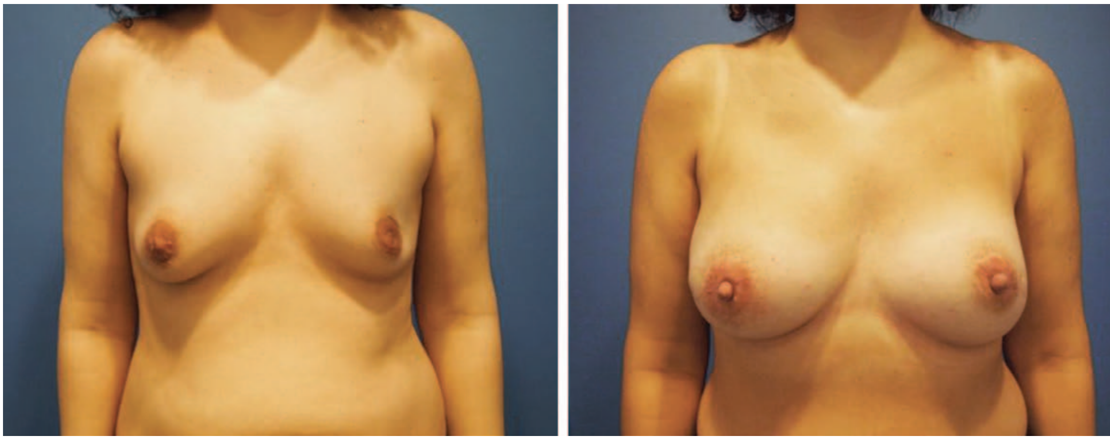

Fig. 1. A 43-year-old patient who underwent bilateral areola-sparing mastectomies for left invasive lobular carcinoma (mastectomy weight, approximately 450 g). Reconstruction was performed using bilateral deep inferior epigastric artery perforator flaps and C-V flap nipple reconstruction.

PATIENT SELECTION

Age

Women aged 65 years or older represent only 3 percent of patients undergoing autologous breast reconstruction. This may be a result of surgeon perception of increased perioperative risk[13–16]; however, multiple studies have found that age is not a predictor for poor outcomes following microvascular reconstruction.[17,18] Patients older than 65 years undergoing abdominally based reconstruction do not differ regarding satisfaction, flap loss, fat necrosis, breast-site morbidity, wound healing, or infection compared to patients younger than 65 years.[16] Autologous reconstruction may be particularly beneficial for the older patient given that these patients generally present with ptotic breasts and abdominal laxity (Fig. 3). Current data support the safety of autologous breast reconstruction in this patient population; however, increasing age may be associated with higher rates of venous thromboembolism and hernia requiring repair.[19,20] Furthermore, coexisting conditions such as hypertension and cardiovascular disease may interact with advanced age to increase perioperative risk, and a careful preoperative screening process is therefore important.

Body Mass Index

A recent meta-analysis including over 6000 patients undergoing free autologous reconstruction has found obesity (body mass index >30) to be associated with increased overall complications, donor- and recipient-site complications, and partial flap failure (Table 1).[9,20–24] The authors concluded that patients with a body mass index greater than 30 can be offered microsurgical autologous breast reconstruction, provided that they are made aware of the increased risk of complications and the surgeon takes special care to modify technique, including minimal abdominal flap undermining, and prioritizes muscle-sparing procedures. Patients must be assessed for intraabdominal fat content. Those with a large degree of intraabdominal fat may be at higher risk for abdominal wall complications and thus not suited to abdominally based reconstruction. There is evidence to suggest that patients with a body mass index greater than 40 are at exceedingly high risk of flap failure and should be considered carefully before free microsurgical reconstruction.[25–27]

Radiation Therapy

The requirement for radiation therapy presents a challenge to the reconstructive surgeon. The options include (1) mastectomy, then irradiation and delayed reconstruction; (2) irradiation, then mastectomy with immediate reconstruction; and (3) mastectomy with immediate reconstruction, then irradiation (Fig. 4). There is also a subset of patients presenting for mastectomy after previous breast conserving surgery with radiation therapy. There are no directly comparative studies of adjuvant timing protocols. A recent systematic review compared patients that had previous breast conserving therapy and radiation therapy with subsequent mastectomy and immediate flap reconstruction to patients that had immediate flap reconstruction and radiation therapy to the flap (Fig. 4c).[22] This study found similar rates of flap loss, wound healing complications, infection, and fat necrosis. They also reported a high rate of flap fibrosis (27 percent) in flaps being

Fig. 2. (*Left*) A 60-year-old patient with a body mass index of 35 who underwent right delayed reconstruction using a deep inferior epigastric perforator flap and nipple-share after mastectomy and radiation therapy. This patient requested decreased overall breast size and underwent a left breast reduction to enhance the postoperative result. (*Center*) A 65-year-old patient with a body mass index of 27 who underwent right immediate reconstruction using a deep inferior epigastric perforator flap after mastectomy. Six months after initial reconstruction, she underwent bilateral Wise pattern mastopexies to enhance her postoperative result (see Fig. 19). (*Right*) A 38-year-old patient with a body mass index of 24 who underwent complete revision using latissimus dorsi flaps with implants following failed implant reconstruction.

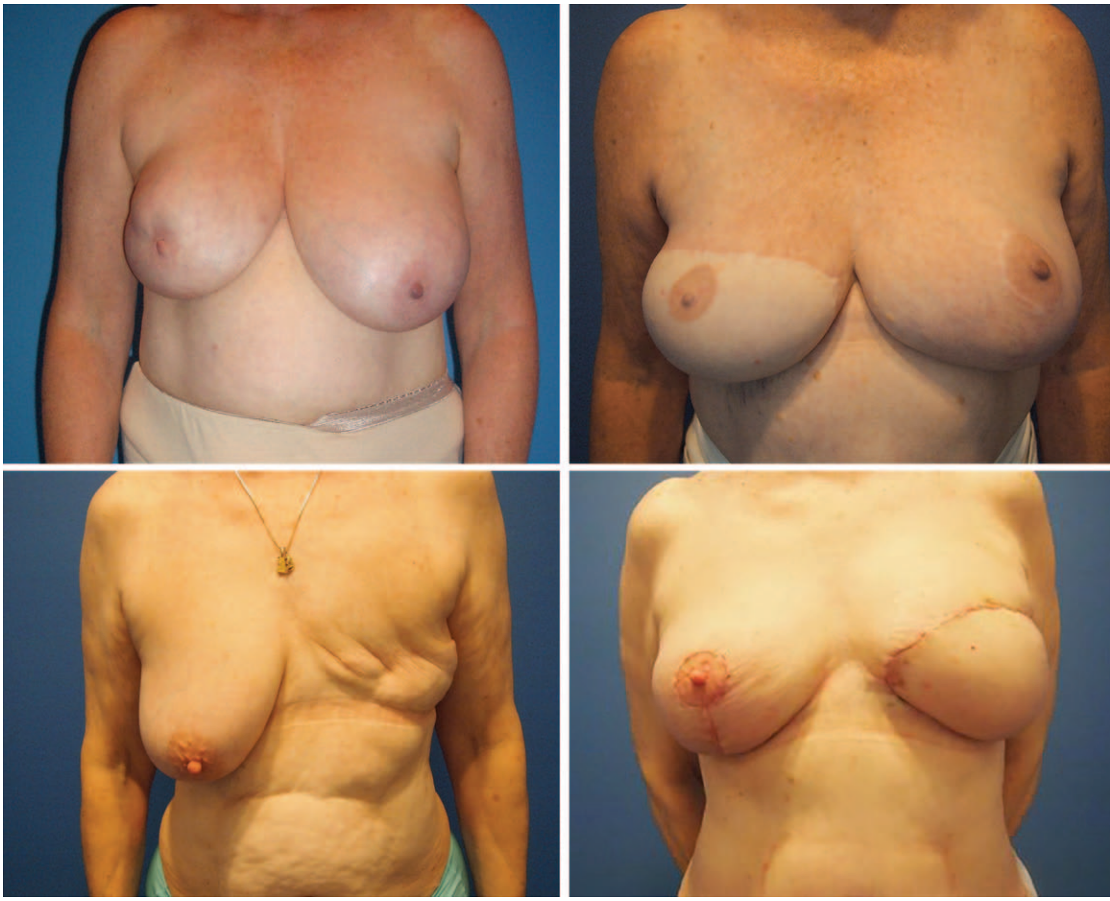

Fig. 3. (*Above*) A 67-year-old, otherwise healthy patient who presented for delayed reconstruction after mastectomy and radiation therapy for right invasive breast cancer. She underwent deep inferior epigastric perforator flap reconstruction and breast reduction, with no postoperative complications. (*Below*) A 75-year-old, otherwise healthy patient who presented for delayed reconstruction after mastectomy for left invasive breast cancer. She underwent deep inferior epigastric perforator flap reconstruction and mastopexy, with no postoperative complications.

Table 1. Patient Factors and Operative Risk: What to Explain to Patients Preoperatively

Patient Factor	Risk
Advanced age (>65 yr)	Increased risk of venous thromboembolism (OR, 3.7)[9]
	Increased risk of abdominal hernia/bulge requiring repair (HR, 1.73)[20]
BMI >30	Increased risk of overall complications (OR, 2.77)[21]
	Increased risk of donor-site hernia/bulge (OR, 1.98)[21]
	Increased risk of partial flap failure (OR, 2.81)[21]
	Increased risk of mastectomy flap necrosis (OR,14.8)[21]
	Increased risk of recipient delayed healing (OR, 2.8)[21]
	Increased risk of donor-site wound infection (OR, 2.0)[21]
	Increased risk of donor-site seroma (OR, 3.0)[21]
Irradiation to flap	Increased risk of flap fibrosis (27%)[22]
	No increased risk of wound healing complications (14%)[22]
	No increased risk of fat necrosis (13%)[22]
	No increased risk of infection (6%)[22]
Prior abdominal surgery	Increased risk of abdominal donor-site wound healing delay (3–23%)[23,24]
	Increased risk of converting to muscle harvest[24]
	Decreased risk of partial flap loss

HR, hazard ratio; BMI, body mass index.

exposed to radiation immediately after reconstruction (Table 1). Similar studies of radiation therapy after reconstruction have found rates of fat necrosis, revision surgery, and flap fibrosis ranging from 17 to 35 percent.[28–32] In contrast, neoadjuvant radiation before mastectomy and immediate reconstruction (Figs. 4, *center*, and 5) has been associated with lower rates of fibrosis (3

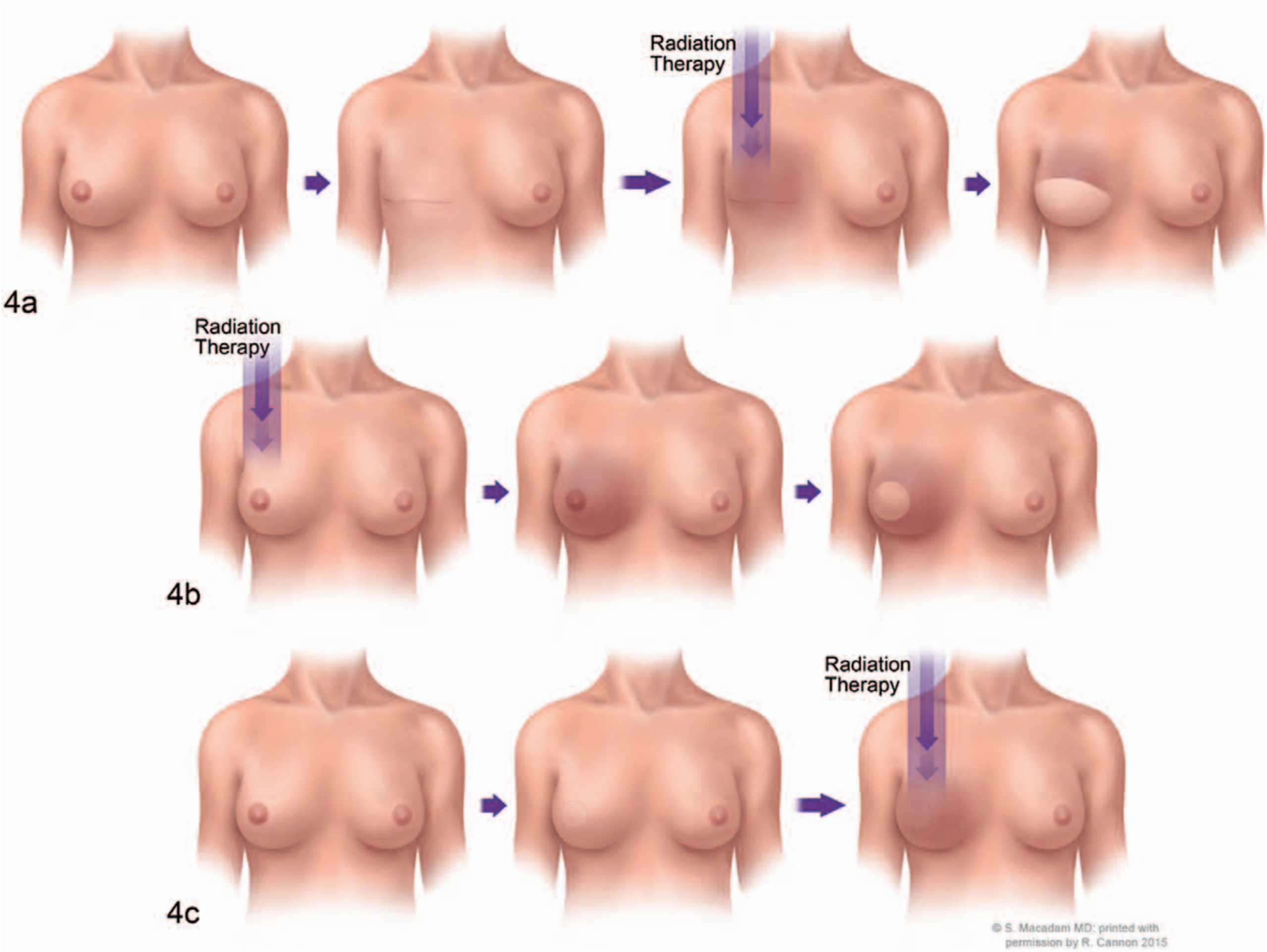

Fig. 4. (*Above*) Mastectomy with radiation therapy of the chest wall and subsequent delayed autologous reconstruction. (*Center*) Preoperative radiation therapy followed by mastectomy with immediate autologous reconstruction. (*Below*) Mastectomy, immediate autologous reconstruction followed by radiation therapy.

percent).[31] Spear et al. have also concluded that aesthetic outcome is consistently favored by sparing irradiation directly to the flap.[32] The limited evidence available suggests that radiation therapy before mastectomy with immediate reconstruction may result in less flap fibrosis than performing radiation therapy after immediate flap reconstruction. Delayed reconstruction will likely result in the least amount of flap fibrosis, as the skin envelope is replaced with nonirradiated tissue. If this sequence is chosen (mastectomy, irradiation, and delayed reconstruction (Figs. 4a and 6), the evidence supports waiting 12 months before embarking on flap reconstruction.[33]

Prior Abdominal Surgery

Two recent studies have compared abdominally based breast reconstruction in patients with prior abdominal surgery to those without and found no differences in major complications or flap loss. However, there was a higher rate of delayed healing of the donor site in patients that had undergone prior abdominal surgery.[23,24] An increased rate of converting to muscle harvest because of scarring has been reported, and decreased partial flap loss may be attributable to the delay phenomenon.[34] Prior abdominal surgery does not preclude the ability to perform an abdominally based reconstruction, but patients should be counseled regarding this evidence (Table 1). Significant caution should be used in bilateral reconstructions with multiple prior abdominal scars, and preoperative imaging may be valuable if perforator flaps are planned for these patients.

TIMING

Indications for immediate breast reconstruction have expanded to include patients with advanced disease, comorbidities, and radiation

Fig. 5. A 49-year-old patient who underwent left preoperative radiation therapy and then skin-sparing mastectomy for left invasive lobular carcinoma (mastectomy weight, approximately 650 g). Reconstruction was performed using a unilateral deep inferior epigastric perforator flap and nipple-share reconstruction.

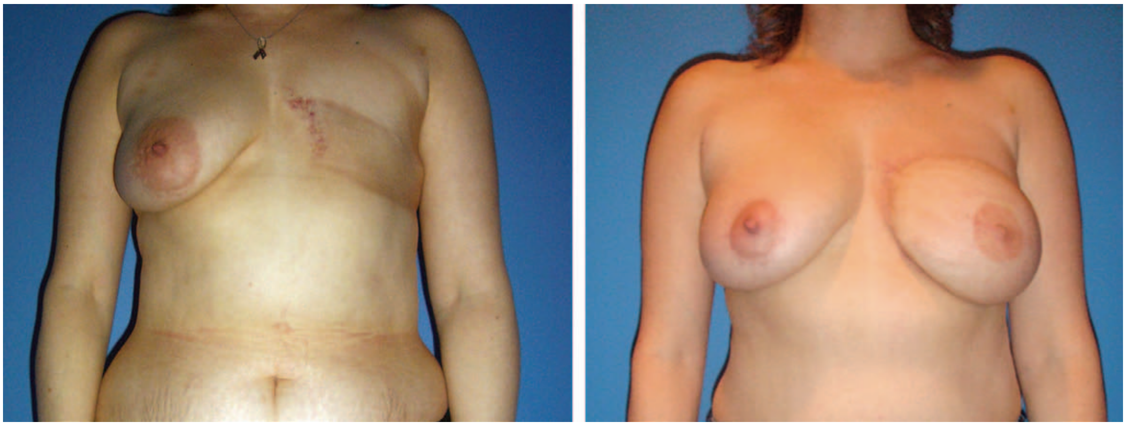

Fig. 6. A 40-year-old patient who underwent left mastectomy, postoperative radiation therapy, and then delayed reconstruction for left multifocal invasive ductal carcinoma. Reconstruction was performed using a unilateral deep inferior epigastric perforator flap and C-V flap nipple reconstruction.

therapy.[35–37] When indications for radiation therapy are unknown, a sentinel lymph node biopsy may be considered before mastectomy. If postoperative radiotherapy is planned, many authors still recommend delayed reconstruction[38–40]; however, increasingly, immediate reconstruction is being performed in this setting.[30,31] In general, immediate reconstruction should be considered for all patients. Factors that may lead to delay of reconstruction include comorbidities, a prohibitively high body mass index, and patient factors such as emotional inability to cope with the recovery period. Delaying reconstruction in the setting of radiation therapy will be institution specific.

NIPPLE-SPARING MASTECTOMY

One of the most influential changes in the field of breast reconstruction has been progression to preservation of the nipple-areola complex. In selected patients, nipple-sparing mastectomy can be performed, with acceptable rates of local recurrence.[41,42] Nipple involvement can be predicted by a tumor-to-nipple distance less than 2.5 cm, positive lymph node status, stage III or IV disease, estrogen and progesterone receptor-negative status, HER2-positive status, and ductal carcinoma in situ.[43–45] A recent meta-analysis of 5594 patients has found no difference in overall survival, disease-free survival, or local recurrence in women undergoing therapeutic nipple-sparing mastectomy versus skins-sparing mastectomy or modified radical mastectomy.[46] This suggests that cancer recurrence is more strongly associated with tumor biology than with surgical approach. Ideal reconstructive candidates include those that have limited to no ptosis, do not require radiation therapy, and have a low risk for nipple involvement (Table 2).[47,48] The patient with the ptotic breast may be a candidate for immediate nipple-sparing mastectomy with reconstruction

Table 2. Factors Predictive for Nipple Involvement

Tumor-to-nipple distance <2.5 cm
Positive lymph node status
Stage III/IV disease
Estrogen receptor-negative
Progesterone receptor-negative
HER-positive
Ductal carcinoma in situ

and subsequent mastopexy as described by DellaCroce et al.[49] Once selected, nipple-sparing mastectomy may be performed in one stage with immediate reconstruction, or in two stages with partial glandular resection and nipple core biopsy (surgical delay) followed by completion mastectomy and reconstruction weeks to months later.[50,51] A positive biopsy mandates nipple removal at the second stage. In the setting of immediate reconstruction, a skin paddle may be inserted within the lateral or vertical extension and can be removed at a secondary procedure (Fig. 7). If the procedure is performed through the inframammary fold, the internal mammary vessels may be approached at the level of the fourth or fifth intercostal space and a skin paddle inserted along the inframammary fold. In all approaches, the small skin paddle size limits the ability to find a vascular signal. Implantable Doppler devices may be required for postoperative care if vascular signals are not locatable.

RECIPIENT VESSEL SELECTION

Recipient vessels include the thoracodorsal vessels and the internal mammary vessels (Fig. 8). In a review of over 1400 cases, Saint-Cyr et al. found these options to be comparable (Table 3)[51–53]; however, the internal mammary artery flow is higher and may be useful when retrograde inflow is required.[54] Contrary to popular belief, Arnez et al. have shown that the internal mammary artery diameter is relatively consistent at the levels of the third, fourth, and fifth intercostal spaces. The vein typically bifurcates at the level of the fourth intercostal space, with the medial vein diameter on average 2.7 mm and the lateral on average 1.8 mm.[55] The impact of excluding the internal mammary vessels as a future option for coronary revascularization has not been studied sufficiently to make a recommendation.[56–58] In patients at high risk for coronary disease, an end-to-side anastomosis at the second or third intercostal space or use of an internal mammary perforator may be considered.[53] Conversion rate is most likely attributable to (1) previous axillary node dissection when using the thoracodorsal vessels and (2) small size when using the internal mammary vessels.[59–61] (**See Video, Supplemental Digital Content 1**, which shows dissection of the internal mammary vessels for use as recipient vessels in free flap breast reconstruction. This video is available in the "Related Videos" section of the full-text article on PRSJournal.com or at ***http://links.lww.com/PRS/B917***.)

AUTOLOGOUS RECONSTRUCTION: HOW TO CHOOSE THE BEST FLAP

Pedicled Transverse Rectus Abdominis Musculocutaneous Flap

Pedicled transverse rectus abdominis musculocutaneous (TRAM) flap reconstruction is associated with the highest rate of abdominal wall morbidity compared with other abdominally based techniques.[20,62–66] In addition, it carries a high rate of fat necrosis and partial flap loss (Table 4). This reflects the supply and

Fig. 7. A 41-year-old patient who underwent bilateral nipple-sparing mastectomies for right invasive ductal carcinoma (mastectomy weight, approximately 450 g). Reconstruction was performed using bilateral deep inferior epigastric perforator flaps with insertion of a lateral skin paddle for monitoring.

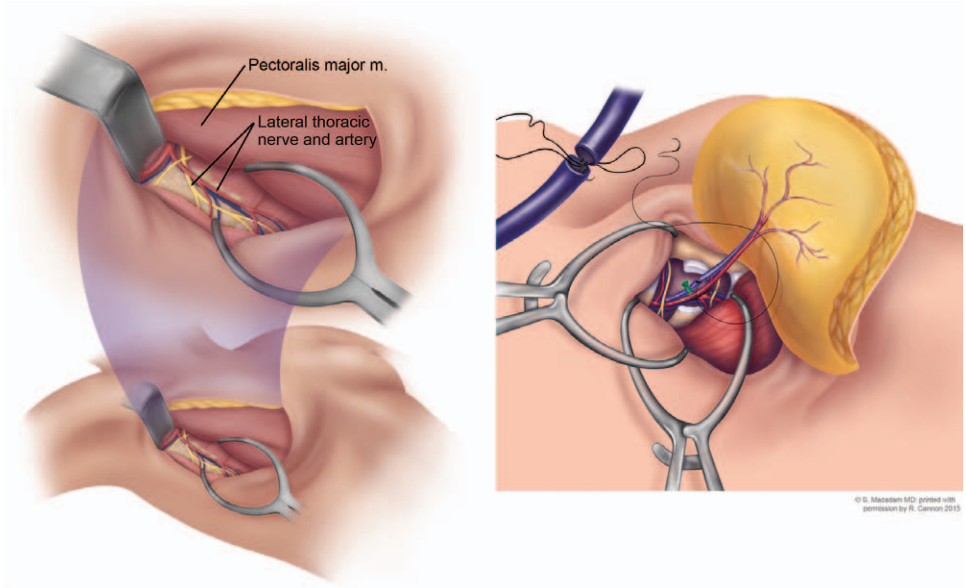

Fig. 8. Exposure of the thoracodorsal recipient vessels (*left*) and internal mammary recipient vessels (*right*).

Table 3. Internal Mammary versus Thoracodorsal Recipient Vessels

	Internal Mammary	Thoracodorsal
Vessel caliber, mm		
Artery	1–2.5[53]	1–2.5[53]
Vein	1–4[53]	1–4[53]
Arterial flow rate, ml/min	25[52]	2–8[52]
Possible complications	Pneumothorax	Iatrogenic injury if axillary node dissection required after reconstruction
Conversion rate, %	1.9[51]	2.8[51]

Video 1. Supplemental Digital Content 1 shows dissection of the internal mammary vessels for use as recipient vessels in free flap breast reconstruction. This video is available in the "Related Videos" section of the full-text article on PRSJournal.com or at ***http://links.lww.com/PRS/B917***.

drainage from the nondominant superior epigastric system requiring a reversal of flow through "choke vessels." Potential for kinking, twisting, or compression of the pedicle also exists during rotation.[67] These factors should be outlined to the patient preoperatively and the alternatives (muscle-sparing options) offered. With increasing popularity of muscle-sparing procedures, the pedicled TRAM flap is most commonly reserved for settings where perioperative support is not conducive to free tissue transfer, unilateral procedures, and in patients requiring shorter operative times

Table 4. Abdominal Reconstruction Complication Rates: What to Explain to Patients Preoperatively*

	Pedicled TRAM Flap (%)	DIEP Flap (%)	Free TRAM Flap (%)	Muscle-Sparing Free TRAM Flap (%)
Total flap loss	1.2	1.6	2.1	1.4
Partial flap loss	8.9	4	7.6	4.8
DVT or PE	1.6	1.2	1.4	1.4
Fat necrosis	25.3	16.3	16.7	15
Abdominal hernia/bulge	16.6	4.2	5.6	8.2
Abdominal hernia/bulge requiring repair	10	3.1	3.5	6.1

DIEP, deep inferior epigastric perforator; DVT, deep venous thrombosis; PE, pulmonary embolism.
*Serletti JM, Moran SL, Orlando GS, Fox I. Thoracodorsal vessels as recipient vessels for the free TRAM flap in delayed breast reconstruction. *Plast Reconstr Surg.* 1999;104:1649–1655.

Table 5. Outcomes: What to Explain to Patients Preoperatively

	Pedicled TRAM Flap (%)	DIEP Flap (%)	Free TRAM Flap (%)	Muscle-Sparing Free TRAM Flap (%)
Total flap loss	1.2	1.6	2.1	1.4
Partial flap loss	8.9	4	7.6	4.8
DVT or PE	1.6	1.2	1.4	1.4
Fat necrosis	25.3	16.3	16.7	15
Abdominal hernia/bulge	16.6	4.2	5.6	8.2
Abdominal hernia/bulge requiring repair	10	3.1	3.5	6.1

DIEP, deep inferior epigastric perforator; DVT, deep venous thrombosis; PE, pulmonary embolism.

(e.g., comorbidities, metastatic disease). Vascular delay by ligating the superficial and deep inferior epigastric systems has been shown to produce a statistically significant rise in vascular inflow to the pedicle.[68] This may be useful in high-risk patients such as smokers or those with obesity or prior radiation therapy. The TRAM flap blood supply is shown in Figure 9[69,70] and the operative technique is shown in Figure 10.[71]

DIEP, Muscle-Sparing Free TRAM, and Free TRAM Flaps

Free TRAM, muscle-sparing free TRAM, and DIEP flaps use the dominant vascular pedicle to the lower abdomen. The free TRAM flap maintains the entire vascular tree of the deep inferior epigastric vessels, and the muscle-sparing technique theoretically keeps a proportion and the DIEP maintains one to three specific perforators. The advantage of free TRAM flap reconstruction is improved blood supply, which is especially useful in patients requiring maximal volume or those at higher risk for partial flap loss. Free tissue transfer also affords easier manipulation during inset. These benefits are gained while accepting the potential for total flap loss. Muscle-sparing procedures were designed to improve donor-site morbidity associated with muscle-harvesting techniques while preserving these advantages. The deep inferior epigastric perforator (DIEP) flap has been shown in multiple studies to have a low rate of abdominal wall morbidity compared with other methods. It is advantageous for abdominal strength, postoperative pain, and cost compared with the free TRAM flap[72–74] and for lower abdominal-site morbidity, postoperative pain, shorter hospital stay, and lower rates of fat necrosis compared with the pedicled TRAM flap.[66,75] The inherent advantage of the DIEP flap is limited functional damage to the rectus muscle and no fascial defect, which reduces fascial closure tension and decreases the requirement for mesh. This potentially prevents a shift in the contralateral rectus muscle toward the midline, which can alter the mechanical advantage of the internal oblique muscles.

A recent large study has shown no difference in abdominal hernia/bulge or flap loss between the DIEP, muscle-sparing free TRAM, and free TRAM flaps and no difference in patient-reported abdominal satisfaction on the BREAST-Q.[62] Although the evidence is conflicting, current data suggest that abdominal wall morbidity outcomes are similar when using these three options.[62,76,77] The muscle-sparing classification is shown in Figure 11 and the DIEP flap operative sequence is detailed in Figure 12. (**See Video, Supplemental Digital Content 2**, which displays harvest of the DIEP flap using electrocautery. This video is available in the "Related Videos"

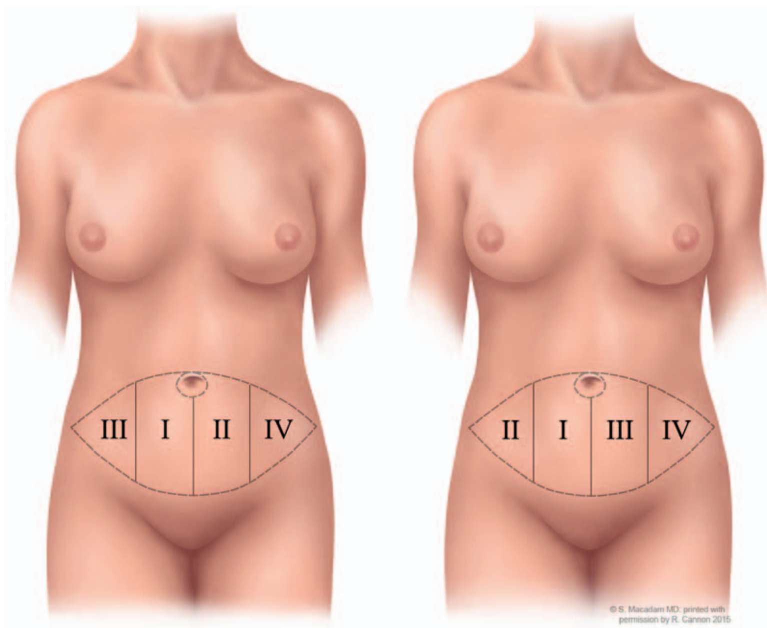

Fig. 9. (*Left*) Hartrampf's classification of TRAM flap zonal blood supply. Hartrampf names zone I directly over the muscle pedicle and zone II lying across the midline. (*Right*) Ninkovic's classification of TRAM flap and deep inferior epigastric perforator flap zonal blood supply. Holm et al. performed an in vivo study of deep inferior epigastric perforator flaps with indocyanine green and concluded that although zone I remains the most reliably perfused zone, any flow across the midline is less than ipsilateral flow and proposed that Hartrampf's zone II should be renamed zone III.

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Superficial Inferior Epigastric Artery Flap

Superficial inferior epigastric artery (SIEA) flap reconstruction confers no functional abdominal wall morbidity, with reported high rates of satisfaction and lower hospital stays compared with the other abdominally based reconstructions.[78,79] The SIEA pedicle is present in 94 percent of patients studied using preoperative computed tomography; however, only 24 percent of cases have a diameter greater than 1.5 mm and thus deemed suitable for free tissue transfer.[80] In a recent series comparing the SIEA flap to the DIEP flap, significantly more SIEA flaps required reexploration, with higher rates of arterial insufficiency and flap failure.[81] The predictive value of computed tomographic angiography for preoperative identification of favorable superficial inferior epigastric vessels is unclear, with most authors relying on direct visualization of these vessels before flap elevation. Surgical delay with ligation of the deep inferior epigastric artery has been shown to increase the caliber of the SIEA,[82,83] although the angiosome and thus volume of the SIEA flap is most commonly limited to the ipsilateral hemiabdomen. If contralateral tissue is needed for the breast reconstruction, intraoperative perfusion studies will need to be performed in order to verify perfusion before transfer. (**See Video, Supplemental Digital Content 3**, which displays harvest of the SIEA flap using electrocautery. This video is available in the "Related Videos" section of the full-text article on PRSJournal.com or at ***http://links.lww.com/PRS/B919***.)

Transverse Upper Gracilis, Profunda Artery Perforator, and Gluteal Artery Perforator Flaps

When abdominal tissue is not suitable, gluteal and thigh flaps are secondary reconstructive options. The transverse upper gracilis flap uses the medial thigh region and produces a relatively small breast (approximately 350 g)[84] in return for a straightforward dissection. Use of this donor site requires sufficient adipose tissue associated with skin laxity, allowing for closure similar to a medial thigh lift. It has been associated with donor-site wound breakdown, loss of volume with time, and sensory disturbance to the thigh.[85,86]

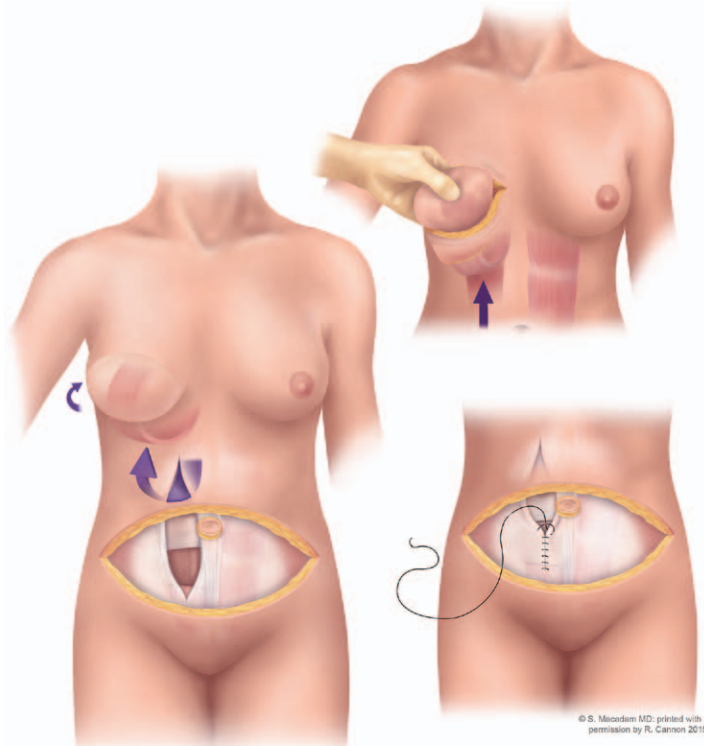

Fig. 10. An ipsilateral pedicled flap is planned whenever possible. Ipsilateral transfer reduces intermammary bulging, reduces pedicle tension, and improves venous drainage (Clugston PA, Gingrass MK, Azurin D, Fisher J, Maxwell GP. Ipsilateral pedicled TRAM flaps: The safer alternative? *Plast Reconstr Surg*. 2000;105:77–82). The flap is elevated off the abdominal wall until the medial row (1 to 2 cm from the linea alba) and lateral row (2 to 3 cm within the lateral border of the rectus sheath) of perforators are visualized on the planned donor side. The deep inferior epigastric vessels are dissected inferiorly with as much length as possible to allow supercharging the flap if needed. A muscle-sparing harvest is then performed, leaving inferior full width muscle and medial and lateral strips as wide as possible. It is essential to denervate the eighth intercostal nerve at the costal margin, which will cause the muscle to atrophy and prevent muscle bulging at the costal margin tunnel. Rotation of the TRAM flap proceeds in a counterclockwise direction if harvested from the left side, and a clockwise rotation when harvested from the right side, before passing the flap through a tunnel from the abdomen to the chest. Closure technique includes layers with figure-of-eight 1-0 Nurolon (Ethicon, Inc., Somerville, N.J.) followed by a running suture of double-stranded 0 PDS (Ethicon). Onlay or inlay Prolene (Ethicon) mesh is used if there is concern about the integrity of the repair or the remaining abdominal wall fascia.

Harvest modifications including resuspension of the superficial fascial system, limiting the width of the flap, and preservation of the saphenous vein may decrease these complications. Flap dissection is shown in Figure 13.[87] (**See Video, Supplemental Digital Content 4**, which displays harvest of the transverse upper gracilis flap using electrocautery. This video is available in the "Related Videos" section of the full-text article on PRSJournal.com or at ***http://links.lww.com/PRS/B920***.)

The profunda artery perforator flap has recently been described and has the advantages of longer pedicle length, better donor-site scar, larger skin paddle, and no muscle harvest.[88–90]

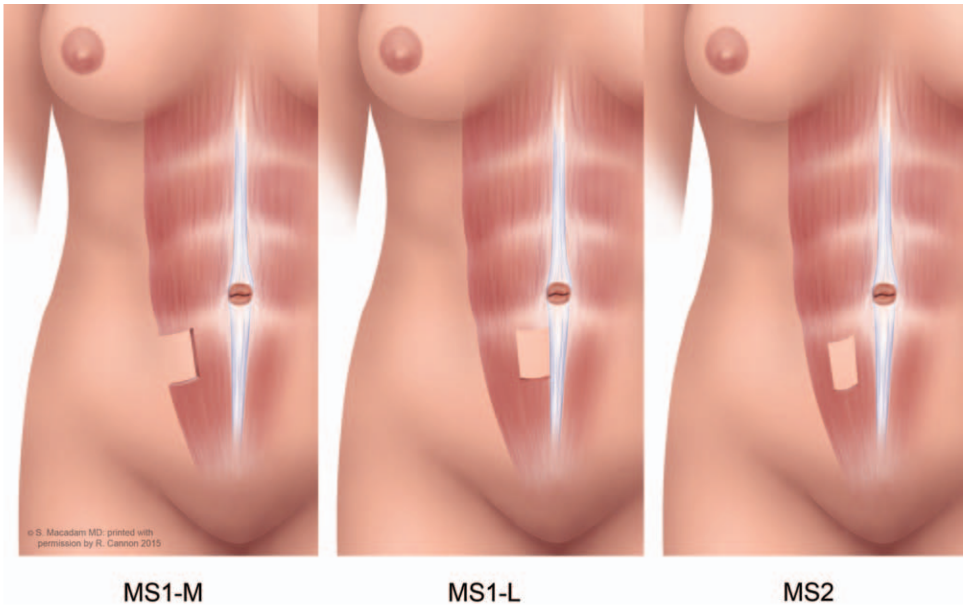

Fig. 11. Classification of muscle-sparing free TRAM flap procedures. MS0 refers to sacrifice of the full width of the rectus muscle, MS1 preserves the lateral segment, MS2 preserves the lateral or medial segments, and MS3 preserves the entire muscle (equivalent to a DIEP flap). MS1 can be further subdivided into MS1-M and MS1-L, depending on whether it is the medial or lateral segment that is spared.

The skin paddle is situated slightly posterior and inferior to the transverse upper gracilis flap. Routine preoperative imaging allows for verification of the perforator course from the profunda femoris vessels and its entrance position into the medial thigh skin. Skin paddle positioning is determined from this information. Disadvantages include a more difficult dissection and the potential need for a position change if harvested in the prone position. The evidence for this technique is limited but suggests that flap volume is similar to the transverse upper gracilis flap harvest. When harvesting a profunda artery perforator flap, care should be taken to preserve the transverse upper gracilis and inferior gluteal artery perforator flaps for bailout, and preoperative imaging should be considered.[91]

Younger or nulliparous patients may have insufficient abdominal donor tissue but sufficient tissue in the buttock region. Buttock fat is more globular and dense compared with abdominal fat, which limits the ability of the flap to conform to the shape of the mastectomy skin envelope. Shaping and insetting of these flaps is more challenging than with abdomen- or thigh-based flaps. Both the superior and inferior gluteal artery perforator flaps can be raised on a single perforator with lateral-based perforators preferentially chosen to increase the pedicle length. Venous anatomy below the gluteus muscle is difficult to dissect because of numerous side branches and the significantly increased size of the dominant vein. Choice of the superior or inferior flap is typically made based on the most favorable distribution of fat (Fig. 14).[92] (**See Video, Supplemental Digital Content 5**, which displays harvest of the superior gluteal artery perforator flap using electrocautery. This video is available in the "Related Videos" section of the full-text article on PRSJournal.com or at ***http://links.lww.com/PRS/B921***.)

Latissimus Dorsi and Thoracodorsal Artery Perforator Flaps

The latissimus dorsi myocutaneous flap and the thoracodorsal artery perforator flap generally do not provide enough soft tissue to recreate a breast mound and thus are used in combination with a prosthesis or fat transfer to provide adequate breast volume. The extended latissimus flap recruits additional adipose tissue from up to five fat compartments, affording flap volumes of 400 cc in 70 percent of patients.[93,94] This obviates the use of an implant but has been criticized for poor donor-site healing and contour.[95] Harvesting the flap in a subfascial plane has been shown to reduce seroma formation and

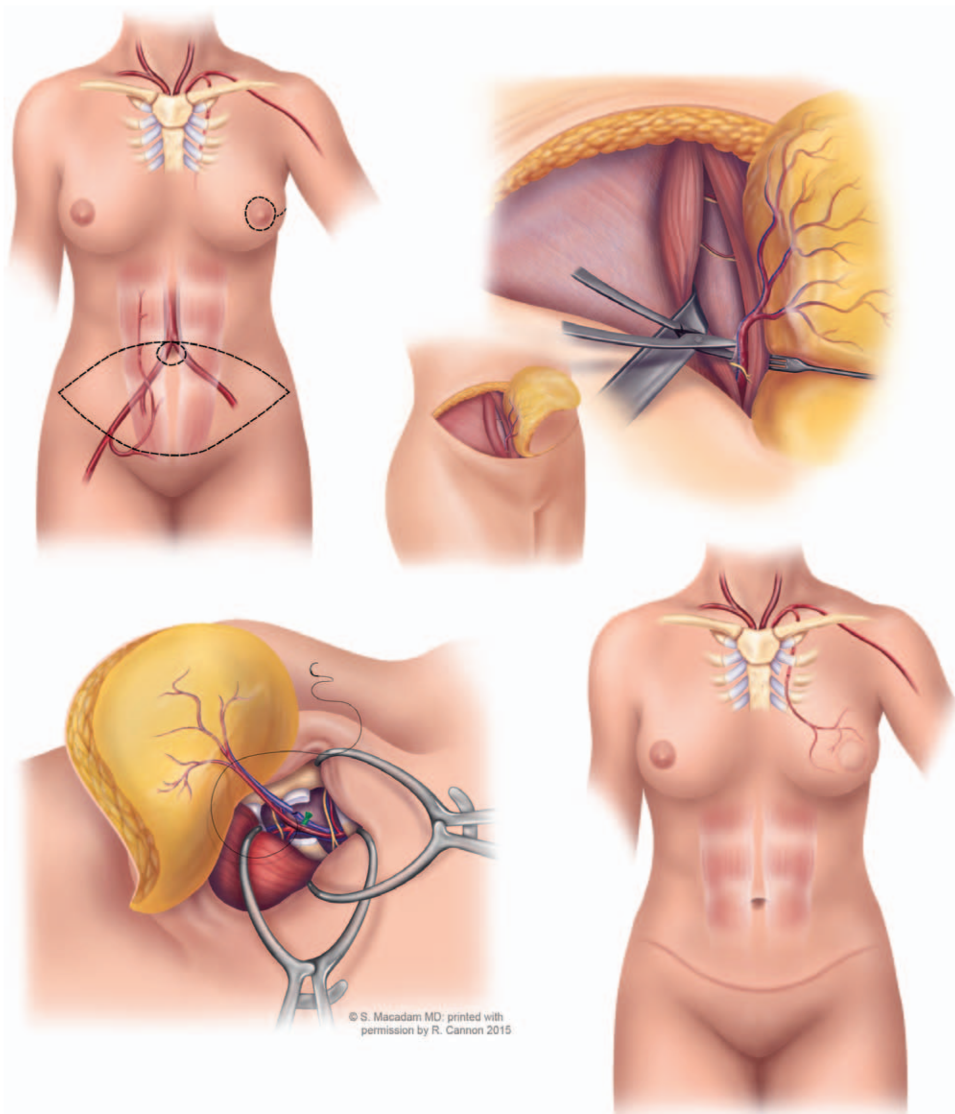

Fig. 12. Skin and subcutaneous tissue are raised from the abdominal fascia and perforators are identified. Differential clamping is performed to identify the dominant perforator. In the majority of cases, a single perforator is chosen. A longitudinal incision is made in the rectus fascia that does not descend inferior to the arcuate line. The dominant perforator is dissected using electrocautery through the muscle to its junction with the deep inferior epigastric vessels. The shortest pedicle length with adequate vessel caliber is used. The pedicle is then divided and passed under any preserved nerves that cross the pedicle. Fascia is closed with interrupted 0 Nurolon sutures and reinforced with a running 0 Nurolon suture.

improve donor-site pain and scar adherence. Although traditionally reserved for partial mastectomy defects, Santanelli et al. have described use of the thoracodorsal artery perforator flap for total breast reconstruction in small breasts. If based on a distal perforator, pedicle length up to 25 cm may be achieved.[96] Proponents of latissimus flaps herald a failure rate of less than 1 percent, with safe use in patients unsuitable for abdominally based or microsurgical reconstruction, including morbid obesity, smoking, and diabetes.[97]

PREOPERATIVE IMAGING

Assessment of perforator anatomy to aid in operative planning can be performed in advance using computed tomographic angiography. Its use is controversial because of cost, nephrotoxicity, and radiation exposure. The

Video 2. Supplemental Digital Content 2 displays harvest of the DIEP flap using electrocautery. This video is available in the "Related Videos" section of the full-text article on PRSJournal.com or at ***http://links.lww.com/PRS/B918***.

Video 3. Supplemental Digital Content 3 displays harvest of the SIEA flap using electrocautery. This video is available in the "Related Videos" section of the full-text article on PRSJournal.com or at ***http://links.lww.com/PRS/B919***.

predictive value of computed tomographic angiography in identifying those perforators ultimately used in DIEP flap reconstruction has been reported from 75 to 82 percent.[98] Computed tomographic angiography has evolved from simple perforator identification to comprehensive mapping enabling perforator selection optimized for both operative time and muscle injury, based on a combination of location, intramuscular course, and caliber (Fig. 15). A recent systematic review has shown preoperative computed tomographic angiography to be associated with significantly fewer flap-related complications, reduced donor-site morbidity, and shorter operative time by 88 minutes.[99] However, complete reliance on this technology is not advised, as intraoperative changes are not uncommon.[100] Intraoperative perfusion analysis by means of indocyanine green fluorescence imaging can aid in the assessment of perforator dominance and flap viability. Although this technology holds promise to potentially decrease the rate of flap and fat necrosis, controlled studies are lacking.

OUTCOMES

When using patient-reported quality of life as an outcome measure, Atisha et al. have shown that autologous reconstruction is the gold standard. In

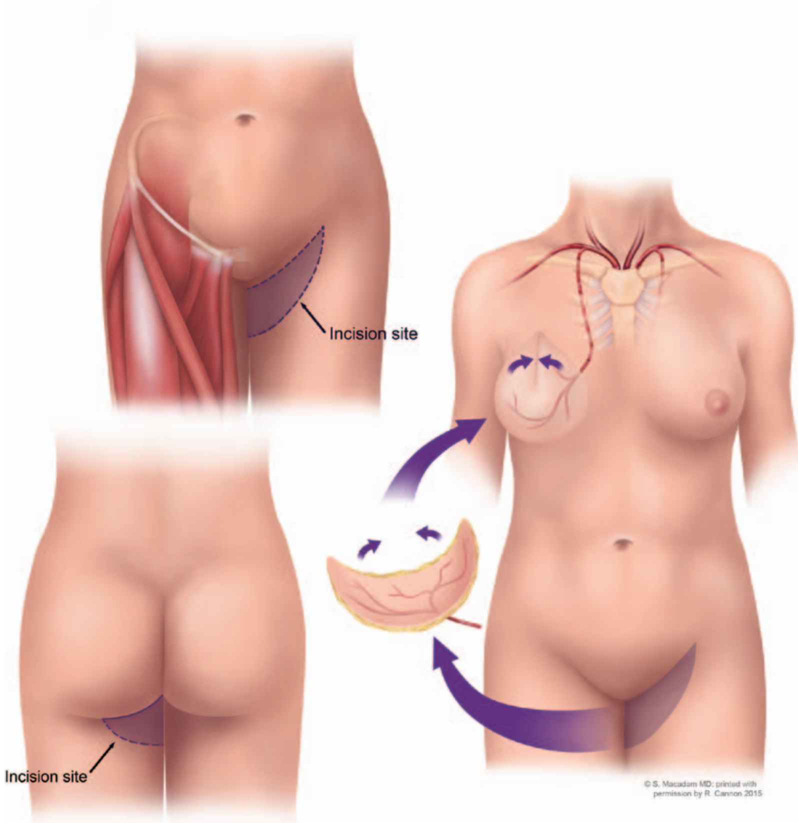

Fig. 13. Transverse upper gracilis flap harvest: the superior aspect of the flap is marked 2 cm below the groin crease and extends into the gluteal crease posteriorly. The anterior limit is approximately 5 cm anterior to the lateral border of the gracilis muscle to avoid damaging lymphatics. The anteroposterior length measures up to 25 cm and the width is determined by the amount of thigh laxity and may vary from 5 to 10 cm. The procedure is performed with the patient in the lithotomy position. The anterior incision is made and the saphenous vein is identified and left in situ. The anterior flap dissection proceeds superficial to the muscular fascia until the adductor longus is visualized. The space between the adductor longus and gracilis is identified, and the vascular pedicle to the gracilis is isolated. To harvest maximal length, the pedicle is taken as close to its origin from the profunda femoris as possible. The posterior dissection is then performed. Fatty tissue is undermined beyond the skin paddle to include as much upper thigh fat as possible with the flap. The muscle is transected superiorly and inferiorly and the flap is transferred to the chest in a contralateral fashion if the internal mammary vessels are used as recipients. (Buntic RF, Horton KM, Brooks D, Althubaiti GA. Transverse upper gracilis flap as an alternative to abdominal tissue breast reconstruction: Technique and modifications. *Plast Reconstr Surg*. 2011;128:607e–613e.)

a study of over 7000 patients, these authors identified a spectrum of postoperative satisfaction scores. Using breast conserving surgery as a reference, patients that underwent mastectomy and no reconstruction scored lowest, patients that underwent reconstruction with implants scored on average 8.6 points lower than those with breast conserving surgery, and patients that underwent abdominal flap reconstruction scored 5.6 points higher than those with breast conserving surgery. Autologous reconstruction with gluteal or thigh flaps scored highest.[1] This has been corroborated by another recent study by Jagsi et al.[101] These authors have also shown that higher BREAST-Q satisfaction is associated with lower stage disease, lower body mass index, higher income, graduate level education,

Video 4. Supplemental Digital Content 4 displays harvest of the transverse upper gracilis flap using electrocautery. This video is available in the "Related Videos" section of the full-text article on PRSJournal.com or at ***http://links.lww.com/PRS/B920***.

and the ability to work or volunteer. Colakoglu et al. surveyed 716 women and found that aesthetic satisfaction is lower in patients that develop a complication, older patients, and those with a prophylactic mastectomy.[102]

Gart et al. analyzed 3296 patients using National Surgical Quality Improvement Program data and found American Society of Anesthesiologists classification 3, body mass index greater than 30, recent surgery, delayed reconstruction, and prolonged operative times to be predictors of increased complications.[103] Overall complications were highest in pedicled TRAM flap reconstruction. The average flap failure rate in free flaps was 5.7 percent. The increase in complications in delayed reconstructions may reflect previous radiation therapy.

In general, patients with muscle-sacrificing flaps have been found to have more abdominal wall weakness relative to muscle-sparing groups. Knox et al. compared 165 DIEP flap procedures to 443 pedicled TRAM flaps and found eight times the odds of hernia/bulge in the pedicled TRAM flap group after controlling for confounders.[66] Vyas et al. compared free TRAM flaps to muscle-sparing free TRAM and DIEP flaps and found a 13.5 percent incidence of hernia/bulge in the free TRAM flap group compared with 3.9 percent in the DIEP flap group.[104] Muscle-sparing free TRAM flap patients had a 6.6 percent incidence of hernia/bulge, and they concluded that although there was a significant difference between the free TRAM and DIEP flap groups, there was no difference between muscle-sparing free TRAM and DIEP flap groups. In a study of over 1700 patients, Macadam et al. found the highest rates of hernia and bulge in the pedicled TRAM flap group and no differences in hernia/bulge when comparing DIEP to muscle-sparing free TRAM and free TRAM flap patients.[62]

Overall, patients embarking on autologous reconstruction should be counseled that the benefits include high postoperative satisfaction and a long-lasting result, with natural aging, ptosis, and responsiveness to change in body weight. Postoperative satisfaction may be lower in the setting of postoperative complications, higher stage of disease, high body mass index, lower income, lower education level, and prophylactic surgery. The effect of age on satisfaction is as of yet equivocal.[16,102] Complications include total and partial flap loss, wound healing delay, donor-site morbidity, fat necrosis, seroma, infection, and venous thromboembolism. Elevated body mass index has consistently been found to be associated with an increased risk of complications.[21] The rate of venous thromboembolism is low (1 to 2 percent) and likely equivalent when comparing abdominally based reconstructions.[62] Patients may be counseled that in the setting of autologous reconstruction, total flap loss ranges from 1 to 6 percent, fat necrosis ranges from 15 to 25 percent, infection ranges from 3 to 7 percent, and the available literature studying the rate of donor-site morbidity has found variable results.[62–66,75–77]

THE DIFFICULT RECONSTRUCTION

Thrombosis in Free Flap Reconstruction

Salvage rates of compromised free flap breast reconstruction are generally high (80 percent), with lower salvage rates being reported for multiple-revision events (53 percent). Salvage rates are improved in the multiple-event situation when an alternate recipient vessel is used.[105] Venous congestion represents the greatest threat to flap compromise[106]; the reported incidence in free abdominal breast reconstruction ranges from 2 to 20 percent.[107] Underlying causes include venous thrombosis, poor perforator selection, and anatomical superficial venous system dominance.[108] Anatomical and in vivo imaging studies have concluded that drainage of the anterior abdominal wall is preferential through the superficial system, with DIEP flap venous outflow from superficial to deep dependent on deep inferior epigastric artery perforator venae

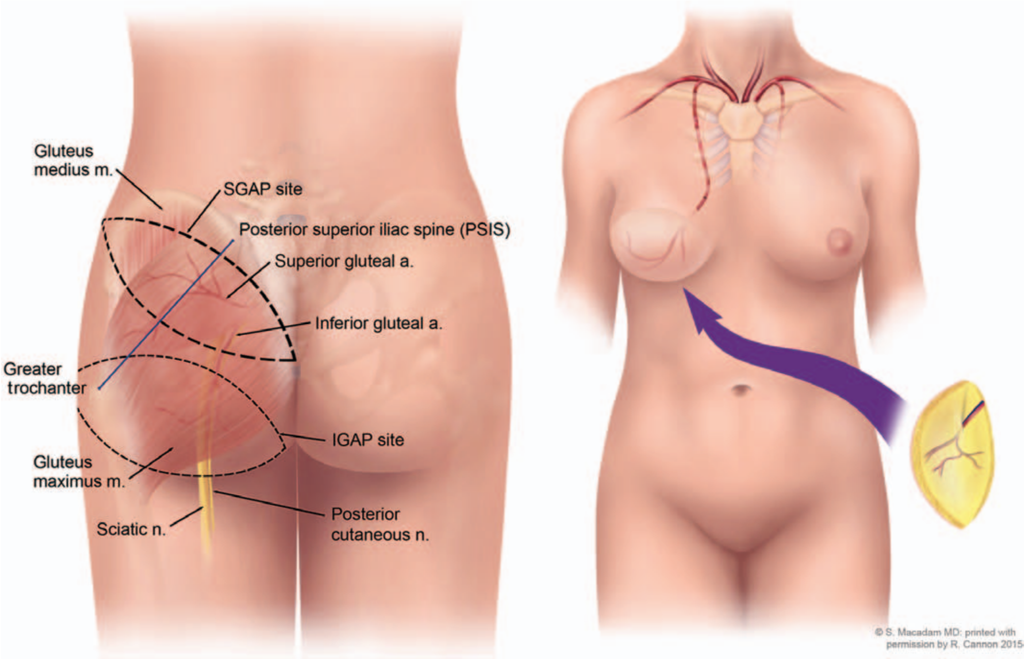

Fig. 14. Superior (*SGAP*) and inferior gluteal artery perforator (*IGAP*) flaps. For the superior gluteal artery perforator flap. The perforators are located approximately one-third of the distance on a line from the posterior superior iliac crest to the greater trochanter. The skin paddle is marked in an oblique pattern from inferomedial to superolateral. Flap width is 7 to 10 cm and length is 18 to 22 cm. For the inferior gluteal artery perforator flap, the gluteal fold is marked and an ellipse is drawn to include perforators with the lower incision in the gluteal fold and the upper incision extended approximately 7 cm superiorly. Beveling is required, and the flaps are elevated from the muscle in the subfacial plane. Perforators are approached from lateral to medial or medial to lateral. Once a large perforator is identified, muscle is spread and the perforator is followed. When harvesting the inferior gluteal artery perforator flap, care must be taken to preserve the medial fat pad over the ischium medial to the gluteus maximus muscle to prevent donor-site discomfort. (Allen RJ, Levine JL, Granzow JW. The in-the-crease inferior gluteal artery perforator flap for breast reconstruction. *Plast Reconstr Surg*. 2006;118:333–339.) The course of the inferior gluteal artery perforating vessels is longer than that of the superior gluteal artery perforators, which leads to a longer pedicle length for the inferior gluteal artery perforator flap.

Video 5. Supplemental Digital Content 5 displays harvest of the superior gluteal artery perforator flap using electrocautery. This video is available in the "Related Videos" section of the full-text article on PRSJournal.com or at ***http://links.lww.com/PRS/B921***.

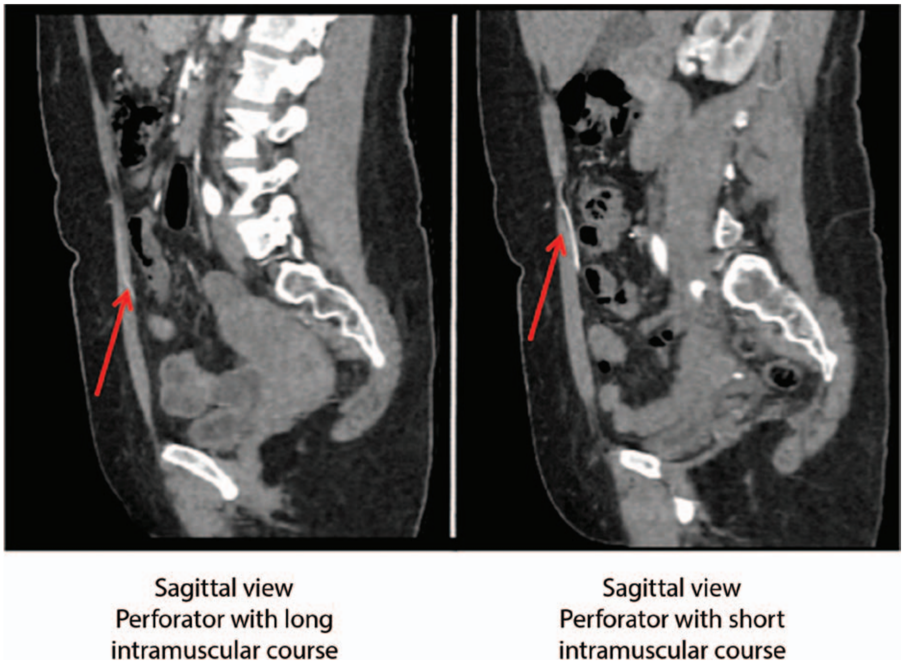

Fig. 15. Computed tomographic angiography images showing the difference between a perforator with a long intramuscular course, versus one with a short intramuscular course (preferred). Axial and sagittal views are viewed side by side and images are linked. This allows a large perforator seen on axial view to be linked in real time to the sagittal view so that intramuscular course and proximity to muscular incisurae are visualized.

comitantes.[109,110] Accordingly, intraoperative DIEP venous congestion has been attributed to persistent superficial system dominance in 0.9 percent, compared to a 0.3 percent rate of venous thrombosis.[111] Presented with congestion despite a patent deep system anastomosis, a previously dissected superficial inferior epigastric vein can be anastomosed to an alternative recipient (supercharging), such as a second internal mammary vein (Fig. 16), lateral thoracic vein, thoracoacromial vein, internal mammary vein perforator, or thoracodorsal vein. A vein graft (saphenous, forearm cutaneous, or redundant deep inferior epigastric vein) may be required to avoid positional and shaping compromise of the flap.[112] The use of vein grafts has success similar to the use of the cephalic venous turndown,[113] but both incur dissection time and further patient morbidity. An alternative strategy involves anastomosis of the superficial inferior epigastric vein to a proximally dissected deep inferior epigastric vena comitans, creating a superficial-to-deep venous loop within the flap.

In the event of arterial thrombosis, the anastomosis is revised. Reported salvage rates using adjuvant intraflap thrombolysis range from 65 to 85 percent.[106,114] A typical protocol includes 2 mg of tissue plasminogen activator infused through the arterial pedicle with the flap isolated from the systemic circulation. Although thrombolysis has not been shown as clearly advantageous over reanastomosis alone, a fourfold reduction in fat necrosis of salvaged flaps has been reported.[114]

Large Breast, Insufficient Donor Tissue

Patients that present with a large breast and limited donor-site tissue represent a reconstructive challenge. In these cases, one option for unilateral reconstruction is reducing the contralateral breast and reconstructing a smaller breast size. However, in some patients, the ultimate result with a standard abdominal flap will be aesthetically unacceptable. In these patients, an abdominally based flap augmented with an implant (performed immediately or >6 months after reconstruction) or a latissimus flap with tissue expander and subsequent implant (Fig. 2, *right*) may be considered. However, many patients wish to avoid implant reconstruction, and in these patients, options include use of the entire abdominal pannus. Unfortunately, perfusion to the entire abdomen is frequently inadequate on a single pedicle, with Hartrampf zones II and IV and Holm zones III and IV being most at risk (Fig. 9). The bipedicled TRAM flap and the stacked

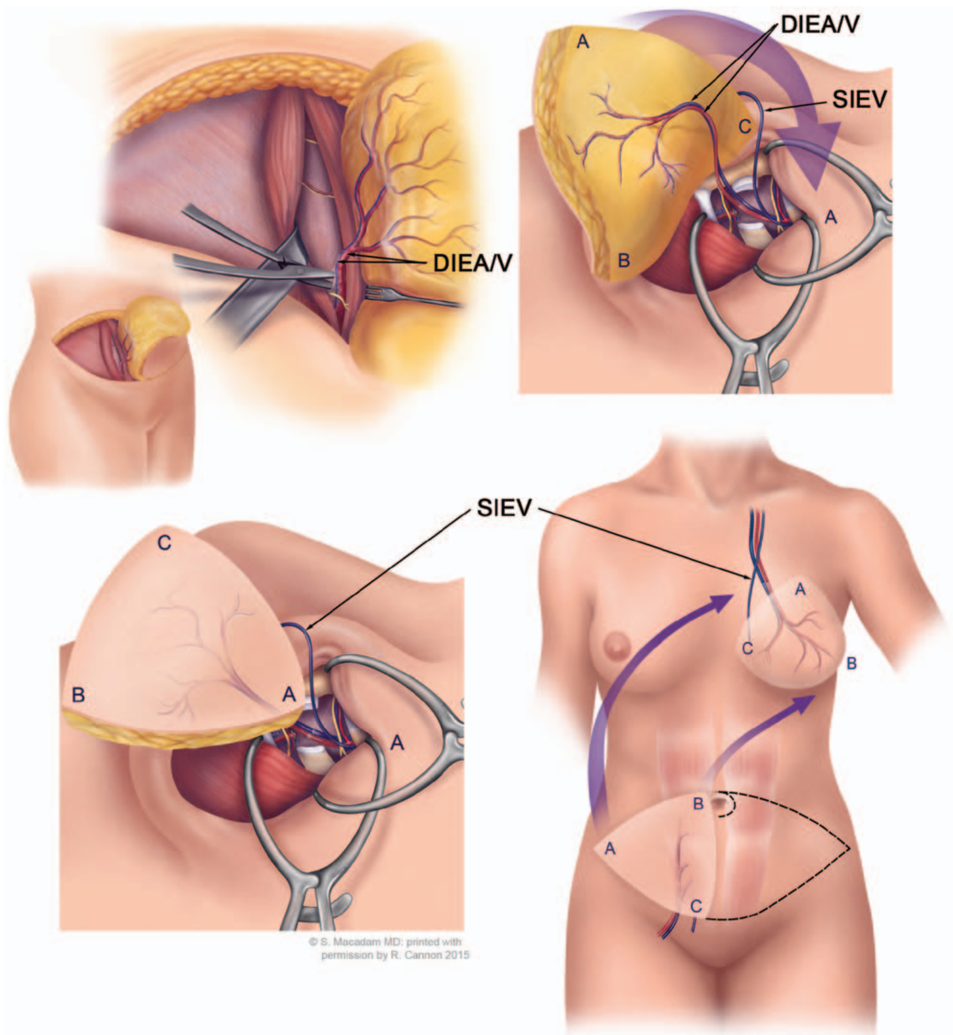

Fig. 16. Approach to salvage of a venous compromised flap. Points *A*, *B*, and *C* orient the reader to the flap. Point *C* is the location of the superficial inferior epigastric vein (*SIEV*), which is dissected with the DIEP flap. In a contralateral transfer, this vein may be anastomosed to a second internal mammary vein to salvage a venous compromised flap. In an ipsilateral transfer, it may be anastomosed to a lateral chest wall vein or the thoracodorsal vein. *DIEA/V*, deep inferior epigastric artery/vein.

DIEP flap reconstruction use the vascular supply of both hemiabdomens, allowing for a larger unilateral reconstruction. DellaCroce et al. have described dissection and stacking of two DIEP flaps. This avoids muscle sacrifice and limitations in flap inset associated with the bipedicled TRAM flap.[115,116] The flaps may be transferred as two separate flaps or as one unit folded on itself. The contralateral flap is anastomosed to the internal mammary vessels. The ipsilateral flap is deepithelialized and anastomosed to a branch point on the primary flap's pedicle (Fig. 17).[115] Similar techniques of using two separate flaps for one breast reconstruction can be performed using SIEA, transverse upper gracilis, gluteal artery perforator, and profunda artery perforator flaps. These techniques are associated with increasing degrees of technical difficulty and are not routinely performed.[117–119]

REVISION AND AESTHETIC REFINEMENTS OF THE PRIMARY AUTOLOGOUS RECONSTRUCTION

Autologous reconstruction is associated with an average of 1.06 additional interventions.[120] This is in contrast to implant reconstruction, which generally requires multiple revision operations over a patient's lifetime because of capsular contracture, implant displacement, and changes in the patient's body habitus. Refinements may be categorized as follows: (1) skin island revisions

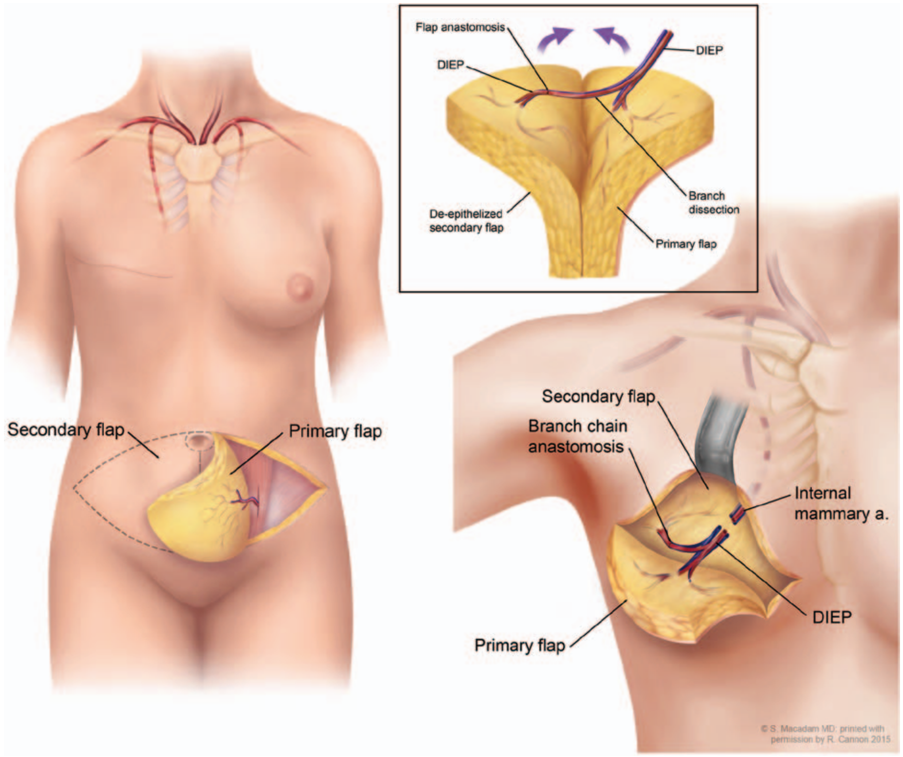

Fig. 17. The primary flap is the flap opposite the breast being reconstructed. This flap is dissected first as described in Figure 12. Dissection of the superficial system is performed and ligated just proximal to entry into the common femoral artery. As the deep inferior epigastric vessels are identified, all large branches including the distal extent of the deep inferior epigastric artery are preserved to serve as anastomosis points for the second flap. The second flap (secondary) is dissected in a manner similar to the first flap without concern for dissection of branch points. The SIEA pedicle is preserved to serve as a backup anastomosis point for connection to the primary flap. The flaps are then separated. The ipsilateral (secondary) abdominal flap is then deepithelialized and inset into the breast pocket. The vascular pedicle of the primary flap is oriented appropriately to provide alignment with the anastomotic branch point in the secondary flap. The secondary flap's DIEP or SIEA pedicle will be anastomosed to the branchpoint or distal pedicle of the primary flap after anastomosis of the primary flap's pedicle to the internal mammary source. If there is a problem in the branch chain anastomosis, the flap that is compromised in this setting is the underlying flap and if lost can be replaced with an implant. (DellaCroce FJ, Sullivan SK, Trahan C. Stacked deep inferior epigastric perforator flap breast reconstruction: A review of 110 flaps in 55 cases over 3 years. *Plast Reconstr Surg*. 2011;127:1093–1099.)

with nipple reconstruction; (2) skin envelope modification; (3) volume modification; and (4) balancing surgery. At the initial reconstruction, care should be taken to choose appropriate mastectomy incisions and to shape the flap to match the preoperative breast as closely as possible. Mastectomy through a vertical skin incision will leave a scar amenable to future mastopexy. In the case of a large breast, a vertical skin reduction mastectomy may be considered over a Wise pattern to maximize perfusion to the skin flaps; a horizontal ellipse of inferior skin may be removed using a secondary mastopexy. In the case of a ptotic breast, the nipple or skin paddle may be left low on the breast mound and secondary mastopexy performed with complete elevation of the mastectomy skin, leaving a central mound (Figs. 18 and 19). Suturing of the flap to the chest wall superiorly and medially will prevent hollowing in these areas, folding of the inferior flap deep to itself will improve projection, and lateral and superior suspension of the inferolateral corner of the flap will narrow the breast and improve projection. In addition, it is of paramount importance to address violation of the inframammary fold at the initial operation with suturing of the fold to the chest wall to prevent descent with closure of the abdominal donor site.

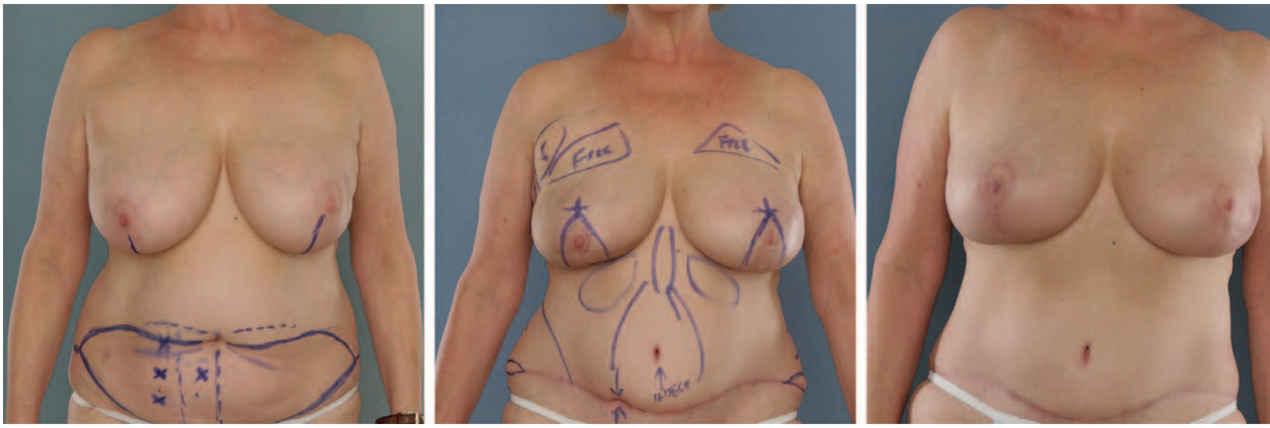

Fig. 18. A 62-year-old patient with left invasive ductal carcinoma who underwent previous left lumpectomy and radiation therapy. She then presented for bilateral nipple-sparing mastectomies and DIEP flap reconstruction. She underwent full mastopexy 3 months after reconstruction. (Photograph courtesy of Dr. Scott Sullivan, New Orleans Center for Restorative Breast Surgery.)

Fig. 19. A 65-year-old patient who underwent right immediate reconstruction using a DIEP flap after mastectomy. Six months after initial reconstruction, she underwent bilateral Wise pattern mastopexy with elevation and reduction of the areolar skin paddle.

Secondary refinements are generally performed 3 to 6 months after initial reconstruction. In the case of a skin-sparing mastectomy, a vertically oriented nipple reconstruction within a skin paddle left intentionally wide prevents widening and flattening of the breast. Circularization of the skin paddle may be performed at the time of nipple reconstruction. Mastopexy can be performed on the flap, and in the case of a skin-sparing mastectomy, incisions are made around the skin paddle to approximate the size of an areola. A subcutaneous plane is developed and is continued to whatever degree necessary for flap modification, flap reduction, scar release, and, ultimately, nipple-areola complex or skin paddle elevation.[49] Flaps may be augmented using large-volume fat grafting (Figs. 20 and 21) or implants or reduced using liposuction. It easier to match a native breast in a unilateral reconstruction when balancing surgery is performed at a second stage after mastectomy flaps have healed and contracted. Balancing surgery will include mastopexy, breast reduction, and possibly fat grafting. The aesthetic outcome of breast reconstruction parallels patient satisfaction, and it is therefore important to discuss that additional revision operations may be necessary to achieve optimal results.

CONCLUSIONS

Perhaps no other subspecialty in plastic surgery has seen advancements as profound as those seen in the field of breast reconstruction over the past three decades. Acceptance of immediate breast reconstruction, increasing preservation of the native breast envelope, advances in microsurgery, and the creativity of multiple surgeons have made autologous breast reconstruction an exciting and ever-evolving part of our field. Autologous tissue reconstruction remains the technique associated with the highest patient satisfaction and represents the gold standard for recreation of the breast mound. The surgeon specializing

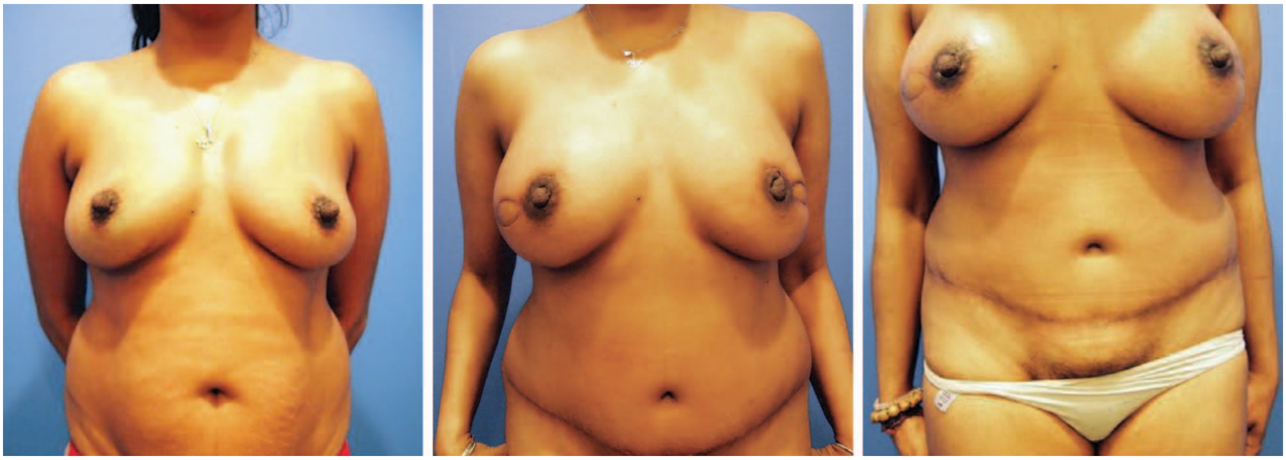

Fig. 20. A 41-year-old patient who underwent bilateral nipple-sparing mastectomies for right invasive ductal carcinoma (mastectomy weight, approximately 450 g). Reconstruction was performed using bilateral DIEP flaps. Six months after reconstruction, abdominal contouring and large-volume fat grafting (320 cc) to the left flap was performed to account for differences in mastectomy flap thickness.

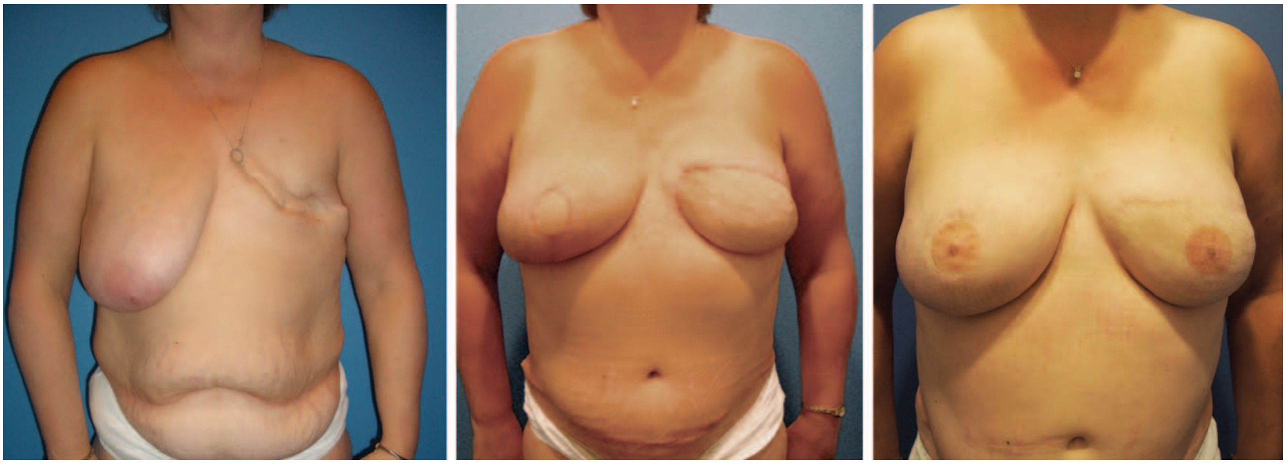

Fig. 21. A 50-year-old patient who underwent right Wise pattern mastectomy with immediate reconstruction using a DIEP flap and left delayed reconstruction using a DIEP flap. She suffered mastectomy flap necrosis of the inferior right skin flaps. Nine months after reconstruction, she underwent right Wise pattern mastopexy, right liposuction (350 cc), large-volume fat grafting from the abdomen to the left breast, and V-Y lateral skin reduction of the left breast.

in this field requires experience and knowledge of all available techniques to guide the patient to the technique best suited to their particular diagnosis, values, and long-term goals.

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