Latest Advancements in Autologous Breast Reconstruction

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Learning Objectives: After studying this article, the participant should be able to: 1. Understand the available donor sites for autologous breast reconstruction. 2. Describe the advantages and limitations of each donor site. 3. Provide a rational, algorithmic preoperative evaluation and approach for patients seeking autologous breast reconstruction. 4. Develop an effective postoperative monitoring system to minimize complications and maximize salvage of microvascular thromboses.

Summary: Breast reconstruction remains at the heart of the field of plastic and reconstructive surgery, and it is continuously evolving. Tremendous advances in breast implant technology and supplemental products, particularly acellular dermal matrices, have revolutionized breast reconstruction in the modern era. However, microvascular free flap breast reconstruction has also witnessed profound advancements with exceptionally high success rates, with the ability to provide the most durable and natural breast reconstruction. Although the pendulum oscillates between prosthesis-based reconstruction and autologous tissue, the present synopsis will focus on autologous free flap breast reconstruction from an historical perspective, recent advancements in microsurgery, and the future of autologous breast reconstruction. (*Plast. Reconstr. Surg.* 147: 111e, 2021.)

The first surgery for breast reconstruction was performed using the contralateral breast but the operation has evolved tremendously over the years.[1] Pedicle flaps were originally the mainstay options for breast reconstruction; however, the first free tissue transfer for breast reconstruction was described using gluteal tissue.[1,2] Since then, the abdominal donor site has become the most common donor site as either a pedicle or free flap.[2,3] With the advancements in technology and comfort with microsurgery, the use of autologous tissue has also continued to evolve, with expanding indications, delineation of new donor sites, and high success rates and excellent patient-reported outcomes and satisfaction. The present article aims to provide a comprehensive synopsis of the advancements and controversies in microvascular free flap breast reconstruction.

PREOPERATIVE EVALUATION AND HISTORY

As with any patient undergoing breast reconstruction, a thorough history is warranted. Although age alone is not associated with increased risks of complications, factors such as obesity have been associated with higher complications in the donor site in addition to flap loss.[4–7] However, recent evidence suggests that prior notions regarding obesity as a contraindication are no longer valid.[8] Similarly, although smoking has not been shown to increase risks for flap loss, there is little debate regarding increased risks for complications and delayed wound healing.[9]

Adjuvant therapies should also be considered before embarking on reconstruction, particularly the need for postoperative radiation therapy.[10] Although some institutions have demonstrated little detriment to radiation therapy, ideally, autologous breast reconstruction should be performed a minimum of 6 months after radiation therapy.[11] In patients with advanced breast cancer or inflammatory breast cancer, reconstruction should

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ideally be performed 1 year after completion of treatment to verify there is no recurrent disease.[12] Patients on hormonal therapy should also be counseled regarding the potential for venous thromboembolic events and thrombosis of the microvascular anastomosis. Although prior studies have recommended withholding tamoxifen, recent studies have questioned their validity.[13,14] Whether or not tamoxifen should be discontinued remains a topic of considerable debate and is at the operating surgeon's discretion. In addition, any history of unprovoked venous thromboembolic events, multiple spontaneous abortions, or miscarriages should alert the reconstructive surgeon to the possibility of a hypercoagulable condition that may warrant further hematologic evaluation.[15,16] Although there are reports of successful reconstructions in prothrombotic patients, these patients should be counseled carefully regarding the need for reoperations, prolonged hospital stays, need for transfusions, and potentially a failed free flap or another life-threatening venous thromboembolic event.[17]

Autologous breast reconstruction should also involve a multidisciplinary approach, including the primary care physician, anesthesiologists, physical therapists and rehabilitation medicine, medical and radiation oncologists, and breast and oncologic surgeons. Patients with a strong family history of breast or ovarian cancer should undergo genetic counseling and testing for a deleterious *BRCA* mutation and should be offered bilateral breast reconstruction with a contralateral or bilateral prophylactic mastectomy.[18–20] Patients undergoing a contralateral symmetry and balancing procedure should have a preoperative mammogram and ultrasound if warranted. In the current era of opioid use, patients should also be educated on the benefits of nonnarcotic analgesics, nerve blocks, and other components of enhanced recovery after surgery protocols.[21]

PATIENT SELECTION, PHYSICAL EXAMINATION, AND WORKUP

A physical examination should be performed, including a thorough breast examination, to document any abnormal findings but should also note breast and bra size, degree of ptosis, asymmetry, prior scars and incisions, and the skin envelop. For patients undergoing a nipple-sparing mastectomy, the presence of periareolar scars should raise concerns of potential complications and warrants a cohesive discussion to plan the incision with the resecting surgeon. Although a nipple-sparing mastectomy can be performed safely through a variety of incisions, the inframammary fold incision is associated with the lowest risk for complications.[22–24] For patients undergoing delayed reconstruction, the remaining skin should be evaluated for pliability and softness, radiation damage, scarring and tethering in the axilla, and amount of skin that is needed to resurface the chest to create an aesthetic breast mound.

Furthermore, the physical examination should evaluate the anticipated donor site. A careful examination of the abdomen is paramount in ascertaining whether the patient has sufficient soft-tissue volume. If there is not ample tissue, the patient should be counseled regarding the need for additional revision operations to augment the reconstructed breast by means of autologous fat grafting or a breast implant. Patients may be offered the option of immediate placement of a breast implant under the flap,[25,26] a bipedicle approach,[27–29] a stacked approach combining alternate flaps,[30,31] or a contralateral reduction procedure that can be performed at the same time or in a staged fashion.[32,33] Conversely, morbid obesity in patients with ample soft tissue should no longer be considered an absolute contraindication; rather, these patients should be counseled regarding the increased risks of complications, particularly in the donor site. [8]

During physical examination, one should also pay close attention to prior scars in the donor site.[34,35] Studies have demonstrated that an abdominal flap can be harvested safely following prior operations, including liposuction, although a formal abdominoplasty is generally a contraindication. The examination should evaluate alternate donor sites such as the gluteal region, medial thighs, and the lumbar region. If additional volume is needed, using multiple flaps to reconstruct a single breast has been performed safely and reliably and has demonstrated excellent results, with high patient satisfaction.

Although many studies have reported added benefits to preoperative imaging, the decision to obtain a computed tomographic scan or magnetic resonance angiogram is at the discretion of the reconstructive surgeon who must consider the potential for decreased operative time, taking into account the accuracy of the study.[36–40] One must also consider the added costs of these studies, which may not be covered by insurance, and the increased exposure to radiation and nephrotoxic contrast dye for a computed tomographic angiogram.

RECIPIENT SITE AND VESSELS

Providing an aesthetic breast reconstruction requires appropriate management of the recipient site with a keen eye for detail and artistic shaping and design. The internal mammary vessels have largely supplanted the thoracodorsal vessels as the preferred recipient vessels, allowing for more medial positioning of the flap, maximizing superior and medial pole fullness, and preserving the latissimus dorsi flap for salvage reconstruction.[41] However, although the internal mammary vessels are reliable and typically of sufficient caliber, careful consideration should be given to the left internal mammary vein, particularly in the irradiated chest.[42] The left internal mammary vein is significantly smaller than the right, and an alternate recipient vein should be used if the diameter is less than 2 mm, which is associated with higher flap loss rates. When the internal mammary vein cannot be used, a cephalic vein transposition should be considered as the primary recipient vein; it can also serve as a second venous outflow to augment venous drainage in a superficial dominant flap (Fig. 1).[43]

Reconstruction of an aesthetic breast mandates restoration of the breast footprint, restoring the natural boundaries of the breast. In delayed reconstruction, dissection of the pocket and breast footprint is critical to the appropriate management of the upper pole to provide the optimal fullness medially and superiorly.[44] In both delayed and immediate reconstruction, the inframammary fold position should be restored to create a distinct fold that is symmetric with the contralateral side.[45]

DONOR-SITE ADVANTAGES AND DISADVANTAGES

Abdomen

The abdominal donor site provides tissue that shares the consistency and texture most closely resembling breast tissue compared to other donor sites. In addition, the harvest creates a favorable abdominal contour, which is also an important consideration.[46,47] Larger, dominant perforators are often centered around the umbilicus; however, the decision to harvest a deep inferior epigastric perforator (DIEP) flap or a muscle-sparing transverse rectus abdominis myocutaneous (TRAM) flap is dependent on the microsurgeon (Fig. 2). Most studies have demonstrated increased morbidity and risks for hernias and bulges with a full-muscle TRAM flap or with sacrifice of increasing amounts of fascia.[48] In this setting, reinforcing the closure with mesh is recommended.[48,49] Consequently, most microsurgeons favor either a DIEP or a muscle-sparing TRAM flap, which have equivalent donor-site outcomes.[49–54] Some studies, however, have found superior outcomes for DIEP flaps, suggesting that surgeon experience and technique are also critical factors in minimizing complications.[55,56] The novice microsurgeon should exercise caution in performing single-perforator DIEP flaps, which have higher total flap loss rates and rates of fat necrosis compared to multiple perforator flaps.[57,58] Alternatively, a superficial inferior epigastric artery flap is another potential option that does not violate the fascia or muscle but has a higher flap failure rates compared to other abdominal flaps (Fig. 2).[57,59] Consequently, although a superficial

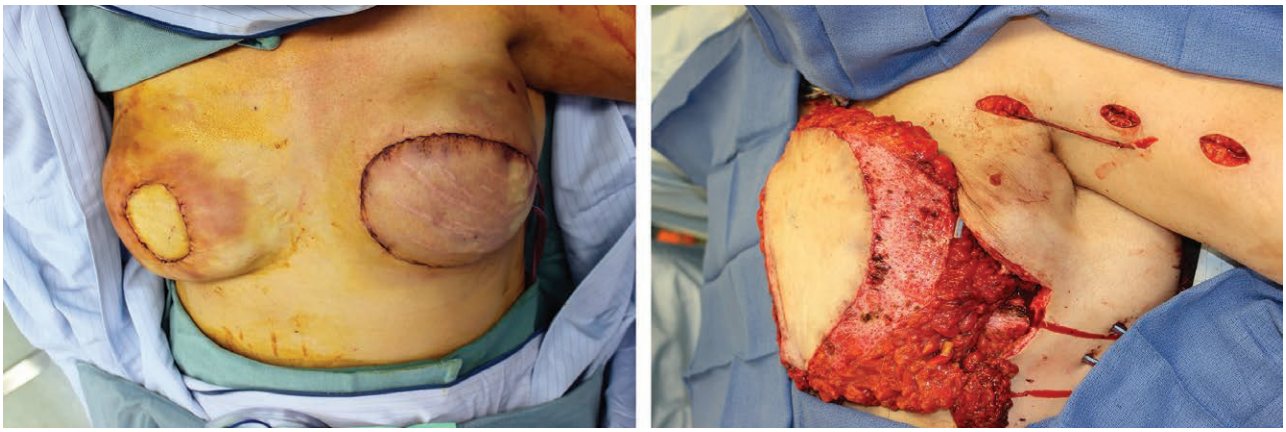

Fig. 1. (*Left*) The left internal mammary vein is typically smaller than the right and more prone to congestion. In the setting where the internal mammary vein is not usable, or if the diameter is smaller than 2.0 mm, an alternate venous outflow should be used. (*Right*) Cephalic transposition is a useful technique for providing an alternate vein for drainage in autologous free flap breast reconstruction. The cephalic vein can be harvested by means of step incisions as shown.

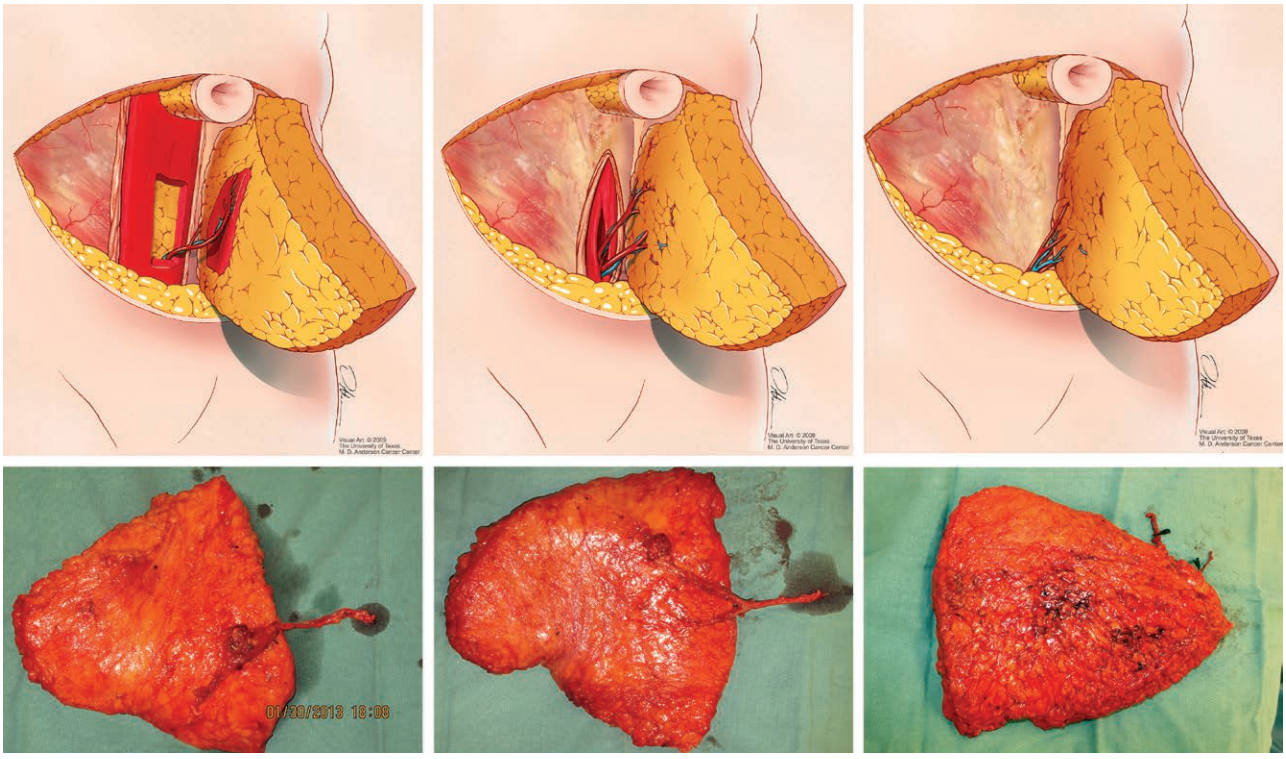

Fig. 2. Schematic representations of a muscle-sparing TRAM flap (*above*, *left*), superficial inferior epigastric artery flap (*above*, *center*), and DIEP flap (*above*, *right*). Muscle-sparing TRAM flap (*below*, *left*). The flap is harvested, and the fascia and the muscle are spared. (*Below*, *center*) The flap is harvested, preserving the rectus abdominis muscle. The muscle may need to be divided to isolate the perforators, but no muscle is harvested with the flap. Superficial inferior epigastric artery flap (*below*, *right*). The abdominal tissue can be harvested, including variable amounts of muscle with the tissue. In the muscle-sparing TRAM flap approach, a portion of the muscle including the perforators is harvested with the abdominal flap.

inferior epigastric artery flap is an option, careful patient selection is warranted.[60,61]

In patients undergoing unilateral reconstruction, the entire abdomen can be used if additional volume or skin is needed. However, a single pedicle may not be sufficient to perfuse the entire abdomen without risks of partial flap loss or significant fat necrosis. The introduction of indocyanine green angiography can aid in identifying areas of poor perfusion and determine whether a bipedicle or dual-pedicle flap is necessary.[62] Harvesting two pedicles, either both deep inferior epigastric systems or the superficial system, requires two sets of microvascular anastomoses. A number of different orientations have been described; however, it is the author's preference to perform the anastomoses to the internal mammary vessels in an antegrade and retrograde fashion (Fig. 3).[62–64]

The abdominal donor site has a number of notable advantages as previously mentioned, including the availability of ample amounts of skin and tissue and ease of harvest. A two-team approach can be used to shorten the operative time, allowing for simultaneous flap harvest at the time of the mastectomy or dissection of recipient vessels. Reconstructive microsurgeons should be aware of the phenomenon of superficial dominance where the primary venous drainage is through the superficial inferior epigastric vein. In this setting, it is imperative to perform a second venous anastomosis to allow drainage from both the deep and superficial systems.[65]

Buttock

The gluteal region can also serve as a donor site and was previously the preferred secondary option when the abdomen was not available.[66–69] A flap can be harvested reliably based on perforators arising from either the superior or inferior gluteal artery (Fig. 4). Most patients have ample amounts of soft tissue in the gluteal region; however, the subcutaneous fat and tissue tend to be firmer and less pliable.[69,70] The superior gluteal artery perforator flap harvests tissue from the upper lateral aspect of the buttock. Although the scar should be concealable in clothing and undergarments, a contour deformity can occur, leading to noticeable asymmetry. The inferior gluteal artery

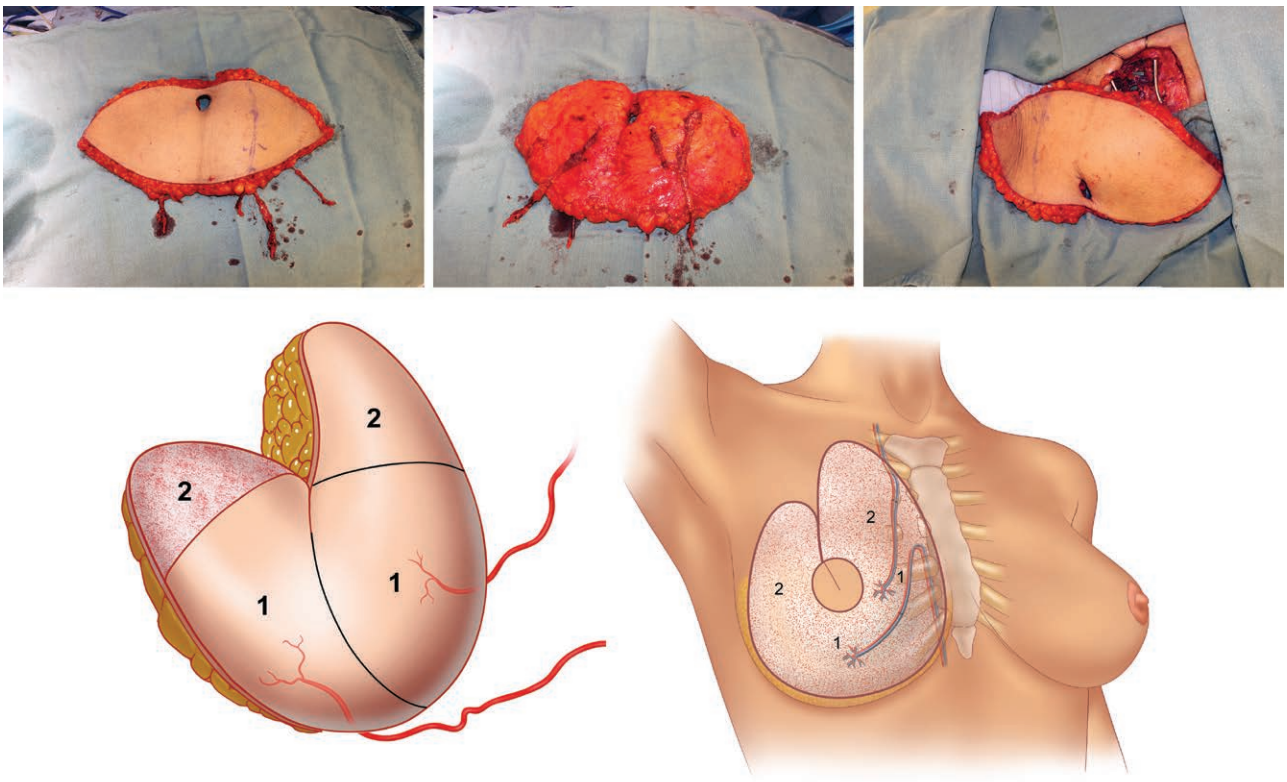

Fig. 3. (*Above*, *left*) When a large volume of skin replacement is needed, the entire abdominal tissue can be harvested to reconstruct a unilateral mastectomy defect. (*Above*, *center*) To provide adequate perfusion to the entire abdominal flap, two separate pedicles are needed. The dual pedicle or bipedicle flap is another useful iteration of an abdominal free flap that can be used in breast reconstruction. (*Above*, *right*) Two anastomoses are needed, which are typically performed to the internal mammary vessels in an antegrade and retrograde fashion. (*Below*) Schematic representations of (*below, left*) bipedicle flap harvest and (*below*, *right*) orientation using antegrade and retrograde internal mammary vessels.

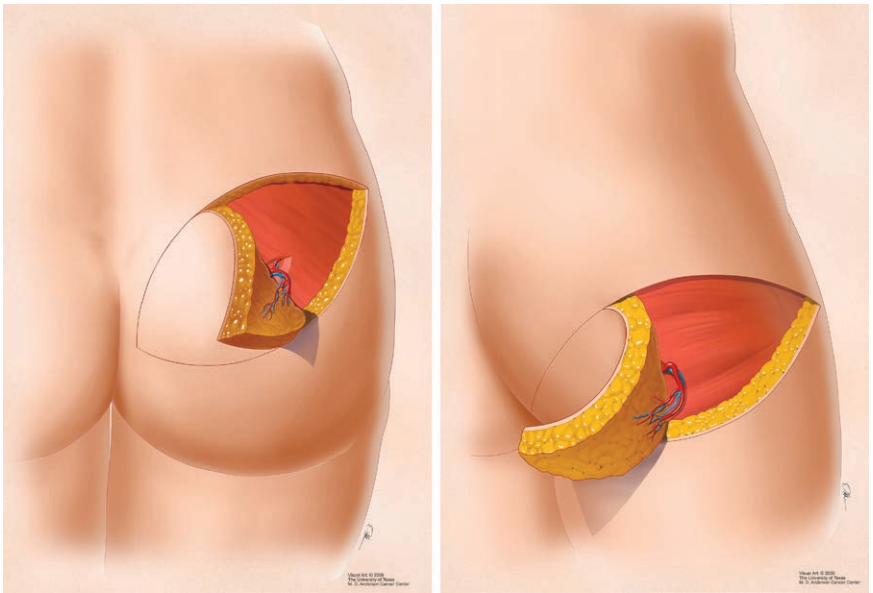

Fig. 4. Schematic depiction of autologous free flaps, which can also be harvested from the gluteal region based on the superior (*left*) or inferior gluteal vessels (*right*).

perforator flap, in contrast, should ideally conceal the scar in the infragluteal crease, which is well-tolerated, although patients should be cautioned about potential sensory and gait disturbances.[71,72]

Although a computed tomographic angiogram may be useful, anatomical landmarks can also be used.[73] The superior gluteal artery perforator flap is designed based on the location of the superior gluteal artery, which arises approximately one-third the distance along a line joining the posterior superior iliac spine and greater trochanter of the femur. A line from the greater trochanter that bisects a third line from the posterior superior iliac spine to the coccyx aligns with the piriformis muscle. The superior gluteal artery perforator flap perforators should be cranial to the piriformis line and in the lateral two-thirds of a line joining the posterior superior iliac spine and greater trochanter.[67,68] The inferior gluteal artery perforator flap is based on the posterior superior iliac spine and ischial tuberosity, which serve as landmarks. The junction between the middle and distal thirds marks the emergence of the inferior gluteal artery pedicle. The posterior femoral cutaneous nerve travels with the inferior gluteal vessels and should be protected during the dissection.[69] In general, laterally based perforators are preferable to maximize pedicle length, allow coning the flap to maximize projection, and achieve an aesthetic donor-site closure.[74–76] Despite studies demonstrating acceptable outcomes, the dissection is more tedious, and a position change is often needed, precluding a two-team approach in many circumstances. With a shorter pedicle and smaller caliber vessels, there is a significantly higher total flap loss rate compared to abdominal flaps, and caution should be exercised when considering gluteal flaps for breast reconstruction.[57,77]

Thigh

Thigh-based flaps have grown in popularity and recently have supplanted the gluteal donor site when the abdomen is not available. Furthermore, the thigh serves as a popular auxiliary donor site when stacked flaps are needed to supplement the volume of an abdominal flap.[78,79] The gracilis myocutaneous flap represents a useful alternative in small-breasted patients with ample medial thigh tissue. The flap can be oriented vertically or transversely, but the transverse upper gracilis flap results in a more well-concealed scar. The gracilis muscle is harvested with the overlying skin, including a perforator arising from the medial circumflex femoral artery, but has a shorter pedicle measuring 6 to 8 cm, with a relatively smaller artery. The length and caliber of the transverse upper gracilis pedicle is often better suited for internal mammary vessel perforators or distal internal mammary vessels to minimize the size mismatch.[80–82] The amount of tissue harvested should allow a tension-free closure to avoid scar widening and migration.[83–85]

The profunda artery perforator flap is supplied by perforators arising from the profunda femoris artery (Fig. 5).[78] It can also be oriented longitudinally or transversely, depending on the distribution of fat in the medial thigh.[86–88] A transverse profunda artery perforator is best harvested in the lithotomy position but requires the presence of a sizable proximal perforator, which may not always be present. [**See Video (online)**, which displays the intraoperative harvest of a profunda artery perforator flap. The flap is harvested in a vertical longitudinal orientation. The profunda artery perforator flap can also be harvested in a transverse orientation; however, this requires the presence of a proximal perforator, which is not

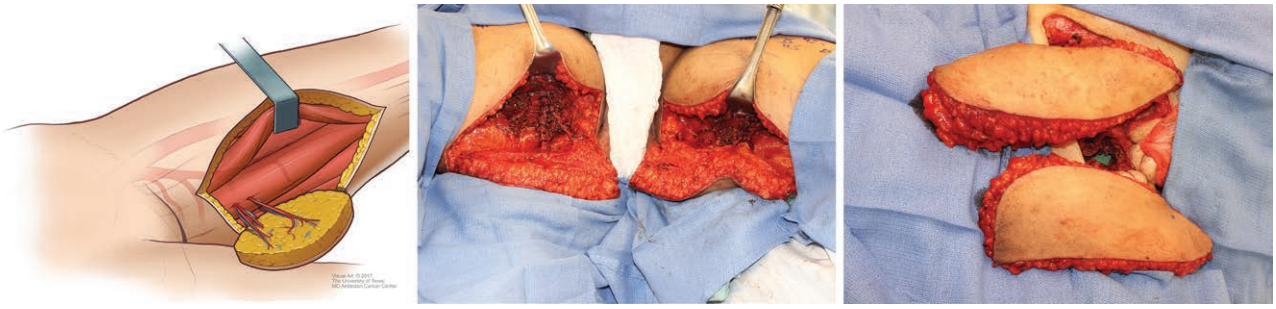

Fig. 5. The profunda artery perforator flap is becoming an increasingly commonly used flap in autologous breast reconstruction, and can be harvested in a transverse, longitudinal, or oblique fashion. Schematic depiction of a longitudinal profunda artery perforator flap that can be based on a single perforator or two perforators that converge (*left*). Bilateral profunda artery perforator flaps were harvested in a longitudinal fashion, both based on two converging perforators (*center*). (*Right*) A single profunda artery perforator was not sufficient to match the volume, so two profunda artery perforator flaps were stacked and oriented using the antegrade and retrograde internal mammary vessels, similar to a dual-pedicle DIEP flap.

always present.] However, in the setting in which a suitable perforator is not encountered, a transverse upper gracilis flap can be harvested.[89] A longitudinal profunda artery perforator flap can be harvested, placing the patient in a supine frogleg position. The transverse orientation provides a more favorable scar, concealed in the infragluteal crease; however, a longitudinal scar is also well-tolerated. The pedicle for the profunda artery perforator is typically longer and larger, measuring 10 to 12 cm in length, with an artery that is often 2 mm in diameter.

All thigh-based flaps allow for a two-team approach. For unilateral reconstruction, the author favors performing bilateral profunda artery perforator flaps, using the antegrade and retrograde internal mammary vessels, which not only provides more volume than a single flap, but also allows for better symmetry and contour of the medial thigh donor site.[63] The transverse scar is well-concealed, and harvesting a longitudinal flap can provide more volume for shaping, with lower risk of fat necrosis, as the flap orientation corresponds with the profunda artery perforator perforasome.[88] Additional concerns with harvesting of the transverse profunda artery perforator and transverse upper gracilis include the risk of partial flap loss at the apices and the potential risk of lymphedema if the flap harvest proceeds too medially.[89,90]

Lumbar

A relatively novel flap that has recently emerged is the lumbar artery perforator flap, based on perforators typically arising at the level of the third or fourth lumbar vertebrae, most commonly 7 to 10 cm from the midline.[91,92] The location of sizable perforators is relatively consistent and can be mapped using a handheld Doppler probe, obviating the need for additional imaging studies.[93,94] For patients who have more fat distribution in the flanks, the lumbar artery perforator flap represents a reasonable option that provides soft, pliable tissue closely resembling breast tissue and also achieves a pleasing aesthetic contour in the donor site. In properly selected patients, the donor site can provide a substantial amount of tissue and can recruit additional tissue from the superior gluteal region if needed.

The flap is best harvested in the prone position, which requires two position changes to isolate recipient vessels followed by the flap harvest and finally the microvascular anastomosis and flap inset. This precludes a two-team approach, which may translate into longer operative times. Likely the greatest limitation of the lumbar artery perforator flap is the pedicle length and caliber. Most recommend harvesting a vein graft or the deep inferior epigastric vessels to mitigate these difficulties, which also corrects the size mismatch with the internal mammary vessels.[92,93] Although more pedicle length can be obtained, the pedicle dissection becomes considerably more tedious and can risk inadvertent injury to nerve roots. Early experiences also demonstrated higher complications and total flap loss rates compared to abdominal flaps.[92] Given the availability of alternate flaps, and the disadvantages of multiple position changes and suboptimal pedicle characteristics, the lumbar artery perforator flap remains a second-tier alternative, in the author's opinion.

POSTOPERATIVE MONITORING AND COMPLICATIONS

The most dreaded complication is a microvascular thrombosis resulting in total flap loss. Fortunately, this is a relatively infrequent event, ranging from 2 to 5 percent at most high-volume institutions.[57] Although such complications are inevitable, a number of maneuvers should be considered to minimize these risks. Such recommendations are likely more applicable to the novice microsurgeon, but all reconstructive surgeons should be cognizant of the potential avoidable risks. Proper patient selection and flap design, thorough preoperative evaluation and appropriate imaging studies, meticulous technique, and diligent postoperative monitoring are critical for maximizing flap success rates.[95] Considerable debate exists regarding the best modality for postoperative monitoring, but most agree that clinical examination remains the gold standard. Whether any of the new technologically advanced devices and modalities such as near-infrared spectroscopy and tissue oxygenation monitors supplant clinical expertise and experience remains to be elucidated. The use of implantable Doppler probes may be useful for nipple-sparing mastectomies when the flap is completely buried.[96–99] However, despite promising results and reportedly high sensitivity and specificity, no modality has been universally adopted and replaced clinical examination.

NEUROTIZATION AND SENSATE FLAPS

Flap neurotization has been described for over two decades, but performing a neurorrhaphy to create a sensate flap has not gained broad acceptance or universal application.[100] Although most studies confirm that coaptation of a nerve supplying the flap (to the third intercostal nerve

Fig. 6. Creating a sensate flap including harvest of the nerve with the abdominal DIEP flap that can then be connected to a lateral intercostal nerve or to an intercostal nerve found medially during the isolation of the internal mammary vessels.

most commonly) can create a sensate flap, currently available studies demonstrate conflicting results, tremendously variable techniques, and inconsistent patient-reported outcome metrics. Some flaps have also demonstrated spontaneous return of sensation without a nerve repair.[101,102] Nonetheless, there are studies supporting the efficacy of performing nerve coaptation. Flaps with a neurorrhaphy generally demonstrated superior and earlier return of sensation compared to noninnervated flaps.[102,103] The reinnervation can be performed directly or using a nerve graft or conduit (Fig. 6).[104] Further studies are needed to decipher the best technique for innervating a sensate breast flap, but the current literature demonstrates promising results.[101–105]

LYMPHEDEMA

Although an exhaustive review of surgical treatment for breast cancer–related lymphedema is beyond the scope of the present article, significant advancements have emerged with the growing field of lymphedema supermicrosurgery.[106] The risk of breast cancer–related lymphedema when patients have had an axillary dissection, chemotherapy, and radiation therapy can be as high as 40 percent.[107–109] Although effective, neither the lymphaticovenular anastomosis, nor lymphovenous bypass, nor a vascularized lymph node transfer is a cure for lymphedema.[110]

For patients suffering from breast cancer–related lymphedema who are also seeking breast reconstruction, combining a DIEP flap with an inguinal vascularized lymph node transfer has proven to be effective in achieving both objectives.[111,112] The superficial inguinal nodes adjacent to the superficial circumflex iliac or superficial inferior epigastric vessels can be taken in conjunction with the DIEP flap (Fig. 7). The entire composite flap, including the inguinal lymph nodes, is then transferred to reconstruct the breast while simultaneously transferring lymph nodes to improve the lymphatic drainage from the arm. The DIEP flap is anastomosed to the internal mammary vessels, but an additional set of anastomoses may be necessary to perfuse the inguinal nodes.[113] The recipient vessels for the lymph nodes are often branches of the thoracodorsal vessels or the subscapular axis. In general, we prefer to preserve the thoracodorsal pedicle so a latissimus dorsi flap can still be used to salvage a failed flap.

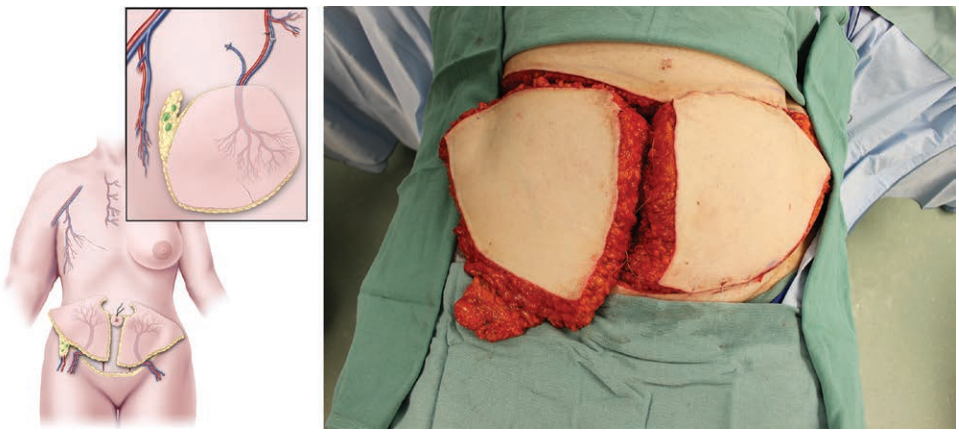

Fig. 7. With the growing field of lymphedema surgery, treatment of breast cancer–related lymphedema has made tremendous advancements, where breast reconstruction with lymphedema surgery can be performed simultaneously. (*Left*) The superficial inguinal nodes can be harvested with the DIEP flap to reconstruct the breast and improve the lymphatic drainage in one operation. (*Right*) Schematic representation of a flap harvested with the inguinal nodes, allowing for anastomosis to the internal mammary system and allowing the nodes to be placed into the axilla. Often, the anastomosis perfusing the DIEP flap will also maintain the vascularized lymph node transfer.

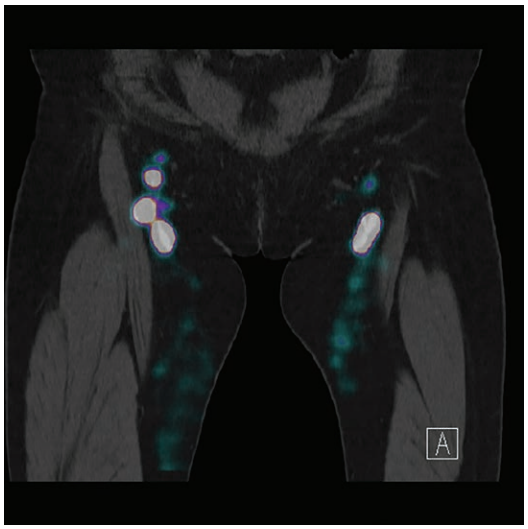

Fig. 8. Preoperative lymphoscintigraph demonstrating location of sentinel nodes in the groin draining the lower extremity to guide laterality for node harvest.

Although some studies have demonstrated that breast reconstruction alone can lower the risk for breast cancer–related lymphedema, others have challenged this claim.[114–116] Thus, a combined DIEP vascularized lymph node transfer represents the optimal means of addressing breast cancer–related lymphedema and should be performed by experienced, trained microsurgeons with supermicrosurgical expertise. The inguinal node harvest should be performed meticulously, taking into account anatomical landmarks, preoperative imaging including lymphoscintigraphy, and reverse lymphatic mapping to avoid precipitating lymphedema of the leg (Fig. 8).[112,113] Other potential complications—including lymphocele, prolonged seroma, and contour deficiencies of the donor site—can also be prevented with proper technique and experience. Despite these serious complications, performed appropriately, the operation is effective in the overwhelming majority of patients suffering from breast cancer–related lymphedema.[117] As the field continues to evolve, modalities aimed to cure lymphedema are on the horizon and will likely become a reality in the near future.

CONCLUSIONS

Autologous breast reconstruction has witnessed tremendous advancements over the years, where the focus is no longer on just achieving a viable flap. The increasing number of available donor sites, growing understanding and expertise with perforator flaps, advancements in technology, and innovations in neurotization and lymphedema surgery have revolutionized breast reconstruction in the modern era. Reconstructive microsurgeons, with more tools available, should strive to deliver safer care, provide the spectrum of options for each individual patient, and be able to achieve high patient satisfaction and superior outcomes to buoy the spirit of those afflicted with breast cancer.

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