Chapter

Immediate Breast Reconstruction with Free Autologous Tissue Transfer

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Abstract

Immediate breast reconstruction in the United States is increasing with the majority of patients undergoing implant-based reconstruction. The use of pedicled autologous tissues has also been used, but due to significant donor site morbidity, free autologous tissue transfer has largely replaced it. The gold standard currently for breast reconstruction is free autologous tissue transfer from the abdomen if no contraindications exist. However, not all hospitals have the expertise available to perform free autologous tissue transfers for breast reconstruction. Other donor sites available for free autologous tissue transfer include the thigh and gluteal areas. With advances in free tissue transfer techniques, the donor site morbidity and flap failure rates are minimal. The ultimate goal for any breast reconstruction patient is to achieve the appropriate size, shape, symmetry, softness, and sensation. The goal of this chapter is to assist in achieving these goals in the immediate breast reconstruction patient through the use of free autologous tissue transfers.

Keywords: breast reconstruction, autologous tissue, free flaps, deep inferior epigastric perforator, transverse rectus abdominis myocutaneous, transverse upper gracilis, profunda artery perforator, superior gluteal artery perforator,inferior gluteal artery perforator, breast ptosis, mastopexy, nipple devascularization, re-innervation, autologous with implant

1. Introduction

The incidence of mastectomy for breast cancer over the last couple decades has been increasing leading to more patients desiring breast reconstruction. While most of these patients undergo implant-based reconstruction there is a significant number of patients that have autologous reconstructions performed [1, 2]. Implant-based reconstruction is technically easier and can have good esthetic appearance but should not be used in all patients. Ideal candidates for implant-based reconstruction are those who are not obese, a non-smoker, require no radiation, and have healthy vascularized mastectomy skin flaps. Not all breast reconstruction patients meet these characteristics nor do all patients want to be subjected to secondary affects of having a foreign body used for reconstruction. More recently patients are also concerned about breast implant associated anaplastic large cell lymphoma (BIA-ALCL) [3].

The use of pedicled autologous tissue to reconstruct the breast started with the transverse rectus abdominis myocutaneous (TRAM) flap by Hartrampf in 1982 [4]. With improved understanding about perforator vascular anatomy and surgical technique, the perforator flap concept was developed. About a decade after the TRAM, the deep inferior epigastric perforator (DIEP) flap by Allen was developed, which addressed donor site morbidity by preserving muscle and fascia [5]. Another abdominal flap that uses the same skin incision and utilizes the identical skin and fat for reconstruction as the TRAM/DIEP is the superficial inferior epigastric artery (SIEA) flap but this flap requires no fascial incision. Abdominally based free flaps are the gold standard for breast reconstruction but not all patients are candidates. Patients that do not desire a scar from hip to hip or have had previous abdominoplasty, abdominal liposuction, or other significant abdominal procedures should not undergo free flaps from the abdomen for breast reconstruction. Other potential sources for autologous tissue include the thigh and gluteal areas.

The purpose of this chapter is to review the common free flaps for breast reconstruction starting from pre-operative workup to flap in-setting along with ptosis management and adjunctive intraoperative procedures.

2. Preoperative workup and flap selection

Patients that desire breast reconstruction must undergo a multidisciplinary approach utilizing a breast oncologist and plastic surgeon from a surgical standpoint and possible radiation oncologist and genetic counselor as indicated. The majority of patients undergo breast reconstruction secondary to breast cancer ablation. However, more recently there is an increase in breast reconstruction for patients desiring prophylactic mastectomies secondary to specific genetic mutations (i.e. BRCA) and/or increased risk of developing breast cancer in the future [2].

After a patient decides that she would like a mastectomy for breast cancer treatment or risk reduction, the patient will be referred to a plastic surgeon who should perform a thorough history and physical examination. The surgeon should not only discuss the risks and benefits of surgery but other alternatives to free tissue transfer breast reconstruction, which should include no reconstruction, tissue expander or implant-based reconstruction, and pedicled flap reconstruction. Possible revisional surgery should also be discussed.

The ideal breast reconstruction would involve free tissue transfer from the abdomen. Most patients in the United States have sufficient lower abdominal tissue to reconstruct a similar size breast. For thin patients with a small abdominal pannus, other sites such as the thigh or gluteal area can be used, but these are typically smaller than the abdominal tissue. In these cases other adjunctive procedures such as fat grafting, free flap stacking, and implant placement can be performed.

Most patients that undergo free tissue transfer for breast reconstruction utilize a DIEP or TRAM flap. There are various algorithms that have been proposed based on perforator size/number and flap size [6, 7]. In general, a DIEP flap can be performed for smaller flaps (<1000 g) that have adequate perforator size (>1.5 mm). Conversely, a TRAM flap is considered for larger flaps with smaller, less dominant perforators. Another abdominal flap that is used in the minority of patients is the SIEA flap. The ideal candidate for an SIEA flap is reconstruction of a small breast with a sizeable/palpable SIEA [8].

Patients that have contraindications to using the abdomen as a free tissue transfer source or who do not want the morbidity associated with these flaps can use the thigh or gluteal areas as donor sites. These flaps include the transverse upper gracilis (TUG), profunda artery perforator (PAP), and superior/inferior gluteal artery perforator (SGAP/IGAP) flaps. The benefit of these flaps is that they can be harvested unilaterally so the contralateral side can be used for later use in the future. The downfall to these flaps is that they are typically smaller than the abdominally based flaps and positioning in the operating room can be more difficult.

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Some absolute contraindications to free tissue transfer breast reconstruction include the inability to undergo a lengthy procedure under general anesthesia secondary to cardiovascular/pulmonary compromise, patient desire for a less complex procedure or unwillingness to have a long donor site scar, vascular compromise of the intended flap secondary to scarring or previous surgery, and coagulopathy that cannot be controlled with medical management. Other more common relative contraindications include severe obesity [9], smoking, diabetes, end stage renal disease [10], and hemophilia/venous thromboembolism [11]. These comorbidities should be optimized prior to breast reconstruction surgery to minimize morbidity/mortality.

3. Preoperative imaging

The standard for immediate breast reconstruction is perforator flaps from the abdomen. To aid in preoperative planning and surgical technique the use of preoperative imaging has been developed. The various forms of imaging modalities to identify perforators include duplex ultrasound, computed tomographic (CT) angiography, and magnetic resonance (MR) angiography. The use of duplex ultrasound can identify the location, size, flow, and velocity of perforators from the deep inferior epigastric artery. Other benefits of duplex ultrasound are ease of use, reduced cost, and no radiation exposure when compared to CT angiography [12].

A superior imaging technique to identify perforators is the use of CT angiography, which can identify perforator size, location, and intramuscular course (**Figure 1a**). The use of CT angiography has shown to reduce operative times, improve the perfusion of flaps, and minimize donor site morbidity. Patients with previous abdominal surgeries resulting in a paramedian scar would benefit from CT angiography to assess patency of the deep inferior epigastric artery and associated perforators [12]. The ideal perforators would be large, centrally located in the flap, and have a short traverse muscular and subfascial course [13]. The sensitivity and positive predictive value of CT angiography is near 100% for locating and mapping out the course of deep inferior epigastric perforators. For patient who do not want to undergo radiation they can elect to undergo MR angiography, which can help map out the perforators but the spatial resolution is inferior to CT angiography [14].

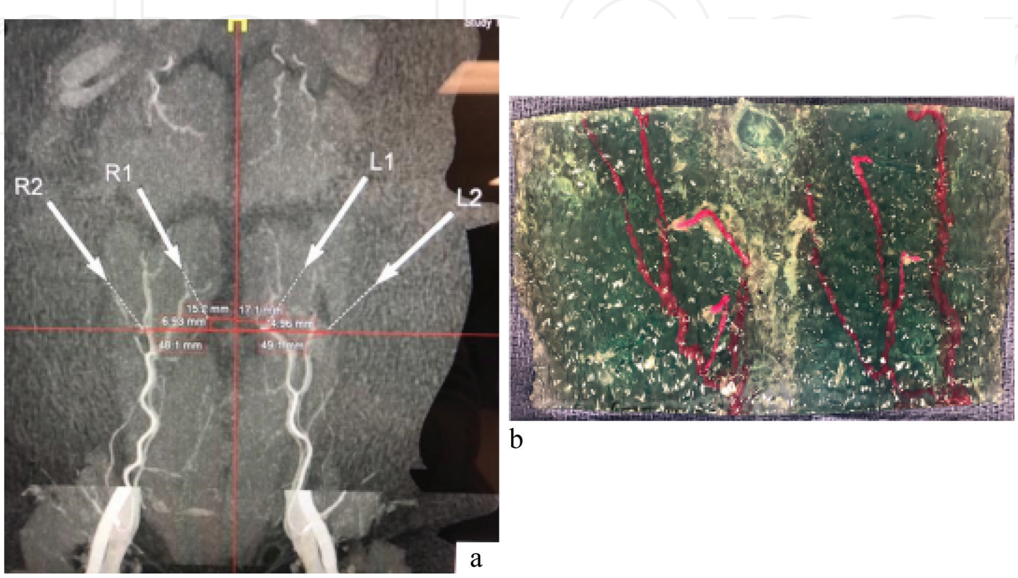

Figure 1.
(a) CT angiogram of deep inferior epigastric artery and perforators and (b) 3D model of deep inferior epigastric artery and perforators.

Our institution has developed 3D printed models of the deep inferior epigastric artery and perforators from CT angiography imaging to further aid intraoperative decision making (**Figure 1b**). The 3D printed models can be sterilized and aid in locating the larger (>1 mm) perforators in relation to the umbilicus and their course through the rectus abdominis muscle to the deep inferior epigastric artery. A limitation of the 3D printed models is their poor sensitivity to identify smaller perforators.

4. Mastectomy incisions

Surgical exposure for immediate breast reconstruction is not only dependent on flap characteristics and setup but also the choice of mastectomy incisions used. As breast cancer treatment has changed over the decades from modified radical mastectomy to nipple/skin sparing mastectomy, so have the incision choices. Traditionally, a wide elliptical incision around the NAC was performed in a transverse or oblique fashion for modified radical mastectomies. To preserve native breast skin, a circumareolar incision with or without a lateral or vertical extension can be performed resulting in a lollipop incision. A vertical extension (**Figure 2**) of a circumareolar incision is preferred over a lateral extension (**Figure 3**) as the incision can be incorporated into a mastopexy incision. Other types of mastectomy

Figure 2.
TRAM flap utilizing circumareolar incision with vertical extension before and after surgery.

Figure 3.
TRAM flap utilizing periareolar incision with lateral extension before and after surgery.

Figure 4.
TRAM flap utilizing wise pattern incision before and after surgery.

incisions that can be used with the aid of a plastic surgeon is a wise (**Figure 4**) or vertical pattern, similar to breast reduction or mastopexy incisions. These incisions allow for removal of excess skin that can be seen in ptotic patients. Additional benefits include reshaping of the breast mound and to allow for a smaller skin envelope for patients that desire a reduction in breast size.

With advances in breast cancer treatment the ability to preserve the nipple areolar complex is now possible. This not only allows for improved cosmesis but also quality of life for patients. The ideal patient for preservation of the nipple areolar complex would have a small breast, minimal ptosis (<grade 2), non-obese (BMI < 30 kg/m^2), and be a non-smoker [15]. There are techniques that will be described later in the chapter to allow for nipple areolar preservation in larger ptotic patients. From a cancer standpoint, patients that have NAC involvement seen on MRI, inflammatory breast cancer, extensive skin involvement, or bloody nipple discharge are not candidates for nipple sparing mastectomies [16].

5. Flaps

Free tissue transfers from an abdominal donor site is most commonly used for breast reconstruction. The TRAM, DIEP, and SIEA flaps all result in similar abdominal donor scars and include the lower abdominal skin/subcutaneous tissue between the umbilicus and the pubis in the flap. The deep inferior epigastric artery supplies the TRAM and DIEP flaps so various amounts of fascia, muscle, and nerve preservation is performed to allow for perforator harvest. In contrary, the SIEA flap is based on the superficial inferior epigastric artery so fascial violation does not occur. The majority of patients have small or absent superficial systems so SIEA flaps are only performed in a minority of patients [8].

An algorithm was developed by Lindsey in 2007 based on perforator anatomy to aid in selection of the appropriate abdominal flap [7]. Evaluation of the lateral row perforators proceeds the medial row perforators. If a large (>3 mm) centrally located perforator is seen from the deep inferior epigastric artery, then a single perforator DIEP can be performed. If moderate (1.5–3 mm) perforators are present, then more than one perforator should be included in the DIEP. When small (<1.5 mm) perforators are present then evaluation of the medial row perforators should be performed.

If the medial row perforators are also small (<1.5 mm) then a muscle sparing (MS) TRAM should be selected [7]. An SIEA flap can be considered if the vessel is large (>1.5 mm) and palpable but should be limited to smaller flaps [6].

If the abdomen is not available to use as a donor site then the thigh and gluteal areas can be used but require more difficult positioning in the operating room and the flaps tend to be smaller in size compared to abdominally based flaps.

5.1 Transverse rectus abdominis myocutaneous (TRAM)

The first abdominally based free and pedicled flaps for breast reconstruction were performed by Hartrampf and Holmstrom nearly 4 decades ago [4, 17]. To minimize donor site morbidity and vascular complications combined with the refinements in microsurgical technique, the free TRAM increased in popularity among surgeons. Even though the TRAM flap is a Mathes and Nahai type III muscle (two dominant vessels), it has a more robust blood supply based on the deep inferior epigastric artery compared to the internal thoracic artery [18]. The free TRAM is now the flap of choice for breast reconstruction in the majority of breast centers.

The TRAM flaps can spare various amounts of muscle to minimize abdominal wall morbidity so a classification system was developed by Nahabedian in 2002. A MS-0 TRAM involves the full width of the rectus abdominis muscle, MS-1 preserves the lateral or medial segment of muscle, MS-2 preserves the lateral and medial segment of muscle, and MS-3 (DIEP) preserves the entire muscle [19].

5.1.1 Marking

For any breast reconstruction patient, the markings for the breast should be in the standing position. The midline (sternal notch to pubis), inframammary folds (IMFs), anterior axillary lines, and the breast footprints are marked (**Figure 5**). If one of the IMF's are not apparent then the contralateral IMF can be used as a guide. A mastopexy incision marking can also be performed as needed. In a patient with a unilateral reconstruction, a symmetry procedure can be performed on the

Figure 5.
TRAM/DIEP/SIEA flap markings.

contralateral side, which should also be marked at this time. It is important to put the nipple-areolar complex on the symmetry side to match the reconstructed breast and not at the level of the native IMF, as is done in routine breast reductions.

For the abdominal marking, the patient is in standing position to identify and mark the lower abdominal fold, which will hide the placement of the incision. In the midline, this incision should be at least 6 cm from the vulvar commissure to prevent urinary stream dysfunction post-operatively. The lower incision is typically extended laterally distal to the anterior superior iliac spine (ASIS) to remove any Burow's triangles. The upper incision is marked about the level of the umbilicus and then extended laterally to meet the lower incision endpoint (**Figure 5**). A pinch test must be used to confirm the location of the upper incision mark to ensure proper abdominal wall closure at the end of the case. It is also helpful to keep the length of the upper and lower incision limbs a similar length to prevent scalloping of the incision upon skin closure.

5.1.2 Flap dissection

The lower skin incision is made first followed by dissection of the SIEA/SIEV for a few centimeters to allow for superficial vascular supply as needed. The SIEA/SIEV can then be clipped and divided if they are not to be used for a SIEA flap. Dissection then proceeds all the way down to the muscular fascia but care should be taken to leave some fat around the ASIS to prevent injury to the lateral femoral cutaneous nerve, which is medial to the ASIS. After confirming the upper incision mark with a pinch test the upper incision can be made, including release of the umbilicus. The upper incision is taken down to the muscular fascia. The upper abdominal flap is then elevated above the muscular fascia in the midline to the xiphoid and costal margins as needed to aid in abdominal wall closure.

The dissection then continues from lateral to medial above the level of the muscular fascia until the lateral row perforators are encountered going through the anterior rectus fascia and into the flap (**Figure 6**). It is imperative to turn down the bovie or bipolar once you start to dissect the perforators. If a bilateral reconstruction is being performed, then the vertical midline incision can be made to separate the two flaps (**Figure 7**). Dissection then proceeds from medial to lateral above the level of the muscular fascia until the medial row perforators are encountered. If a unilateral reconstruction is being performed, then the vertical midline incision is

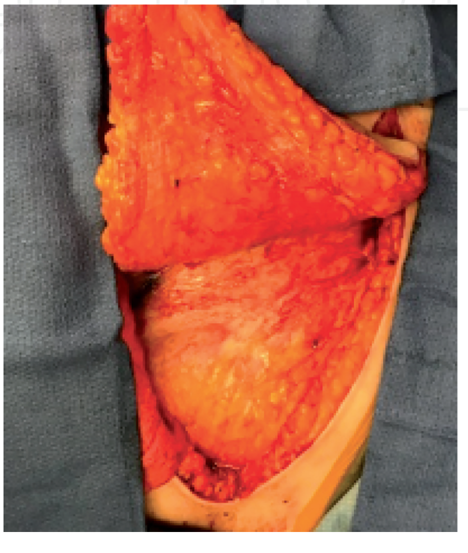

Figure 6.
Lateral to medial dissection of TRAM flap above muscular fascia to lateral row perforators.

Figure 7.
Vertical midline incision separating bilateral TRAM flaps.

not performed. Dissection in this case then proceeds in the midline at the level of the muscular fascia until the medial row perforators are visualized. After visual inspection of all perforators, a Doppler can be used to see which perforators are more dominant. A decision is made (based on the above algorithm) about taking the lateral, medial, or both row perforators. Further dissection between the perforators along the muscular fascia occurs to help preserve fascia for the abdominal wall closure. A marking pen is used to design the planned longitudinal incision in the anterior rectus sheath, which is then extended to the lateral edge of the rectus inferiorly to aid in pedicle dissection. Various amount of anterior rectus sheath are incorporated into the flap depending on the number and location of the perforators. The anterior rectus sheath is incised and the lateral aspect of the sheath elevated off of the rectus abdominis muscle (**Figure 8**). The deep inferior epigastric artery/vein is then identified deep and lateral to the rectus abdominis muscle. The pedicle is then dissected all the way to the external iliac vessels and then separated near their origins (**Figure 9**). The pedicle is then dissected superiorly to identify the perforators going into the flap. Care should be taken to preserve the vascular and nerve supply to the rectus abdominis muscle. The rectus abdominis muscle is then split longitudinally between the perforators and the rectus abdominis muscle that will remain in-situ (**Figure 10**). If a MS-2 TRAM is being performed then a second longitudinal spit is made in the rectus abdominis muscle on the other side of the perforators. Once the pedicle is cleared posteriorly from the posterior rectus sheath, then the pedicle can be dissected away from the rectus abdominis muscle inferior to the takeoff of the first perforator. The rectus abdominis muscle can then be divided with cautery inferiorly with care taken to protect the pedicle. Attention is then turned to identify the superior epigastric vessels, which are then temporarily clamped. The Doppler is used to identify perforators on the skin, which can then be marked with a 5-0 prolene suture. After confirming the vascular supply to the flap, the superior rectus abdominis muscle and the superior epigastric vessels can be divided (**Figure 11**). The deep inferior epigastric vessels should not be divided until the recipient vessels are identified.

Figure 8.
Lateral anterior rectus sheath elevated after fascial incision.

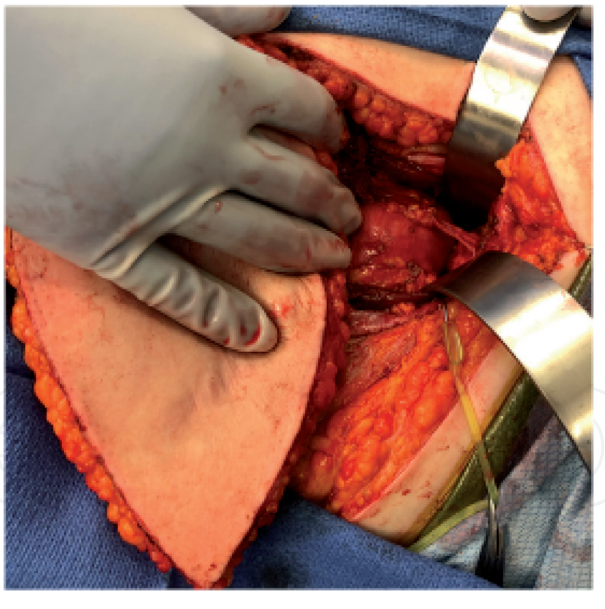

Figure 9.
TRAM flap pedicle dissection to external iliac vessels.

5.1.3 Recipient vessel harvest

After completion of the mastectomy attention is then turned to the chest to harvest recipient vessels, typically the internal mammary vessels or the thoracodorsal vessels. The internal mammary vessels at our institution are preferred because the thoracodorsal vessels can be damaged during the mastectomy or lymph node dissection and require a long pedicle to allow for medialization of the flap. Some prefer the thoracodorsal vessels because of easier dissection but either recipient vessel has the same outcomes and are proven to be safe and reliable [20].

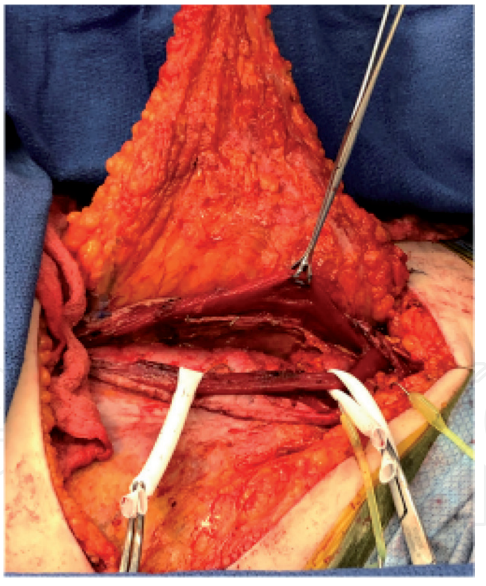

Figure 10.
TRAM flap after longitudinal split of rectus muscle with exposed pedicle.

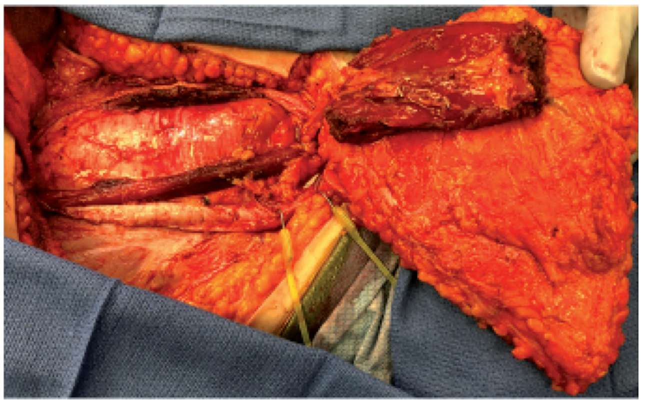

Figure 11.
TRAM flap in-situ after division of rectus muscle.

To expose the internal mammary vessels, the mastectomy skin is gently retracted and then the pectoralis major muscle is split over the third costal cartilage. A Weitlaner retractor is placed between the split pectoralis major muscle for exposure. The third costal cartilage perichondrium is incised anteriorly from the sternal attachment then 2–3 cm laterally. A freer elevator is used to elevate the perichondrium anteriorly then posteriorly off of the third costal cartilage. The third costal cartilage segment can be incised sharply laterally with use of a Doyen rib raspatory to protect the pleura posteriorly. The third costal cartilage is then removed in piecemeal fashion using a rongeur until the sternal edge is encountered. Some prefer not to use the Doyen rib raspatory and only use the rongeur. Bipolar is then used to remove the third costal cartilage perichondrium along with some of the adjacent intercostal muscles. As the internal mammary vessels are encountered about 1 cm lateral to the sternal edge, it is important to clip any small branches from the vessels entering the posterior perichondrium. Care is taken to preserve the anterior branch of the third intercostal nerve if flap re-innervation is desired. The internal mammary vessels can be dissected as needed to obtain length. If one is struggling with the vessels dissection it is important to finish further dissection with increased loupe magnification or the microscope. An internal mammary lymph node is often encountered along the artery, which can be sent for permanent pathology to aid in oncologic staging. A neurosurgical patty and microsurgery background sheet is

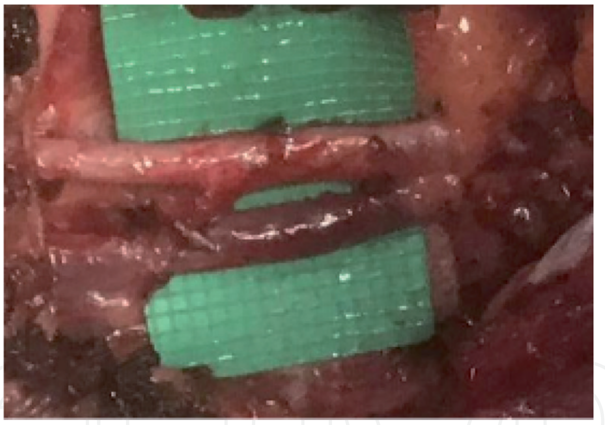

Figure 12.
Internal mammary vessel preparation.

then placed posterior to the internal mammary vessels (**Figure 12**). Vasodilating agents such as lidocaine 4% or papaverine can be injected around the vessels per surgeon preference and then covered with a warm moist RayTec sponge. The retraction on the mastectomy flaps should be released to allow for improved perfusion until the microsurgical anastomosis will be performed.

For exposure of the thoracodorsal vessels, the mastectomy skin is gently retracted to allow for visualization of the anterior border of the latissimus dorsi muscle. Once identified, the anterior border of the latissimus dorsi muscle is followed superiorly to the axillary vein. The thoracodorsal vessels will then be located between the chest wall and the latissimus dorsi muscle. The vessels are dissected until the appropriate length and caliber is obtained. Another option for recipient vessels that are less commonly used are the thoracoacromial vessels. These vessels are identified in the midclavicular area by using a Doppler. The pectoralis major muscle is then split and dissection of the thoracoacromial vessels occurs. The axillary vessels and the scapular circumflex vessels can also be used if the above recipient sites are not available. Additional venous drainage can occur via cephalic vein or external jugular vein transposition [21].

5.1.4 Anastomosis

Once the recipient vessels are dissected and the TRAM flap elevated, the flap pedicle can be clipped and divided. The artery should be clipped prior to the vein so the flap does not get engorged with blood. The flap is placed on an iced lap sponge and then transferred to the contralateral chest. The flap is rotated 90° so the pedicle lies adjacent to the recipient vessels. Care is taken to make sure the flap pedicle is laying in its natural orientation without twisting. The flap is secured to the chest wall using sutures and/or staples. A microscope is then brought into the field if loupe magnification is not preferred and centered over the recipient vessels. The pedicle vessels are further dissected until enough length is obtained and the vessel ends are cleared of fat and adventitia. Attention is then turned to the recipient vessels, which are dissected in a similar fashion. An Acland clamp is placed proximally on the recipient artery and vein and then the distal ends clipped and divided. The recipient vessels should be irrigated with heparinized saline (100 units per ml) until the lumen is clear. The flap should also be flushed with heparinized saline through the artery until the venous output is clear. After the recipient and pedicle vessels are prepared, the vessels ends are approximated in a way to ensure no kinking or twisting of the vessels. The first anastomosis performed is the vessel which will be more posterior after the artery and venous anastomoses are completed. For the

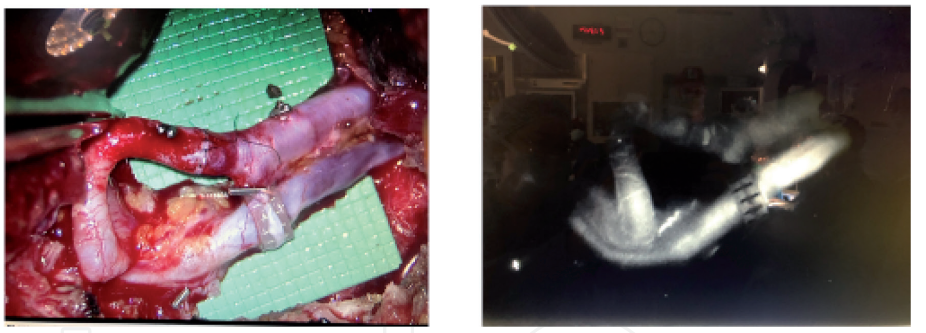

Figure 13.
Internal mammary vessel anastomosis and ICG angiography.

artery, the double apposing Acland clamp can be used to approximate the arterial ends if needed. 8-0 or 9-0 nylon is used in an interrupted fashion for the arterial anastomosis. The venous anastomosis is performed using a venous coupler after the diameters of the veins are measured. The use of the venous coupler has been shown to reduce operating room times and take-backs to the operating room [22]. The venous followed by the arterial Acland clamps are released and the vessels checked for leakage and patency. We routinely use indocyanine green angiography to evaluate anastomotic patency [23, 24] (**Figure 13**). A study by Holm showed that the intrinsic transit time (ITT) or the time it takes for the indocyanine green dye to travel from the arterial to the venous anastomosis can help predict flap compromise and early re-exploration. An ITT greater than 50 s was significantly associated with these negative outcomes [24].

5.2 Deep inferior epigastric perforator (DIEP)

As techniques in microsurgery developed along with the need to reduce the amount of donor muscle sacrifice, the DIEP flap was developed and first performed by Allen in 1994 [5]. Some consider the DIEP flap the gold standard for autologous breast reconstruction but there can be higher fat necrosis rates compared to the TRAM flap if only a few perforators are included in the flap [6].

Similar to the TRAM flap, the DIEP flap can preserve various amounts of muscle and nerves. Based on the Nahabedian classification, DIEP flaps are considered MS-3 TRAM flaps because they preserve the entire rectus muscle [19]. Lee in 2010 developed a DIEP classification because not all DIEP flap harvests are the same as they vary with how much muscle and nerves are transected. A DIEP-1 has one perforator and preserves all muscle and nerves. A DIEP-2 has two or more perforators in the same row requiring segmental nerve sacrifice but the muscle is preserved. A DIEP-3 has perforators in different rows so both muscle and nerve are sacrificed. When comparing the DIEP-1 to DIEP-3 flaps, the DIEP-1 flaps had a significantly higher fat necrosis rate (19.8 vs. 9.2%) [6].

5.2.1 Flap dissection

The breast and abdomen markings pre-operatively are the same as for the TRAM flap above (**Figure 5**). The lower and upper abdominal incisions are made with dissection/preservation of the superficial inferior epigastric vessels. The lateral and medial row perforators are identified in standard fashion. The surgeon then determines which perforators to include in the flap. A DIEP-1 can be performed if the perforator is greater than 3 mm. If the perforators are between 1.5 and 3 mm, a DIEP-2 or DIEP 3 can be performed. However, if no perforators are greater than 1.5 mm, a TRAM should be considered [6, 7]. Usually if there are multiple

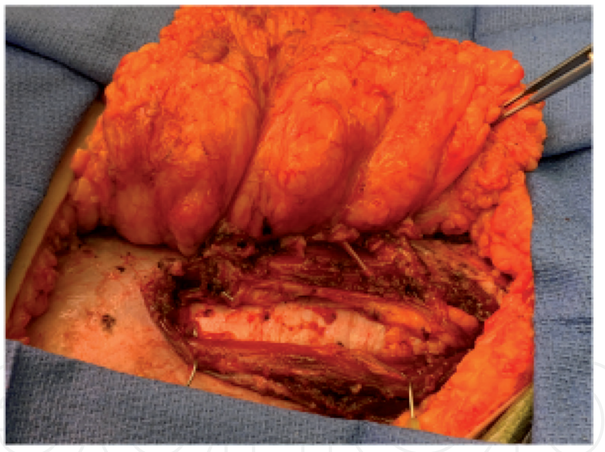

Figure 14.
Longitudinal rectus muscle longitudinal split during DIEP flap harvest.

Figure 15.
DIEP flap based on three perforators.

perforators in the same row, they will all be included in the DIEP flap. In order to preserve more fascia and muscle dissection certain perforators can be temporarily clamped so the flap can be assessed based on desired perforators. The ideal perforators should not only be large but also centrally located to allow for centric perfusion. Once the perforators are selected the anterior rectus sheath is incised, the pedicle identified, and the rectus muscle split longitudinally adjacent to the perforators (**Figure 14**). The perforators are dissected circumferentially from the pedicle to the fascia. A small fascial cuff around the perforators can be left intact if the perforators are tiny or if the surgeons prefers. Once the perforators and pedicle are dissected, the flap should be assessed for perfusion after the extraneous perforators and superior epigastric vessels are temporarily clamped. The extraneous perforators and superior epigastric vessels can then be clipped and divided (**Figure 15**). In a unilateral reconstruction, the contralateral perforators should be left intact as a backup if needed. Once the recipient vessels are prepared the DIEP flap pedicle can be clipped and divided (**Figure 16**).

5.3 Superficial inferior epigastric artery (SIEA)

In 1991, Grotting was the first person to use a free SIEA flap for breast reconstruction [25]. Compared to the TRAM and DIEP flaps, the SIEA flap minimizes donor site morbidity because it does not violate the rectus fascia. Therefore, the risks

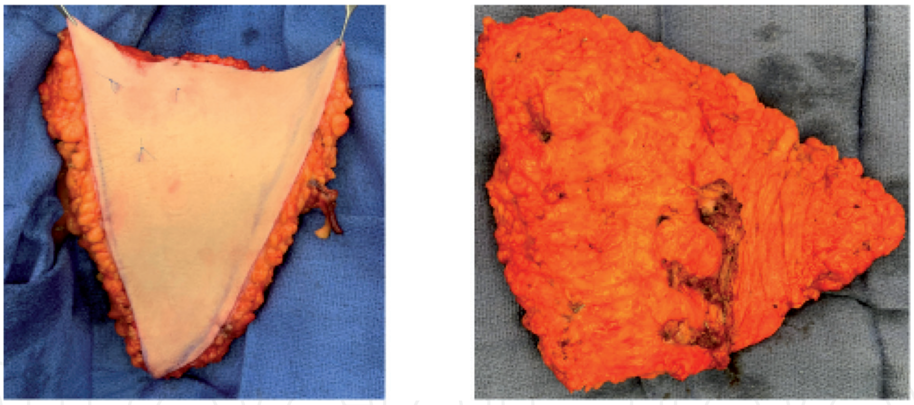

Figure 16.
Anterior and posterior surfaces of the DIEP flap with visible superficial inferior epigastric vein.

of hernia, bulging, and abdominal wall weakness are reduced. Other benefits of the SIEA flap is that it can reduce patient discomfort and hospital stay [8]. The SIEA flap is performed in the minority of patients because 35–51% of patients do not have an SIEA [8, 26]. Other disadvantages of the SIEA flap is it can only perfuse zones I and II, has a short pedicle length (5–8 cm), and the pedicle exits the flap just below the skin. The use of the SIEA flap should be performed if the vessel is palpable with a diameter that is at least 1.5 mm [8, 27]. If the SIEA is absent or small then one should proceed to evaluating the deep inferior epigastric perforators as discussed above.

5.3.1 Flap dissection

The breast and abdomen markings for the SIEA flap is the same as the TRAM and DIEP flaps (**Figure 5**). The lower abdominal incision is made and then the SIEA is identified. The SIEA is usually one third of the distance from the pubic tubercle to the ASIS. A couple techniques to help identify the SIEA is the use of Doppler or to apply traction on both sides of the lower incision with your fingers to help separate the fat from the SIEA. The SIEA and SIEV can be dissected to their origin on the superficial circumflex iliac vessels or less commonly the femoral vessels. If one is not confident that the SIEA will perfuse the flap, the deep inferior epigastric perforators can be dissected suprafascial and then temporarily clamped so the perfusion of the flap can be assessed. Once perfusion of the flap is confirmed, then the deep perforators can be transected and the pedicle clipped/divided. The flap needs to be placed medially to allow the short pedicle to reach the internal mammary vessels. Hence, the ipsilateral SIEA flap is preferred.

5.4 Transverse upper gracilis (TUG)

For patients that have contraindications to using abdominal tissue for breast reconstruction or who do not want a scar from hip to hip they can use their thigh tissue. Another benefit of using thigh tissue as a donor site is that it can result in a thigh lift and the scar is usually inconspicuous. The transverse upper gracilis (TUG) flap was modified by Yousif in 1992 to allow for improved skin paddle survival [28]. It was not until 2002 when Arnez performed the first free TUG flap for breast reconstruction [29].

The TUG flap is a Mathes and Nahai type II flap with the dominant vascular supply from the ascending branch of the medial circumflex femoral artery [18]. The pedicle is around 6 cm in length and enters the gracilis muscle on its medial side about 8–10 cm inferior to the pubic tubercle [29, 30]. There are one or two minor pedicles from the superficial femoral artery that enter the distal aspect of the gracilis muscle [29].

5.4.1 Marking

The breast markings are performed in the standard fashion (**Figure 5**). The patient is then frogged legged with the thigh abducted and externally rotated. The adductor longus is marked from the pubis to the medial femoral condyle. The gracilis muscle is located 2–3 cm posterior to this line. A doppler is used to identity the perforator for the TUG flap 8–10 cm inferior to the pubic tubercle over the gracilis muscle. The skin paddle is centered over the perforator and the vertical height of the flap determined by a pinch test (**Figure 17**). Primary closure can occur with a width of 10–12 cm. The proximal incision marking is at or 1 fingerbreadth below the groin crease and extends from just lateral to the adductor longus to the midline of the posterior thigh along the gluteal crease. The distal incision marking is then drawn to form a semilunar skin paddle that can have a length up to 25 cm [31, 32].

5.4.2 Flap dissection

The patient is placed in the supine position with the thigh abducted and the knee flexed. The anterior part of the flap is raised first above the level of the muscular fascia. Care is taken to preserve the saphenous vein but the posterior branch can be included in the flap. Once the medial aspect of the adductor longus is reached, the muscular fascia is incised. The interval between the adductor longus and gracilis is entered so the pedicle can be identified entering the medial aspect of the gracilis muscle. The ascending branch of the medial circumflex femoral artery is dissected all the way to the profunda femoris artery, which can allow for a pedicle length of 5–6 cm [29, 31]. After the pedicle is dissected, the posterior aspect of the flap can be raised above the muscular fascia. At the posterior aspect of the gracilis, the dissection becomes subfascial. The gracilis muscle is then transected 3 cm above and below the entrance of the pedicle. The obturator nerve branch to the gracilis is clipped and divided followed by the pedicle. In contrast to the abdominal flaps, the TUG flap needs to be coned by approximating the superior edges of the two wings

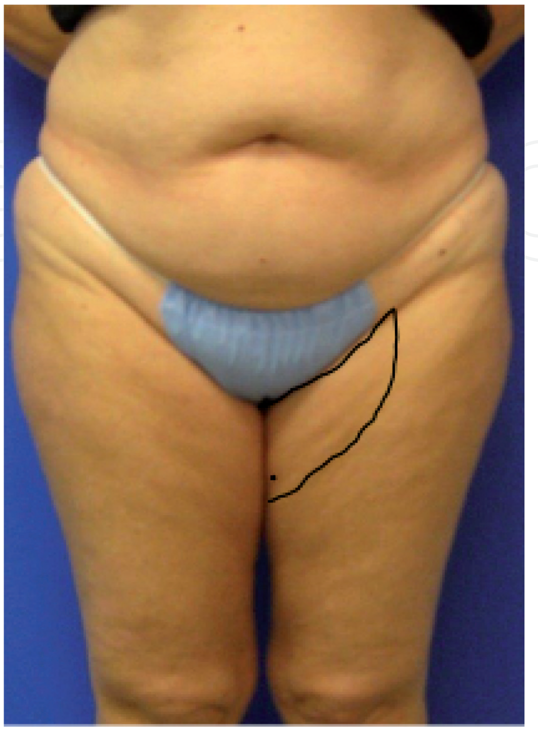

Figure 17.
TUG flap and perforator markings.

Figure 18.
Bilateral breast reconstruction using TUG flaps.

of the flap. The apex of the coned flap can then be used to reconstruct a nipple areolar complex (NAC). The post-operative results of a patient that underwent bilateral TUG flaps for breast reconstruction is shown in **Figure 18**.

5.5 Profunda artery perforator (PAP)

Another thigh-based flap for patients with contraindications to abdominal donor tissue is the profunda artery perforator (PAP) flap, which was first performed by Allen and Haddock in 2010 for breast reconstruction [33, 34]. Prior to this in 2000, Angrigiani developed the PAP flap based on the first medial branch of the profunda femoris artery [35]. Suitable patients for a PAP flap would have excess tissue in the posterior medial thigh and small to moderate sized breasts [34].

The PAP flap is a fasciocutaneous flap that is based on the second or third perforator from the profunda femoris artery. The pedicle length can be up to 13 cm and can be septocutaneous or go through the adductor magnus muscle [36]. The benefits of the PAP flap over the TUG flap is it has a larger volume, longer pedicle, requires no muscle sacrifice, and less anterior thigh scar. The PAP flap can also be converted to a TUG or IGAP flap if needed intra-operatively [36].

5.5.1 Marking

The breast markings are made in standard fashion (**Figure 5**) then the patient is placed in the supine position with the thigh abducted and knee flexed. The gracilis muscle is identified just posterior to the adductor longus muscle. A mark is made 2 cm posterior to the gracilis muscle and 8 cm inferior to the groin crease. A Doppler is used to confirm the perforator around this location [35]. There are also other posterior or lateral thigh perforators from the profunda femoris artery that

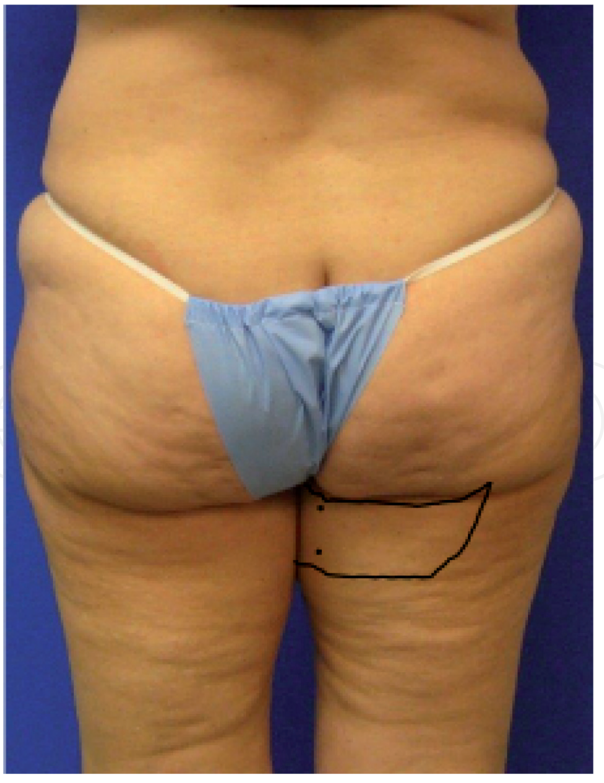

Figure 19.
PAP flap and perforator markings.

are seen on preoperative CTA or MRA that can be used but the medial perforators are preferred because of ease of positioning and size of the medial perforators [34]. The flap is designed in an ellipse shape with the superior border of the flap at or 1 cm below the gluteal crease and the inferior border around 7 cm below the superior marking (**Figure 19**). A pinch test can also be performed to increase the vertical height of the flap if needed. Care is taken to make sure the flap is centered on the marked perforator(s). The length of the flap can be up to 35 cm, which extends from the posterior lateral thigh to the medial thigh. If the TUG flap is being considered as a bailout plan then the medial incision should be carried to the adductor longus [37]. If more posterior perforators are being considered the patient can be in the prone position.

5.5.2 Flap dissection

Similar to the TUG flap, the PAP flap is performed in the supine position with the thigh abducted and knee flexed. The anterior medial aspect of the flap is raised above the level of the muscular fascia until the posterior border of the adductor longus is reached. A subfascial plane is dissected between the adductor longus and gracilis muscles. The perforator to the PAP flap can be identified along the adductor magnus muscle as you dissect posteriorly. If no perforator is seen then the flap can be converted to a TUG flap. After confirming the perforator to the PAP flap the gracilis muscle can be retracted anteriorly to aid in further perforator dissection. If further pedicle length is needed then the pedicle can be dissected to the profunda femoris artery (**Figure 20**). The posterior lateral aspect of the flap can then be dissected in the suprafascial plane and then below the fascia once the perforator is nearby. To increase volume in the flap and improve lateral thigh contour, the flap can be beveled in the lateral thigh [34]. The pedicle to the flap can be clipped and divided after the flap is elevated. The PAP flap is coned in the same fashion as the TUG flap with the apex of the flap able to reconstruct the NAC as needed.

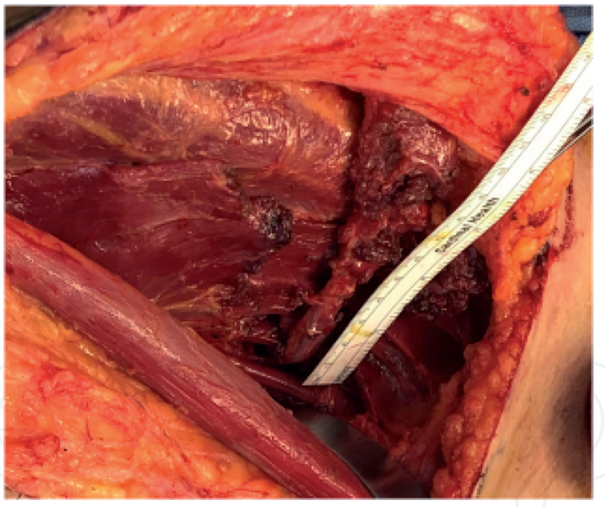

Figure 20.
PAP flap pedicle dissected through adductor magnus muscle to the profunda femoris artery.

5.6 Superior gluteal artery perforator (SGAP)

Breast reconstruction can be performed by utilizing gluteal tissue if the abdomen and thighs are not usable as donor sites. The first superior gluteal artery myocutaneous flap for breast reconstruction was by Fujino in 1975 [38]. With the development of perforator flaps, Allen in 1993 developed the superior gluteal artery perforator (SGAP) flap to allow for a longer vascular pedicle and gluteus maximus muscle preservation [39, 40]. The use of the SGAP is not considered the first option for breast reconstruction because of a tedious flap dissection, change in positioning in the operating room, smaller volume flap, and gluteal scarring [40].

The SGAP flap is based on the superior gluteal artery, which is a branch of the internal iliac artery. The superior gluteal artery leaves the pelvis above the piriformis muscle and then divides into a deep and superficial branch. The superficial branch transverses the gluteal muscles and gives off perforators to the skin [30]. The use of CTA or MRA preoperatively can be used to aid in identification of the SGAP perforators.

5.6.1 Marking

To aid in intra-operative positioning, the patient is placed in the lateral decubitus position and the ipsilateral flap is used so a two team approach can be utilized for the chest and gluteal areas. If bilateral gluteal flaps are needed then the patient will have to be in the prone position for flap harvest after the mastectomies and recipient vessels are harvested. The posterior superior iliac spine (PSIS), anterior superior iliac spine (ASIS), greater trochanter, and coccyx are marked. The perforators are identified one third of the distance from the PSIS to the greater trochanter, which is confirmed with Doppler. There can be more lateral perforators located between the gluteus maximus and gluteus medius muscles that can allow for a longer pedicle length, which can be included in the flap. The flap is then centered on a line from the coccyx to the ASIS. It is desirable to have a less centric but more laterally placed perforator, which will allow for a longer pedicle. The height of the flap can vary from 7 to 14 cm but must be confirmed with the pinch test to allow for appropriate closure (**Figure 21**). The length of the flap can also vary from 18 to 30 cm [30, 40].

Figure 21.
SGAP (right) and IGAP (left) flap and perforator markings.

5.6.2 Flap dissection

The SGAP flap skin incisions are made and then beveled outward once past the superficial fascia to increase flap volume and to improve the transition onto the chest wall. The gluteus maximus fascia is incised and then the dissection proceeds in this plane above the muscle from lateral to medial until the perforators are identified. Similar to DIEP flap dissection, the dominant perforators are identified and preserved. Usually one large perforator is selected but two perforators in the same muscle fiber plane can also be dissected together. The selected perforators are dissected vertically between the gluteus maximus muscle fibers and through the deep gluteal fascia until a fat pad is seen. Once the pedicle is of the appropriate size and length the dissection can cease. In a unilateral reconstruction in the lateral decubitus position, the pedicle to the flap can be clipped and divided followed by the microvascular anastomoses. If a bilateral reconstruction is performed in the prone position, the flaps should be placed in a bag on an ice saline bath. The patient is then flipped supine so the anastomoses can be performed. The internal mammary vessels are the main recipient vessels for the SGAP flap. If the SGAP flap has two perforators then one can be connected in an antegrade fashion and the other in a retrograde fashion to the internal mammary vessels. After confirming flap perfusion, the flap can be coned or the tips excised to improve flap contour [30, 40].

5.7 Inferior gluteal artery perforator (IGAP)

The inferior gluteal artery perforator (IGAP) flap is another gluteal based free flap for breast reconstruction. The first IGAP free flap for breast reconstruction was performed by LeQuang in 1978 [41]. The ideal patient will have excess tissue in the inferior buttock or a saddlebag deformity. The benefit of the IGAP flap over the SGAP flap is the scar can be hidden in the gluteal crease and it does not leave a hollowing in the superior gluteal area [42]. However, the IGAP flap tends to be smaller than the SGAP and can lead to increased patient discomfort if the sciatic nerve is exposed [27].

The IGAP flap is based on the inferior gluteal artery, which is a branch of the internal iliac artery. The inferior gluteal artery leaves the pelvis below the piriformis muscle and is soon accompanied by the sciatic nerve, posterior femoral cutaneous nerve, and the internal pudendal vessels [32]. The IGAP can also be neurotized if the inferior gluteal nerve is preserved. Similar to other perforator flaps, preoperative CTA or MRA can be used to aid in identification of the IGAP perforators.

5.7.1 Marking

The gluteal crease is marked in the standing position. The positioning of the patient for the IGAP flap is the same as for the SGAP flap. Lateral decubitus for a unilateral reconstruction and prone for a bilateral reconstruction. The PSIS and ischial tuberosity are marked. The inferior gluteal perforators are identified two third of the distance from the PSIS to the outer aspect of the ischial tuberosity. The inferior border of the flap is marked at or 1 cm inferior to the gluteal crease. After confirming the location of the IGAP perforators with a doppler, the superior border of the flap is marked to form an ellipse that is parallel to the gluteal crease [42]. The height of the flap is usually around 7–8 cm but must be confirmed with a pinch test (**Figure 21**). The length of the flap is around 18 cm. The flap can be designed to include the saddle bag deformity laterally. Care must be taken to leave tissue over the ischial tuberosity to prevent patient discomfort and wound dehiscence when in the sitting position [30].

5.7.2 Flap dissection

The IGAP flap skin incisions are made and then continued just distal to the gluteus maximus fascia. Beveling of the flap can occur to increase flap volume or to remove tissue in the saddle bag area. The dissection proceeds in this plane above the muscle from lateral to medial until the inferior gluteal artery perforators are identified. Typically, two to four perforators from the inferior gluteal artery can be identified but the dominant perforators are preserved [42]. Usually one perforator that is greater than 1 mm is selected but two perforators in the same muscle fiber plane can also be dissected together. The selected perforators are dissected vertically between the gluteus maximus muscle fibers and through the deep gluteal fascia. Once the pedicle is of the appropriate size and length the dissection can cease. Similar to the SGAP harvest, a unilateral reconstruction in the lateral decubitus position can then proceed with pedicle clipping and dividing followed by the microvascular anastomoses. If a bilateral reconstruction is performed in the prone position, the flaps should be placed in a bag on an ice saline bath. The patient is then flipped supine so the anastomoses can be performed. The recipient vessels for the IGAP flap are the internal mammary vessels but they can also reach the thoracodorsal vessels since the pedicle length is around 8–11 cm. The elliptical IGAP flap is coned or the tips trimmed after the microvascular anastomoses [30, 42].

6. Insetting

After the arterial and venous anastomoses are deemed to be patent by using various techniques such as the strip test, uplift test, checking for dermal bleeding, and SPY-angiography, the flap should be placed into the breast pocket gently as to not avulse the anastomosis. If an abdominal flap is performed, the contralateral flap is usually chosen and rotated 90° so the corner of the flap with the umbilical carve out is placed inferior laterally. Therefore the vertical height of the flap will represent the width of the reconstructed breast. If the thoracodorsal vessels are preferred, then an ipsilateral flap should be used and rotated 90° so the pedicle vessels exit the flap laterally. A limitation to using the thoracodorsal vessels include the inability to medialize the flap that can result in a narrow breast. The rotation of the flaps can also be modified to increase or decrease the new breast mound width and/or height.

The shape of the neo-breast mound can be over looked and is a critical proponent to breast reconstruction from an esthetic standpoint. The first step to aid in shaping of the breast is to trim the flap to the desired breast footprint. Often it is necessary to trim and tapper the most lateral aspect of the flap or zone 4 to improve the contour of the upper pole of the breast. The projection of the flap can also be easily modified by folding the flap on itself or coning. In unilateral breast reconstructions, stacked or bipedicled abdominal free flap can be performed to increase volume as needed [43]. Once the shape of the flap is optimal, the flap should circumferentially be sutured down to the chest wall using 2-0 absorbable suture. Usually the medial aspect of the flap is sutured first to insure medial fullness of the neo-breast mound. The superficial fascia and/or dermis of the flap can be sutured to the deep fascia and inframammary fold (IMF) of the chest.

7. Mastectomy flap assessment and skin closure

Upon completion of flap in-setting, the viability of the mastectomy skin should be performed. Clear areas of devascularized mastectomy skin should be sharply excised. For areas of the mastectomy skin that are not so obvious, indocyanine green (ICG) angiography can be used to assess perfusion (**Figure 22**).

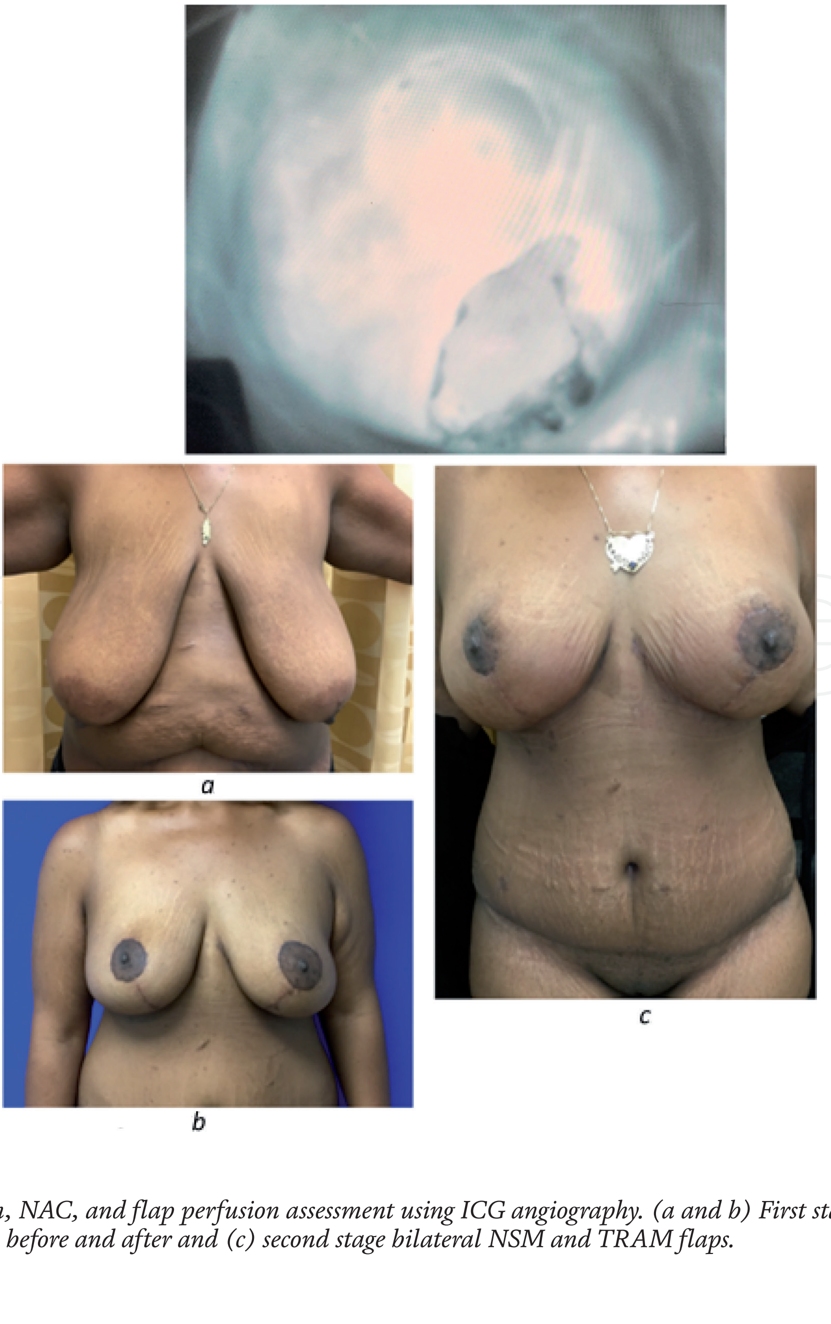

Figure 22.
Mastectomy skin, NAC, and flap perfusion assessment using ICG angiography. (a and b) First stage bilateral breast reduction before and after and (c) second stage bilateral NSM and TRAM flaps.

The trimming of mastectomy skin with the use of ICG imaging reduces the need for future operations secondary to deep skin necrosis [44]. Another alternative if a large or critical area of mastectomy skin is concerning for poor perfusion, the flap can be buried and then a second look procedure in 72 h can be performed to re-assess the mastectomy skin [45]. Aside from excising devascularized mastectomy skin, areas with significant radiation changes, scarring, and/or tethering need to be excised to allow for optimal outcomes. If the mastectomy skin is constricted causing pin cushioning of the flap, a superior lateral incision in the mastectomy skin can allow for release of the constricted mastectomy skin.

Once the mastectomy skin defect is known, the skin paddle on the flap can be designed. The excess skin on the outside of the skin paddle is then de-epithelialized using Gorney scissors or a scalpel. It is important to preserve the dermis in order to protect the subdermal plexus of the flap. However, from an esthetic standpoint to prevent an indentation along the flap suture line it is necessary to score the dermis about 1–2 mm away from the skin paddle. Prior to skin closure, hemostasis in the breast pocket and along the de-epithelized flap need to be confirmed. A 15F round channel drain is placed along the axilla and IMF then exits the skin inferior to the IMF along the anterior axillary line. The dermis is then approximated using 2-0 or 3-0 absorbable suture followed by 4-0 running subcuticular for the skin. The Doppler signal on the skin paddle should be confirmed and marked with a 5-0 prolene suture. Our preferred dressings for the flap incision is antibiotic ointment and xeroform then coverage with abdomen battle dressing (ABD) pads.

8. Ptosis management

Nipple-sparing mastectomy (NSM) has increased overtime with refinements in oncologic techniques and protocols, allowing for improved patient satisfaction and esthetics [46]. Patients with large or ptotic breasts were traditionally contraindicated to have nipple preservation over concerns of poor mastectomy skin and nipple perfusion. Some techniques that have been developed to increase nipple perfusion in ptotic patients include mastopexy or reduction (**Figure 22a–c**) before NSM, mastopexy during the time of the NSM, and nipple devascularization [47–49].

Figure 23.
Single stage bilateral NSM, de-epithelization wise pattern mastopexy, and TRAM flaps.

The use of mastectomy or reduction with a minimum of 3–4 weeks prior to nipple sparing mastectomy was performed by Spear in fifteen patients. No reports of total nipple-areola complex necrosis occurred and 13% had partial nipple-areola complex necrosis [47]. It is important to note that the majority of patients in this study underwent prophylactic NSM's because by adding an additional procedure can delay oncologic treatment of cancer patients. Another technique is to perform the mastopexy at the time of the nipple sparing mastectomy, which can be in a peri-areolar, vertical, or wise fashion [48]. Nguyen described an approach of skin reduction with deepithelization and tissue infolding that preserves dermal plexus perfusion and promotes nipple and skin flap survival in immediate breast reconstruction after skin sparing and NSM [49] (**Figure 23**).

Staged devascularization of the NAC can also be performed 1–3 weeks prior to NSM [50, 51]. This is performed by using a pre-existing incision or making a vertical or radial lateral incision then undermining the NAC and the adjacent skin for 4–5 cm in the mastectomy plane. During this time a biopsy of the subnipple is performed to confirm absence of tumor. The staged devascularization of the NAC in a study by Jensen in 20 patients resulted in 100% NAC survival after the NSM [50]. A follow up study by Nguyen a few years later also support the use of staged devascularization of the NAC in high risk women that undergo NSM [51, 52].

9. Adjunctive procedures

9.1 Neurotization

The ideal reconstructed breast should not only take into consideration size, shape, symmetry, and softness but also sensibility. The presence of sensation in the reconstructed breast has shown to improve patient satisfaction and quality of life [53]. The neurotization of abdominally based free tissue transfers have shown to have significantly increased sensory recovery [53, 54]. Coaptation of the flap nerve is typically performed to the anterior branch of the third intercostal nerve (**Figure 24**). This donor nerve can be found just below the third rib and crosses just anterior to the internal mammary vessels. The benefits of using the anterior branch of the third intercostal nerve is minimal dissection needed and it is in the vicinity of the vascular anastomoses. A less commonly used donor nerve is the lateral cutaneous branch of the third or fourth intercostal nerve because it can be damaged with the mastectomy procedure and is far away from the flap pedicle [54]. If primary coaptation of the nerves is not possible, a nerve conduit or graft can be used to improve sensibility. A meta-analysis

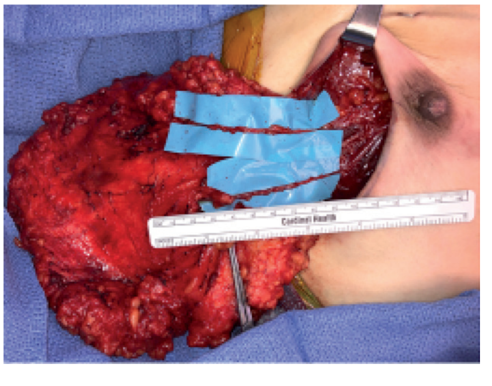

Figure 24.
TRAM flap neurotized to the anterior branch of the third intercostal nerve.

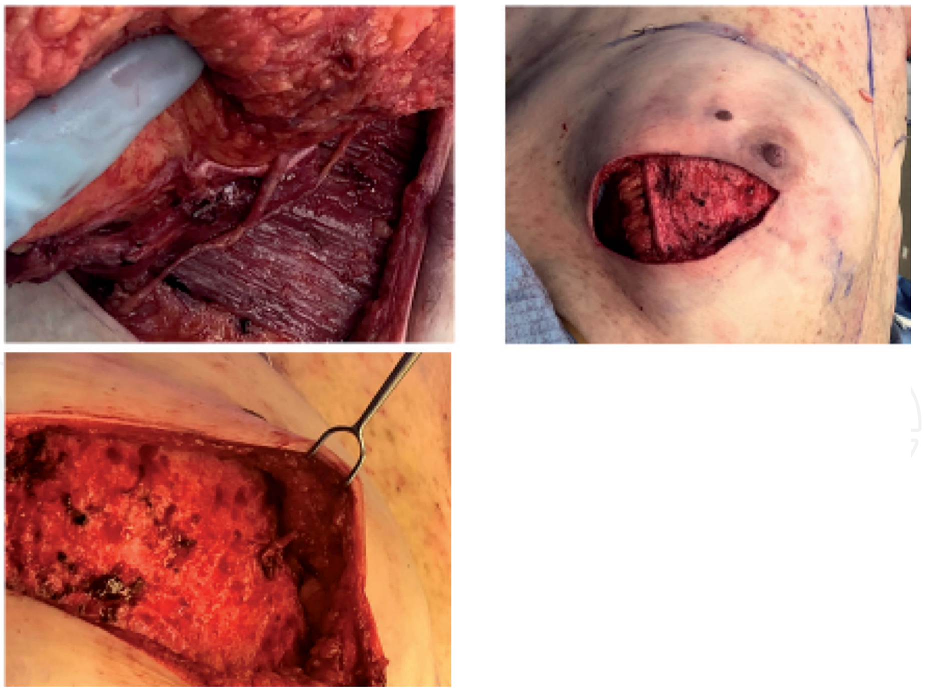

Figure 25.
NAC neurotization to lateral branch of fourth intercostal nerve using nerve graft and tunneled through TRAM flap.

of 37 articles on neurotization of breast reconstruction showed that sensation returns spontaneously but neurotization can lead to earlier return of sensation and increased magnitude [55]. Beside neurotization of the flap, the NAC can be neurotized with the aid of a nerve graft to the lateral branch of the fourth intercostal nerve (**Figure 25**).

9.2 Autologous with implant

Another adjunctive procedure for patients that need flap skin for their breast reconstruction but do not have enough donor tissue volume to reconstruct a larger size breast is the addition of an implant or tissue expander at the time of free tissue transfer [56–60]. This was first reported in 5 patients who had combined TRAM flaps with implants placed by Miller in 1996 [56]. In this study no flap compromise or implant complication

Figure 26.
Bilateral TRAM flap breast reconstruction combined with immediate implant.

was reported. Others have shown that immediate expander/implant placement at the time of the free tissue transfer is associated with higher late (>30 days) implant related complications such as infection, implant rupture, implant malposition, rippling, and capsular contracture [58]. These could be secondary to a longer procedure with unrecognized contamination of the implant and difficulty with forming an appropriate implant pocket [58]. A more recent study by Momeni in 2018 demonstrated that no implant infection, implant malposition, and flap loss occurred in 23 patients that underwent autologous reconstruction with simultaneous prepectoral silicone implant placement [59]. In patients that have undergone neoadjuvant irradiation, the use of TRAM flap combined with an implant significantly lowers the implant loss rate (5 vs. 30%) and reconstruction failures (10 vs. 42%) when compared to expander/implant only reconstructions [60]. Often patients that undergo immediate autologous reconstruction with implant placement have increased esthetic appearance with more breast fullness and less ptosis when compared to their breasts prior to their mastectomies (**Figure 26**).

10. Conclusion

Free autologous tissue transfer from the abdomen is the ideal reconstruction option for the majority of breast cancer patients. The use of autologous tissue can result in a natural appearing breast that is soft, symmetric, and sensate. With improvements in microsurgical techniques, the donor site morbidity and flap complications are minimal allowing for free tissue transfers to be performed in most breast reconstruction patients. Although the abdomen is the preferred donor site, there are other areas that can be utilized for reconstruction. This chapter reviews some of the common free autologous tissue transfers for breast reconstruction along with some adjunctive procedures.

Conflict of interest

The authors have no conflict of interest to disclose.

Notes/thanks/other declarations

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