The Pedicled TRAM Flap in Breast Reconstruction

36

Glyn Jones

36.1 Introduction

Breast reconstruction using autologous techniques [1] have undergone considerable change in recent years. Earlier implant and expander-implant reconstructions achieved mound creation, but a natural ptotic breast shape remained an elusive goal. Recent advances in implant shape and texture technology coupled with the use of acellular dermal matrices have done much to dramatically improve implant-based outcomes in reconstruction, constituting over 80% of all breast reconstructions performed in the United States at this time. Some surgeons find the attendant complication rates and need for long-term maintenance troubling. Distortion and capsular contracture did little to encourage reconstructive surgeons and may well have contributed significantly to Veronesi's successful focus on breast conservation therapy. While capsular contracture is no longer the major problem it used to be, implant-based reconstruction definitely requires ongoing maintenance in the long term. The advent of autologous techniques with the latissimus dorsi and then transverse rectus abdominis myocutaneous (TRAM) flap and its derivatives for breast reconstruction revolutionized breast reconstruction, enabling surgeons to create a breast that is soft, warm, and well integrated into a patient's psyche. The latissimus flap often requires an additional implant, but TRAM flap techniques enabled us to create a truly autologous breast reconstruction without the need for long-term maintenance or adverse events. The popularity of skin-sparing mastectomy (SSM) and nipple-sparing mastectomy (NSM) has made further landmark advances in breast reconstruction, attaining the goal of a natural, almost scarless reconstructed breast. These oncologically safe procedures do not compromise mastectomy outcomes [2–4]. Combined with TRAM flap reconstruction whether pedicled or free, the technique offers potential for increasing patient acceptance of mastectomy as an alternative to breast conservation therapy (BCT). In our practice, 95% of patients undergoing mastectomy select immediate reconstruction with skin- or nipple-sparing mastectomy, while a minority present for delayed reconstruction.

36.2 History of the Pedicled TRAM Flap

Millard described the use of a tubed lower abdominal pedicled flap in reconstructing the radical mastectomy defect in 1976 [5]. The flap was transferred onto the chest via the forearm, using a waltzing technique, achieving a successful autologous tissue reconstruction for the time. In 1979, Robbins used a vertical rectus abdominis flap for breast reconstruction [6]. Independently, Drever, Dinner, and Sakai all refined variations on the use of vertical rectus abdominis myocutaneous flaps for breast reconstruction [7–10]. Hartrampf and Scheflan took the bold step of changing the skin island orientation to a transverse one across the mid-abdomen, making a more sizeable volume of tissue available for breast reconstruction with a cosmetically desirable donor site [11–14]. Scheflan confirmed the dominant deep inferior epigastric arterial supply to the lower abdominal skin and fat. Blood supply was most reliable directly over the designated rectus muscle from which perforators were most abundant, while the periphery of the flap relied on the capture of successive angiosomes through the subdermal plexus. Milloy had documented the blood supply of the rectus muscles in 1960, and these findings together with Scheflan's dissections found their culmination in the lead oxide injection studies of Taylor, Moon, and Palmer. Their publication of the angiosome concept was an extension of Michel Salmon's anatomic studies [15–17]. From these beginnings, the TRAM flap became the gold standard procedure for breast reconstruction and remains in widespread use today. In the interim, free flap options have arisen as refinements of the original pedicled technique, including the free TRAM (FTRAM), the muscle-sparing free TRAM, and the deep inferior epigastric

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artery perforator (DIEP) flaps, as well as the superficial inferior epigastric perforator (SIEA) flap. While the younger generation of plastic surgeons is rarely trained to perform pedicled TRAM flaps, they are still widely performed in the United States as well as in Europe at this time. Part of this relates to the dramatically shorter operating times, easier technical procedure, and lack of potential total flap loss in the pedicled flaps. Physician reimbursement has certainly impacted the nature of autologous reconstruction in some areas where perforator flaps are consistently rewarded with higher payment schedules.

36.3 The Vascular Anatomy of the Pedicled TRAM Flap

The skin and fat of the lower abdomen and periumbilical area are supplied by perforators arising from five major sources:

- Superior epigastric vessels arising from the termination of the internal mammary vessels
- Deep inferior epigastric vessels
- Superficial inferior epigastric vessels
- Intercostal segmental vessels
- Terminal branches of the superficial and deep circumflex iliac vessels

Of these, only the superior epigastric vessels are utilized when raising a pedicled TRAM flap. The predominant blood supply of the lower abdominal tissues is, however, unquestionable from the deep inferior epigastric system [14, 16, 17]. The vessels from both epigastric systems penetrate the rectus muscles on their deep surfaces and travel as single or duplicated vessels up and down the flap to anastomose in the periumbilical region through a system of choke vessels described by Taylor [17–19].

Three vascular patterns have been identified within the rectus muscles:

Type I (29%) had a single superior and inferior arterial supply.
Type II (57%) had a double-branched system from each source artery.
Type III (14%) had a triple-branched system from each vessel.

Bilateral vascular symmetry was noted in only 2% of patients.

Moon and Taylor proposed three variations in skin island design: the upper, mid-abdominal, and lower abdominal flaps. Vessels injections studies suggested increasing paucity of inflow the lower the skin paddle was placed on the abdominal wall in the case of a pedicled flap. This finding was corroborated by Harris [20] and has led to most surgeons designing the flap from just above the umbilicus to above the pubic crease and not below it.

Macroscopic communication between the two systems is present in only 40% of cases, while 60% of patients have choke vessels of microscopic caliber [16, 21]. These choke systems allow for reversal of flow to open up between the two systems to provide increased blood flow to the tissues. The superior vessels pass into the muscle from the deep aspect of the costal margin and run inferiorly. The deep inferior epigastric supply enters the posterolateral aspect of the muscle below the arcuate line and passes up to anastomose with the superior vessels in the periumbilical area. It provides significantly more circulation to the flap and is accompanied by two large venae comitantes which drain into the iliac circulation [14, 19]. These venae comitantes are usually larger than the superior veins, which partially explains the improved venous drainage associated with the free TRAM. The most dominant venous outflow is often supplied by the superficial inferior epigastric vein, the basis of the SIEA flap. This fact can lead to venous congestion in free flaps requiring decompression through the superficial inferior epigastric vein (SIEV). The periumbilical anastomosis has a bidirectional venous outflow confirmed by Taylor. Following elevation of a pedicled TRAM flap, distal venous flow has to reverse, following the drainage pattern of the superior veins. In order to achieve this, the venous flow pressure has to overcome the venous valves within the choke system described by Taylor [16, 17]. Arterial perforators arise from both systems and run in two roughly parallel lines on either side of the linea alba. The lateral row lies 2–3 cm within the lateral border of the rectus sheath, while the medial row lies 1–2 cm from the linea alba [17]. These vessels vary significantly in both size and number; their caliber may be miniscule to several millimeters in diameter.

The anterior rectus sheath is densely adherent to the muscle at the tendinous inscriptions. During flap elevation, a gently tapering cuff of this fascia is left on the muscle with its apex toward the costal margin helping to maintain the integrity of the muscle, thereby reducing the risk of injury to the pedicle. It also aids in reducing tension during closure [22]. A muscle-sparing technique can be used to leave a strip of muscle laterally and/or medially to assist in maintaining abdominal wall strength, but the rationale for this is flawed as it is poorly vascularized (if at all) and probably just contributes some fibrous scar to the long-term abdominal closure. The intercostal nerves and vessels penetrate the posterior aspect of the rectus muscle at the junction of the mid and lateral thirds of the muscle and not in the lateral third. Any lateral segment is probably devoid of neurovascular input [23, 24]. Harris demonstrated an 80% reduction in intraoperative blood flow when clamping the medial and

lateral thirds of the rectus muscle to simulate muscle-sparing harvest [20]. Consequently, there seems little value to incorporating muscle-sparing surgery into TRAM flap harvest.

36.4 Vascular Zones in TRAM Flap Blood Supply

Two major vascular classifications exist for TRAM flap blood supply. The best known and earliest description was that of Hartrampf (Fig. 36.1) who divided the supply into four zones:

Zone I overlying the muscle pedicle
Zone II lying across the midline, immediately adjacent to zone I
Zone III lying lateral to zone I on the ipsilateral side
Zone IV lying lateral to zone II on the contralateral side from the pedicle

Historically, zone I is the most reliable portion of the flap. This was followed by the medial portion of zone III. The end of zone III becomes increasingly unreliable as one moves toward the tip of the flap and it is wise to discard it in most patients. The medial portion of zone II is also usually reliable, but the lateral part is less predictable followed by zone IV which should be discarded routinely. Taylor documented the anatomic theory behind this approach in his paper on the angiosome concept [16]. It is his belief that a single adjacent vascular territory could be captured relatively reliably, but more than one angiosome capture becomes increasingly unpredictable, particularly once the midline is crossed. These observations led Taylor to popularize the concept of TRAM flap delay in an effort to bolster the blood flow to the flap prior to elevation.

Ninkovich and Holm [25] performed dynamic indocyanine green perfusion imaging of DIEP flap blood supply in vivo. They reached the conclusion that while zone I remains the most reliably perfused portion of the flap, any flow across the midline is more precarious than ipsilateral flow. The Ninkovich classification proposes that Hartrampf's ipsilateral zone III should be renamed zone II, while Hartrampf's zone II should be renamed zone III with a less reliable flow due to its cross midline location (Fig. 36.2). One of their DIEP flaps is shown in Fig.

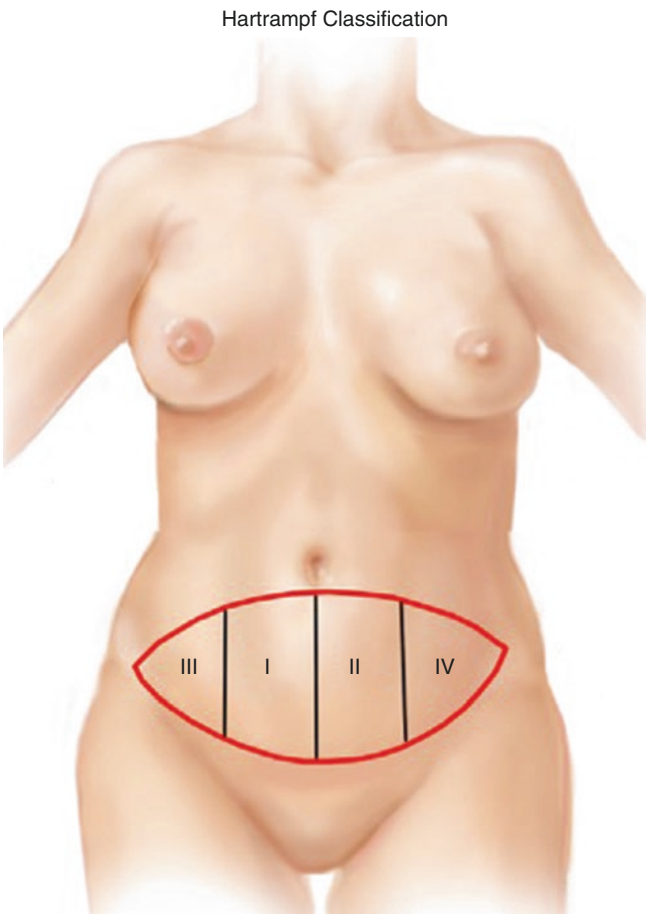


Fig. 36.1 Hartrampf's classification of TRAM flap blood supply zones

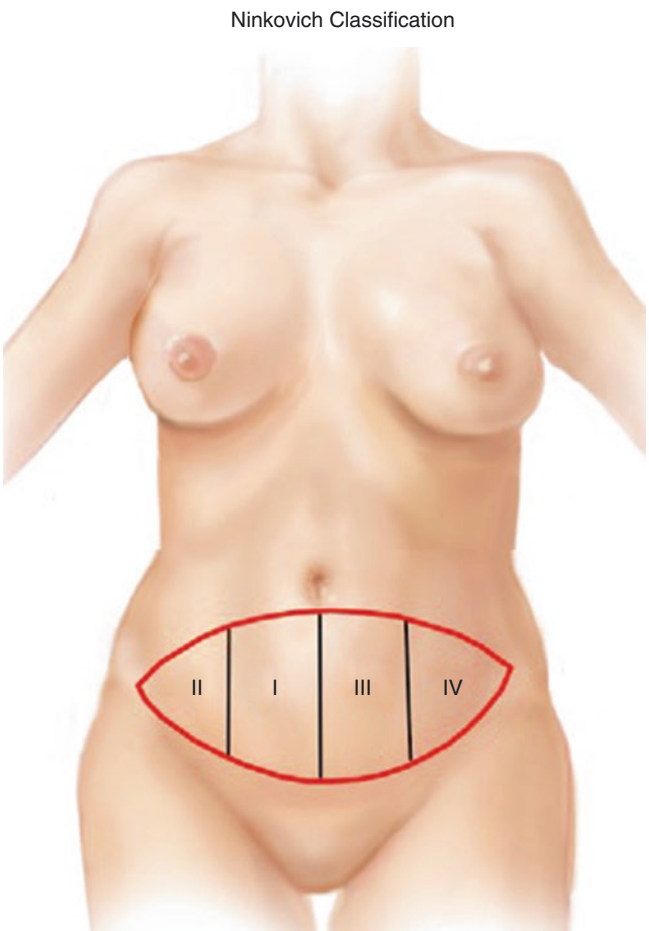


Fig. 36.2 Ninkovic's classification of TRAM/DIEP flap blood supply zones

(Fig. 36.2) clearly illustrating this phenomenon with all of the cross midline tissue showing signs of ischemia, while the ipsilateral tissue remains well perfused. These findings are borne out by both reperfusion times and the rate of flow in each zone. There is an increasing trend among both pedicled and free flap surgeons to rely more on the ipsilateral side than any cross midline tissue in an effort to reduce flap necrosis.

36.5 The Anatomic and Physiologic Basis of TRAM Flap Vascular Delay

Vascular delay is a historic concept, the efficacy of which was documented during the era of tube pedicled flaps for general reconstruction [26]. Moon and Taylor recommended surgical delay of the TRAM flap 1 week prior to definitive elevation. The procedure focused on ligation of the superficial and deep inferior epigastric systems in an outpatient setting. Although timed for 1 week prior to flap elevation and breast reconstruction, Taylor believes the delay phenomenon reaches its functional peak at 72 h after surgery rather than the classic 10-day window suggested in past literature [26]. The procedure is effective but adds another step to the operation with added costs incurred. One creative approach used by Rezai is to perform a contralateral breast reduction at the time of vascular delay, coming back several days later to transfer the vascular-delayed TRAM flap to the fresh mastectomy site. This maximizes operating room time utilization. Codner demonstrated a statistically significant rise in vascular inflow to the pedicle after delay with improved perfusion pressures in the vascular-delayed cases [27]. This was corroborated by Restifo and Ribuffo [28, 29]. Restifo demonstrated a flow in the superior epigastric vessels similar to that of the inferior system once delay had been performed. He was also able to demonstrate no additional benefit to waiting longer than 1 week after delay prior to formal flap elevation. Ribuffo used color Doppler studies to demonstrate increased caliber of, and flow within, the superior epigastric system after vascular delay [29]. The indications for delay can be summarized as follows:

- An alternative for plastic surgeons not comfortable with microsurgical reconstruction
- Useful for the higher-risk patient—obesity, smoking, and prior radiation to the proposed TRAM flap pedicle

36.6 Abdominal Anatomy and the Use of Pedicled TRAM Flaps

Competent rectus sheath closure is an essential element to success with any TRAM flap procedure, be it pedicled or free [22, 30, 31]. Laterally the rectus sheath consists of two fascial components derived from the external and internal oblique muscles. These blend into a confluent anterior sheet which fuses at the linea alba with the contralateral sheath. It is imperative that *both* lateral components be incorporated into the fascial closure when closing the donor defect if hernias or bulges are to be prevented [22, 32]. Nerve supply to the muscle is segmental and must be divided when raising the flap. It is essential to denervate the eighth intercostal nerve at the costal margin as this maneuver causes the muscle to atrophy so as to prevent muscle bulging at the costal margin tunnel when the patient sits up.

36.6.1 The Case for Delayed or Delayed-Immediate Reconstruction

Immediate breast reconstruction is the most favorable context in which to perform breast reconstruction as it offers the benefit of retaining the natural breast skin envelope's shape and consistency. It also retains the natural location and composition of the inframammary fold, assuming that the breast surgeon has not violated this critical structure. This leaves behind the patient's natural skin brassiere together with a defined inframammary fold [2] to help mold the newly reconstructed breast. While this is most valuable in immediate reconstruction, it does offer maintenance of the inframammary crease for delayed reconstruction. The original breast shape may be more readily matched as a consequence [33].

Traditional mastectomies leave a large skin defect making access to the chest wall, axilla, and TRAM flap tunnel communicating with the abdominal dissection very simple. In skin-sparing mastectomy, the excision usually incorporates a peri-areolar biopsy if this has been performed and axillary dissection is either done through the nipple-areola complex (NAC) wound or through a separate axillary incision [3]. The closer an excised skin biopsy site is to the excised nipple-areola disk, the greater is the risk of skin bridge necrosis. Skin incisions for the procedure have been suggested by Carlson, Toth, and Skoll, all of whom highlight the risks of the Wise pattern approach for ptotic patients [3, 34, 35]. Skin flaps must be handled gently in order to minimize the risks of skin necrosis. Every attempt should be made to preserve the inframammary fold as Carlson has shown that this does not

compromise the oncologic safety of the procedure and it greatly enhances the ultimate appearance of the reconstruction [36] . Although skin-sparing mastectomy may be used without immediate reconstruction, the retention of the additional breast skin does little to ease the reconstructive surgeon's task when delayed reconstruction is finally performed. This is particularly true of radiated patients. Data published by Kronowitz [37] has supported the concept of immediate-delayed reconstruction. In this process, mastectomy flaps may be held out to size by an immediately placed expander which can be inflated and then deflated during radiation if reconstruction is to be delayed, followed by re-expansion and either implant or free flap insertion. This approach has been given the label of "immediate-delayed" reconstruction but has a reputation for 35% complication rates from seromas and infection. Andree has more recently proposed the IDEAL concept of delayed reconstruction in which an implant and not an expander is placed and used as a spacer until radiotherapy has been completed, followed by early DIEP flap substitution. It does allow the surgeon to take advantage of nipple- or skin-sparing mastectomy in the face of delayed reconstruction.

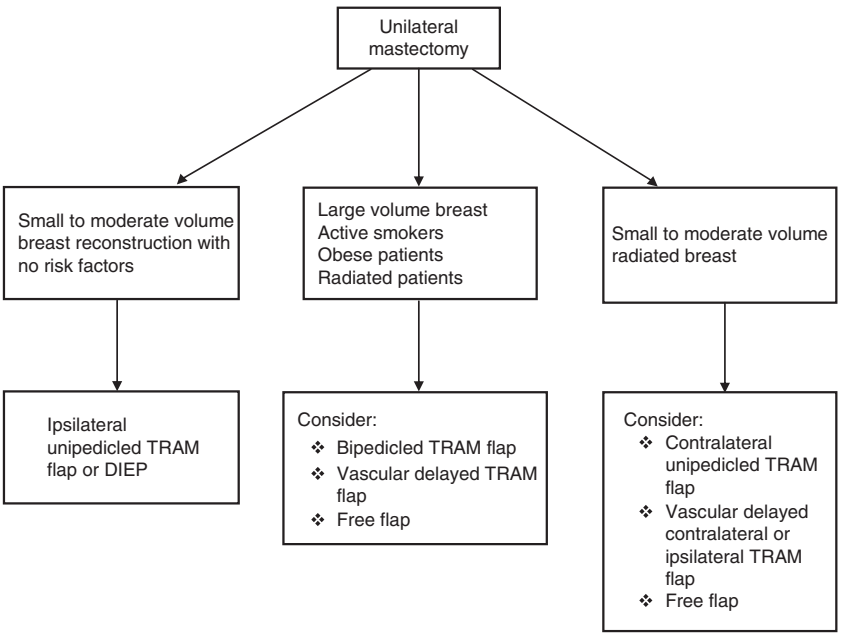
36.7 Patient Selection for TRAM Flap Breast Reconstruction

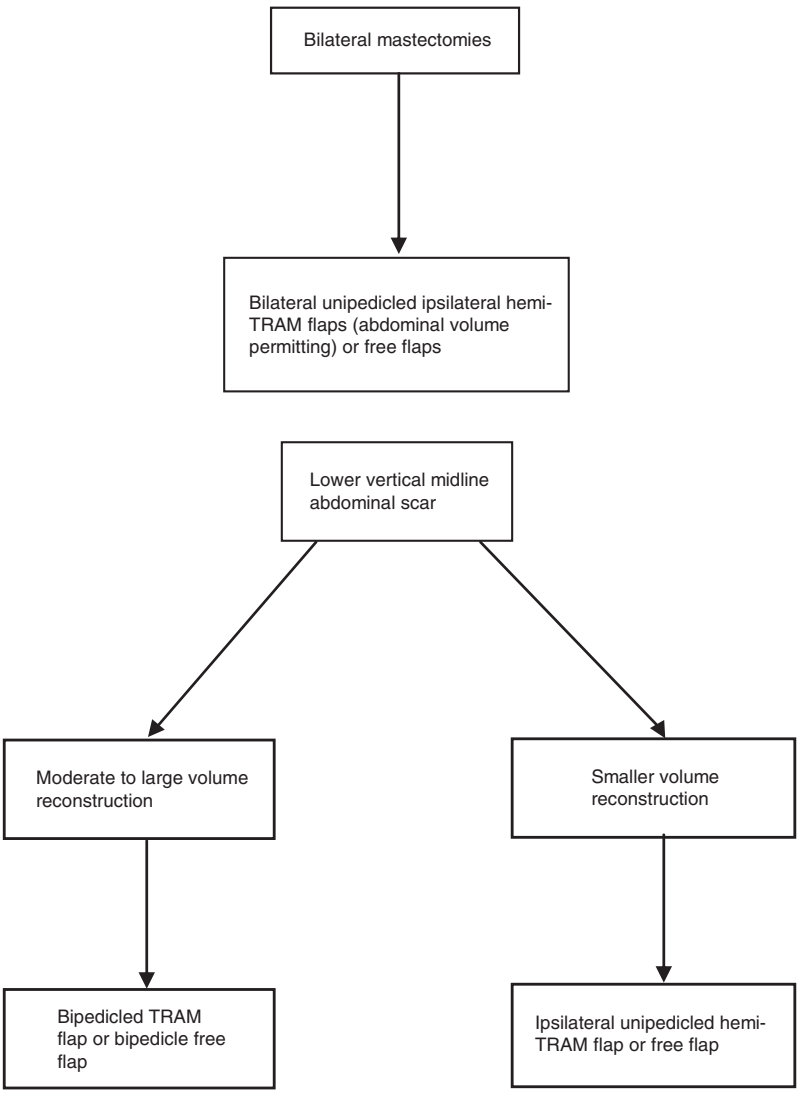
The first prerequisite for this procedure is a patient healthy enough to undergo a 2–3-h operation, a 3–5-day hospital stay, and a 4–8-week recovery period before the patient begins to feel that life is returning to some degree of normality. The second major requirement is an available donor site. The patient should have a thorough history taken including an evaluation of comorbidities such as gastroesophageal reflux disease (GERD), irritable bowel syndrome, lumbar spine problems, smoking history, and cardiovascular risk factors. We did not find diabetes mellitus to be a risk factor in TRAM flap usage [32] although Hartrampf has assigned it a significant value [11]. Collagen vascular disease is potentially problematic although we have performed the procedure safely in patients with systemic lupus erythematosus and mild rheumatoid arthritis. Scleroderma would present more of a risk if anterior chest tightness were present as this could compromise abdominal skin closure. Considerable caution should be exercised in deciding to operate on a patient with Ehlers-Danlos syndrome. A history of prior abdominoplasty or abdominal liposuction represents relative contraindications to the procedure in theory (although we have successfully performed the procedure in a patient with complete abdominal wall undermining 20 years previously as well as in patients with conservative liposuction). Preoperative CT or MR angiography is not particularly helpful in pedicled TRAM flap planning, but delineation of perforator location is helpful in planning perforator flaps. Intraoperative indocyanine green perfusion assessment is more helpful in this author's experience. Clinical examination should be performed noting body habitus and weight. The abdomen should be examined for old scars, particularly cholecystectomy scars or vertical midline incisions [38]. Pfannenstiel incisions are not a risk factor. Laparoscopic incisions are rarely a problem, but port sites may injure the vessels within the rectus muscle in the upper abdomen, and Doppler evaluation is probably prudent during surgery. It is unwise to operate within 6 weeks after laparoscopic surgery. A final factor in flap selection is that of the patient's occupation and lifestyle. Very active, young individuals are better served by a DIEP or SIEA flap, and patients engaged in musical careers occasionally express concerns about the impact of muscle loss on their ability to sing. This does not appear to be a significant issue in practice.

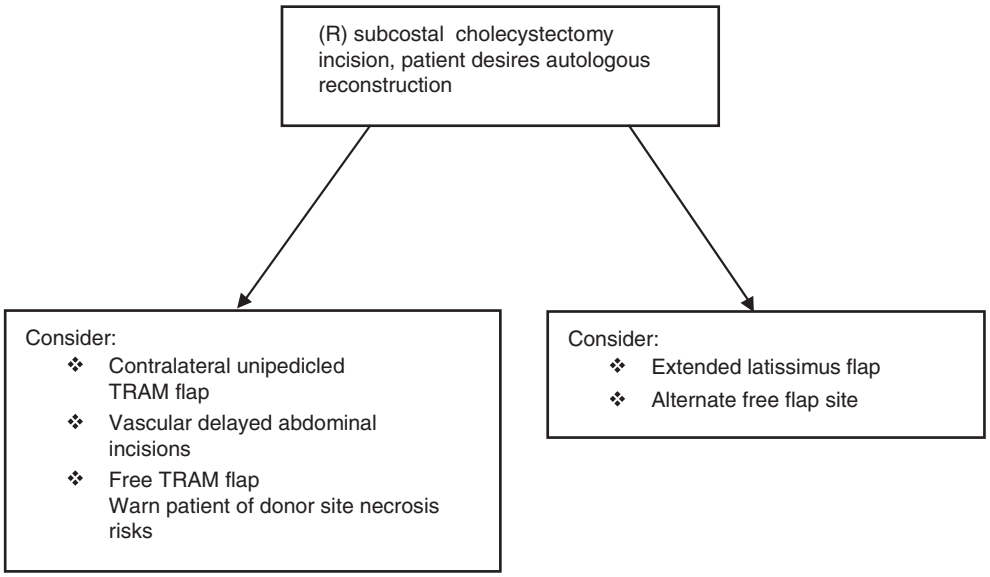
Hartrampf attempted to assign risk scores to patients in order to determine their eligibility for TRAM flap reconstruction [11]. Risk factors included smoking, obesity, psychological instability, autoimmune disease and diabetes mellitus, severe systemic disease, and surgeon inexperience. Using this rating system, a patient with two risk factors or a score of <5 represented a borderline risk, while patients with three or more risk factors or a score of >5 were considered a poor candidate for surgery [11]. In our own series, diabetes did not correlate well with complications, but obesity, smoking, abdominal scars, and prior radiation therapy did [31, 32]. The following algorithm is an attempt at simplifying flap choices for patients with differing risk factors as well as including the surgeon's preference and level of comfort with microsurgery.

36.7.1 TRAM Flap Selection Algorithms

1. Small- to moderate-volume breast reconstruction with no risk factors—ipsilateral unipedicled TRAM flap or DIEP flap
2. Large-volume breast, active smokers, obese patients, and radiated patients—bipedicled TRAM flap, vascular-delayed TRAM flap, and free flap (excluding DIEP)
3. Small- to moderate-volume radiated breast—contralateral unipedicled TRAM flap (or ipsilateral TRAM flap if radiation injury appears mild) or free flap


Unilateral mastectomy
Small to moderate volume breast reconstruction with no risk factors
Large volume breast
Active smokers
Obese patients
Radiated patients
Small to moderate volume radiated breast
Ipsilateral unipedicled TRAM flap or DIEP
Consider:
Bipedicled TRAM flap
Vascular delayed TRAM flap
Free flap
Consider:
Contralateral unipedicled TRAM flap
Vascular delayed contralateral or ipsilateral TRAM flap
Free flap


Bilateral mastectomies
Bilateral unipedicled ipsilateral hemi-TRAM flaps (abdominal volume permitting) or free flaps
Lower vertical midline abdominal scar
Moderate to large volume reconstruction
Smaller volume reconstruction
Bipedicled TRAM flap or bipedicle free flap
Ipsilateral unipedicled hemi-TRAM flap or free flap



36.8 Anesthetic Requirements

Patients are kept warm and well hydrated to provide robust circulation [11]. Urine output should be high throughout the procedure. Nitrous oxide administration can cause small bowel distention resulting in potential difficulties with abdominal wall closure; nitrous oxide inhalation is not used at all in our practice. Intraoperative body-warming blankets are used routinely as are leg compression stockings. We use prophylactic heparin therapy or low molecular weight enoxaparin as these drugs do not appear to increase the risk of hematomas. Intravenous ketorolac for postoperative pain has not been shown to increase hematoma rates [39, 40]. The reported incidence of deep venous thrombosis complicated by pulmonary embolism in our series was just under 0.006%, while the incidence of fatal pulmonary embolism is approximately 0.1% [31, 32].

36.9 Unipedicled Operative Procedure

The upper abdominal incision is made first and the upper abdominal skin flap is elevated over the costal margins laterally and to the xiphoid centrally. The patient is flexed to assess the adequacy of closure to the inferior incision line. The inferior incision may need to be elevated slightly to allow for a less tense suture line in patients with a long narrow torso. Tight closure can seriously compromise blood flow to the skin edges causing skin necrosis. Obese patients are particularly at risk. Pfannenstiel incisions are routinely ignored. The distal incision is then made, and TRAM flap is elevated from lateral to medial identifying the lateral row of perforators and the lateral border of the rectus abdominis muscle. The decision as to which side to base the flap depends upon abdominal anatomy and surgeon preference. In the unscarred abdomen, either side may be used and I prefer the ipsilateral pedicle (Figs. 36.3 and 36.4a, b). Ipsilateral

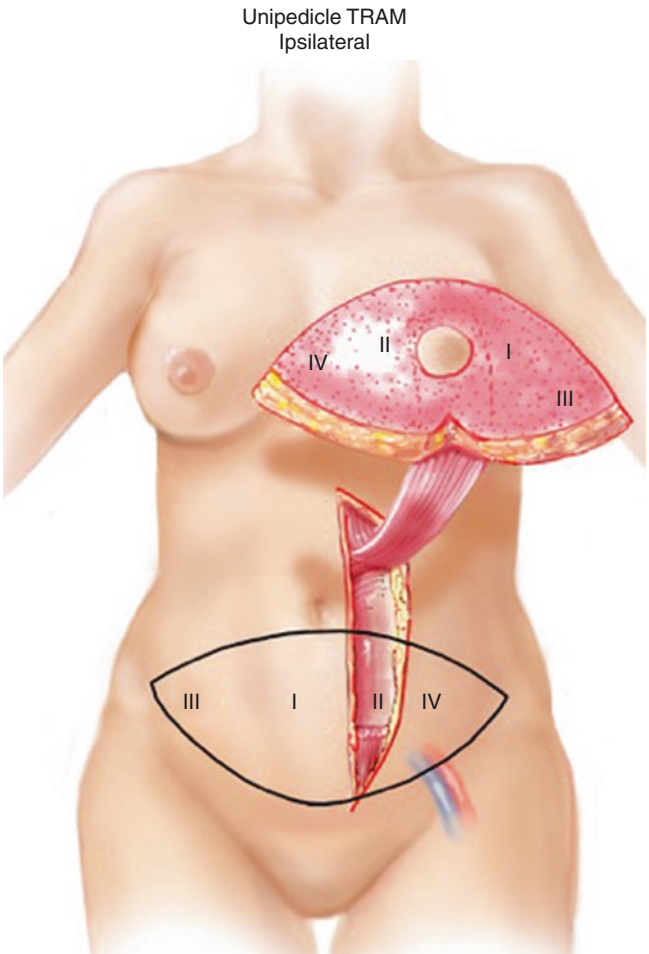


Fig. 36.3 Ipsilateral unipedicled TRAM flap with 180° flap rotation

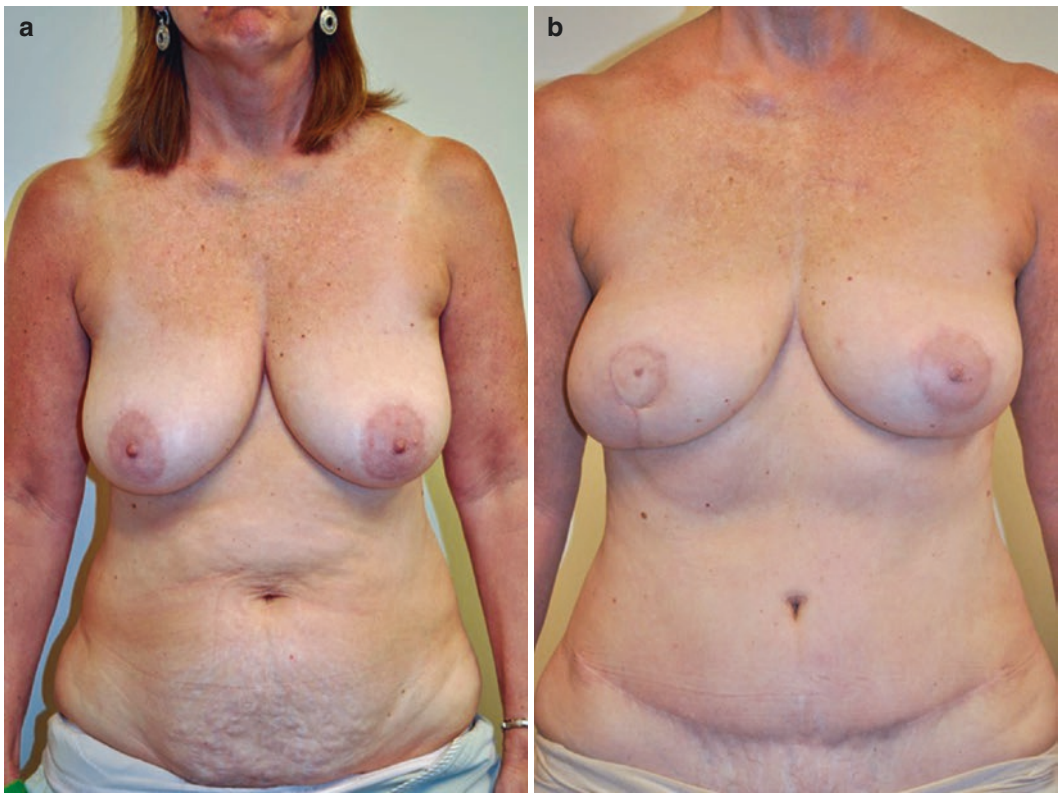


Fig. 36.4 (**a**) Preoperative views of patient with DCIS of the left breast. (**b**) Postoperative views after (L) ipsilateral TRAM flap reconstruction

transfer reduces initial intermammary bulging, and the definition of the ipsilateral inframammary crease tends to be excellent. Pedicle tension is reduced and flap positioning is easier. Venous drainage of the flap appears better with ipsilateral transfer [41]. The contralateral pedicle (Fig. 36.5) tends to create more blunting of the medial inframammary crease and limits the ease of flap positioning laterally.

Radiation to the affected breast necessitates either a contralateral unipedicled flap (with or without surgical delay) or preferably a bipedicled or free TRAM flap. While the ipsilateral radiated pedicle can be used in many patients, it may be unreliable and I always use Doppler to assess the ipsilateral pedicle signal and compare it to the non-radiated side. We have clearly shown a higher fat necrosis rate in patients with preoperative radiation to the internal mammary supply [42]. A contralateral pedicle is useful in such cases but tends to cause some degree of blunting of the medial inframammary fold and softens the depth of the intermammary cleavage, although careful denervation of the pedicle may ameliorate this problem**.** A surgical delay performed 5–14 days previously improves TRAM flap blood supply and may be considered for a pedicled procedure if a large breast is to be fashioned [26, 27, 43, 44]. If vascular delay is performed, it should include an incision right across the lower inferior end of the TRAM flap with elevation of the flap tips as described by Taylor [26, 45] and not just two small groin incisions to give access for vascular

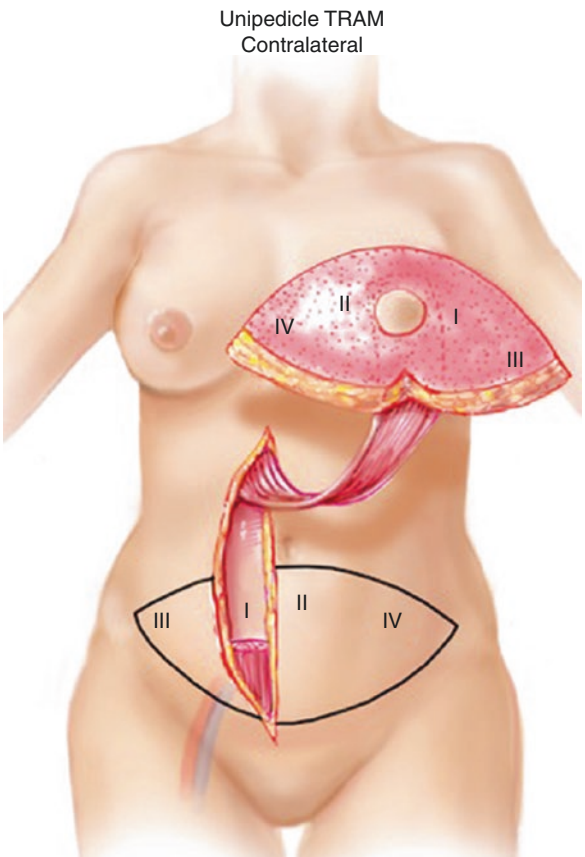


Fig. 36.5 Contralateral unipedicled TRAM flap with 180° flap rotation

division. The rectus fascia is incised as a long ellipse to facilitate closure and maintenance of muscle integrity at the inscriptions and is freed from the underlying rectus muscle. Care must be taken not to penetrate the muscle while separating the tendinous inscriptions. The muscle can be elevated in its entirety or using a muscle-sparing technique (Fig. 36.6). Muscle sparing involves identifying the intramuscular course of the superior epigastric vessels with a Doppler probe and then leaving a lateral strip of muscle some 2 cm in diameter. Theoretically, this leaves muscle innervated and vascularized by the intercostal vessels and nerves for further abdominal wall competence postoperatively. In practice, however, the intercostal supply penetrates the rectus muscle in its middle third, thereby leaving no innervation and probably little, if any, blood supply to the lateral muscle strip. A medial strip of muscle may also be left but its functional value is also questionable. As noted earlier, Harris demonstrated an 80% reduction in pedicled blood flow by clamping the medial and lateral thirds of the rectus muscle intraoperatively [20]. Suominen's data on the diminishing size and strength of residual upper rectus muscle left after free TRAM flap harvest calls into question the validity of performing muscle-sparing procedures [24]. The rectus muscle is divided distally, and the deep inferior epigastric vessels are ligated with LIGACLIP®. These vessels should be dissected out with the flap just in case they are needed for conversion to a free flap in the event of vascular compromise of a pedicled flap.

Flap elevation is based on the superior epigastric supply. Care should be taken to divide the eighth intercostal nerve as it enters the muscle near the costal margin. This causes muscle atrophy, reducing epigastric bulk in the long term. A wide subcutaneous tunnel is made between the abdominal dissection and the mastectomy site allowing passage of the pedicle without compression. When using a contralateral pedicle, it is tunneled adjacent to the medial border of the normal breast. Ipsilateral flaps are passed straight up through the inframammary fold of the mastectomy site. If venous congestion occurs, repositioning may be helpful. Additionally, one may remove the LIGACLIP on the deep inferior epigastric vein stump and allow it to bleed for several minutes for venous decompression.

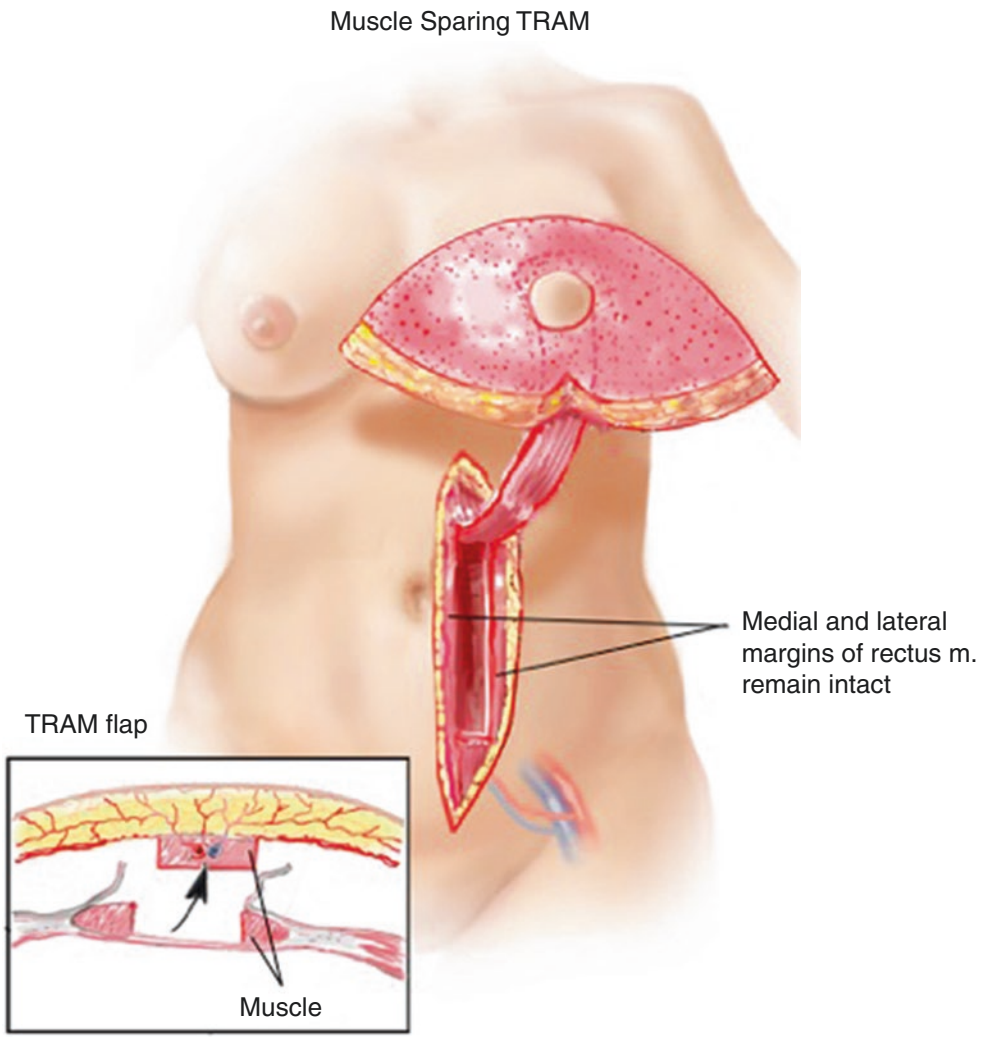


Fig. 36.6 Muscle-sparing unipedicled TRAM flap

Alternatively, Hartrampf's "mechanical leech" drainage system may be inserted into the deep inferior vascular system to aid in venous decompression [46].This involves inserting a pediatric feeding tube or venous cannula into the deep inferior epigastric vein and using this as a decompression valve which can be opened periodically to bleed the flap of congested, poorly oxygenated venous blood under pressure. The catheter can be flushed with dilute heparin solution to maintain its patency over a period of 2–3 days as needed.

Abdominal closure should be performed meticulously as poor closure dramatically increases the risks of hernia formation. It is essential to incorporate both the internal and external oblique aponeuroses into the sheath closure [47]. If fraying of the fascia occurs, it can be darned with a suture weave or covered with an onlay of AlloDerm®. Bucky and May have reported the routine incorporation of mesh into all TRAM flap abdominal closures with excellent success; one patient of 65 patients treated developed a mesh infection, and one patient developed hernia [48]. Once abdominal fascial closure has been securely closed, the upper abdominal skin flap is redraped over suction drains and closed. An umbilicoplasty is then performed. TRAM flap shaping follows and technical caveats are discussed later in this chapter. Careful attention should be paid to recreating the lateral inframammary fold with quilting sutures to prevent loss of definition at this site. This maneuver should be performed with the patient in the erect position to evaluate the effect of gravity on the final shape of the reconstruction.

36.10 Bipedicled TRAM Flap

The bipedicled TRAM flap is potentially indicated in:

1. Large-volume reconstruction
2. Patients with midline abdominal incisions
3. Smokers
4. Obesity
5. Patients with radiation injury to one pedicle

Most of the above represent indications for free TRAM flap transfer in many surgeons' hands. Bipedicled flaps are robust and probably have a better blood supply than free TRAM flaps due to the conversion of zones II and IV to additional zones I and III, respectively. They allow for more reliable survival of a greater proportion of the flap at the expense of greater abdominal donor site muscle loss. While this impacts the patient's abdominal strength in the short term, longer-term function appears eminently compatible with activities of daily living. Flap complications are less, and the procedure enables the non-microsurgeon to safely perform TRAM flap breast reconstruction in higher-risk patients [31].

Preoperative preparation and positioning are similar to those outlined for the unipedicled procedure. Initial flap elevation is identical in that both sides of the flap are dissected to the lateral perforators. Medial dissection differs in that a tunnel must be fashioned down the linea alba between the two pedicles (Fig. 36.7). This leaves a fascial strip on either side of the linea for fascial closure. As two pedicles have to pass up onto the chest wall, a more generous tunnel has to be fashioned causing more initial bulging about which patients should be informed. Once the flap is elevated, it is passed onto the chest taking care to prevent compression of the pedicles within the tunnel. I use a dou-

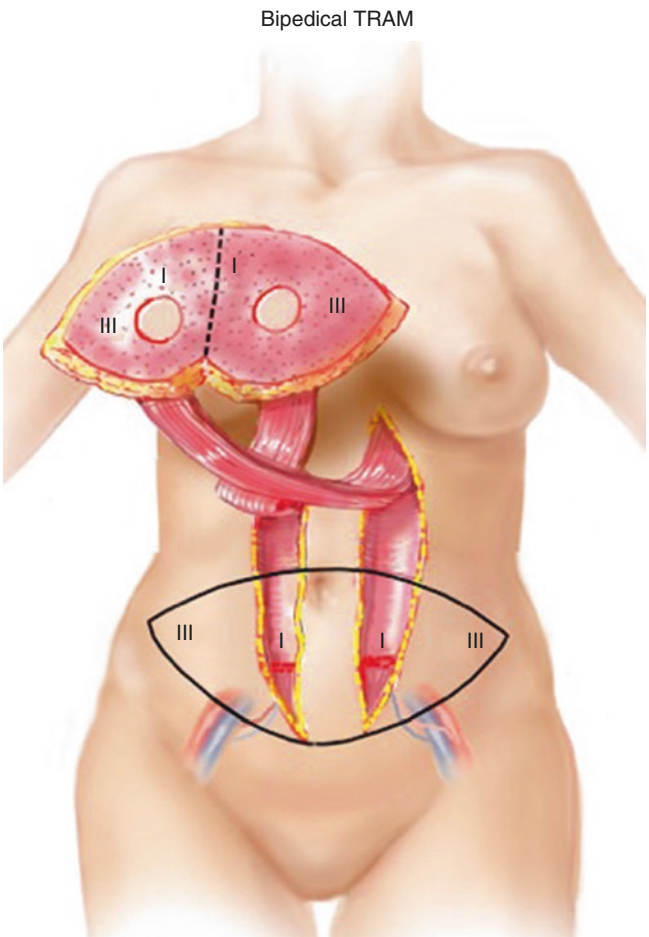


Fig. 36.7 Bipedicled TRAM flap transfer

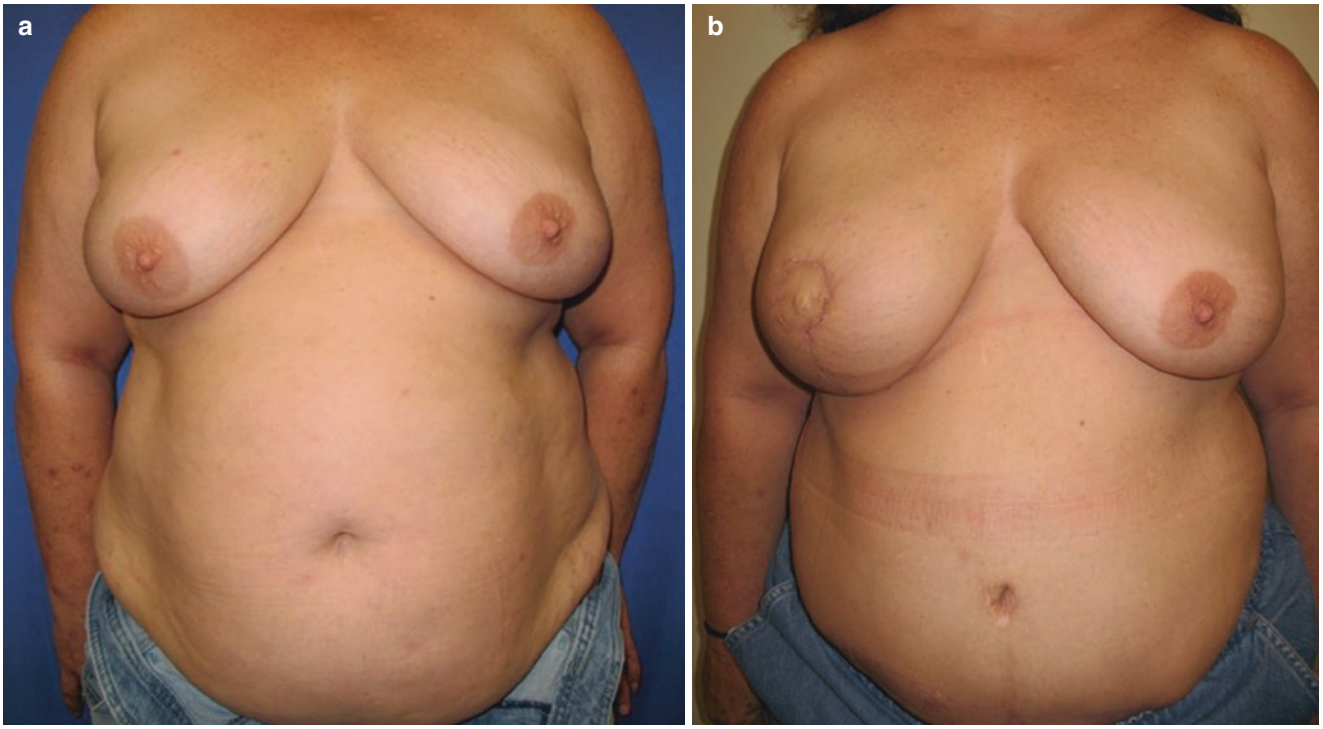


Fig. 36.8 (**a**) Preop view of obese patient with large-volume breast for TRAM flap reconstruction; (**b**) post-op result after bipedicled TRAM flap breast reconstruction

ble-layer mesh closure routinely in bipedicled flap procedures. The Prolene mesh is sutured from linea semilunaris to linea semilunaris using 0-Prolene. Abdominal wall strength is almost certainly more compromised when compared with the unipedicled procedure [49, 50], and it should be performed with caution in the younger patient. In the Emory review of bipedicled patient results, flap complications and abdominal wall complications were no worse than with unipedicled flaps, and flap blood supply was predictably better given the dual blood supply [31]. Our large experience with bilateral and bipedicled flaps has confirmed our initial experience with this procedure as being safe and reliable with remarkably few complications considering the higher-risk patients in whom it is performed. The abdominal strength objections voiced by some surgeons do not appear to be as significant as initially thought, and patients cope remarkably well with activities of daily living. While it is true that strength is diminished significantly initially, particularly with respect to patients' ability to perform sit-ups, abdominal wall function improves with time, and a remarkable number of patients achieve little or no negative impact on activities of daily living. Hernia rates are not significantly higher with this procedure when compared with unipedicled TRAM flaps. These issues will be discussed at greater length in the outcomes section. It is an excellent option for the non-microsurgeon who performs large numbers of breast reconstructions in higher-risk patients or those patients requiring large-volume reconstructions (Fig. 36.8b).

36.11 Bilateral Unipedicled TRAM Flap Breast Reconstruction

Bilateral reconstruction using two unipedicled TRAM flaps follows an identical operative sequence to that described for the bipedicled procedure, the exception being that the skin island is split down the midline during the initial dissection creating two flaps of equal size (Fig. 36.9a, b). The flaps are transposed to the chest wall through ipsilateral tunnels to prevent possible compression and kinking through a common central tunnel. Flap rotation on the chest wall is typically 90°. Abdominal closure is identical to that for the bipedicled TRAM flap.

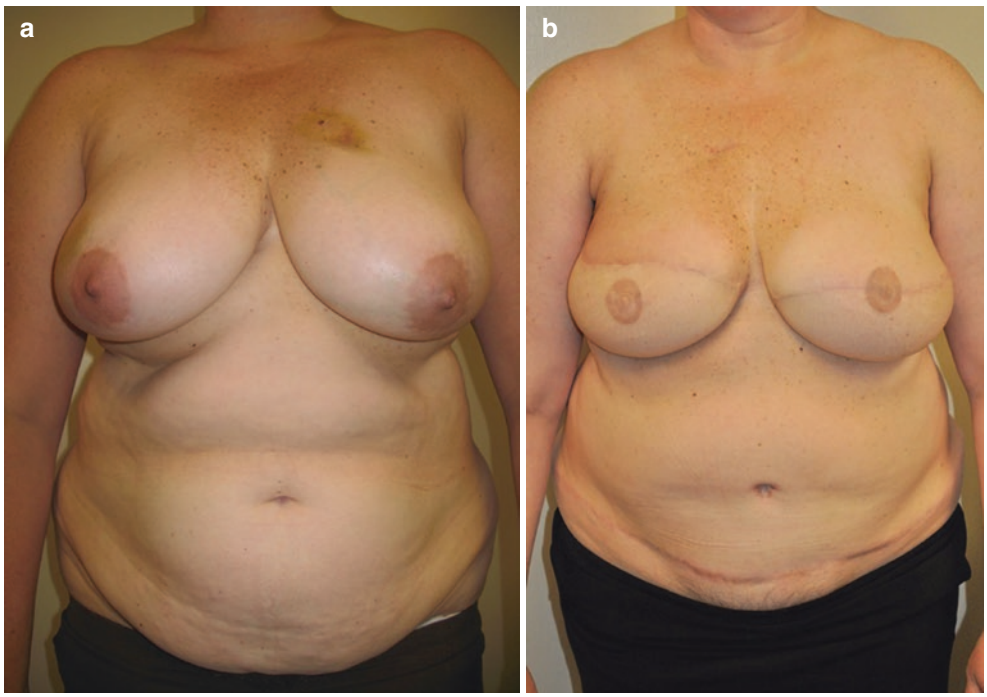


Fig. 36.9 (**a**) Preop view of obese patient requiring bilateral mastectomies and autologous reconstruction for breast cancer. (**b**) 1-year postoperative result after bilateral ipsilateral unipedicled TRAM flaps

36.12 Intraoperative Volume Assessment

During immediate reconstruction, the mastectomy specimen can be weighed off the surgical field. The problem becomes how to determine the volume of the TRAM flap available to achieve a match for the contralateral breast. Wagner devised a formula to calculate flap volume, $L \times W \times T \times 0.81 = V$ where L, W, and T represent the length, width, and thickness, respectively, of the TRAM flap [50]. Hudson has suggested the use of a simple hanging balance gas sterilized for intraoperative measurement of flap weight rather than volume [51]. Volumetric assessment by the hand is a simple but crude and somewhat inaccurate alternative.

36.13 Dealing with the Old Mastectomy Scar

The previous mastectomy scar, whether radiated or not, poses significant technical problems. If incised and used as the inset for the TRAM flap, its tight horizontal contraction tends to act as a band across the upper pole of the reconstruction, creating a linear groove. If this occurs, the scar should be excised completely, and a lateral modified Z-plasty should be created to soften the contour of the inset**.** The procedure is more of an oblique back-cut than a true Z-plasty, allowing a tongue of the TRAM flap skin island to angle up toward the axilla.

36.14 Flap Shaping and Positioning in Delayed TRAM Flap Reconstruction

The tip of zone I and all of zone IV should be discarded unless their blood supply appears unusually good. Many surgeons work primarily with ipsilateral tissue only in an effort to reduce fat necrosis. Flap orientation exerts a major influence on shape and symmetry. Secondary shaping is always feasible and often necessary [52], but time spent shaping the flap at the initial procedure is well spent, and it is possible to achieve excellent shape and symmetry at this first stage when adjustments are made most easily [33, 53–55]. The most common orientations used by the author are a transverse lie with a 180° rotation or an oblique orientation with a 120° or 80° rotation. Generally, it is preferable to place as much volume inferiorly in order to maximize projection and natural shape.

36.15 Donor Site Closure

Donor site closure is critical to the successful completion of TRAM flap breast reconstruction. A few words on donor closure are pertinent. Sheath closure should always incorporate both the internal and external oblique fascial layers to limit the risk of hernia formation. A deep layer of either running or interrupted #1Prolene suture followed by a second layer of running #1PDS suture is commonly used. Closure with double figure-of-8 #1Prolene interrupted sutures provides an extremely powerful closure with a built-in pulley-like

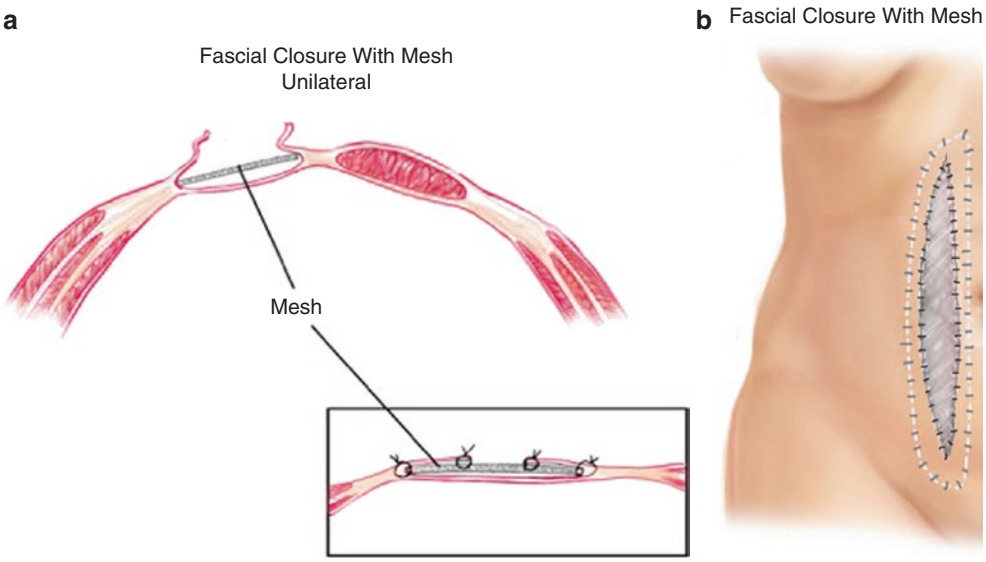


Fig. 36.10 (**a**) Unilateral mesh insertion within rectus sheath, (**b**) final anterior sheath overlay onto mesh inlay

mechanism to reduce fascial tearing as the fascia is closed. This is reinforced with a running #1PDS layer secondarily. Contralateral vertical sheath plication to centralize the umbilicus in unilateral pedicled flaps is unnecessary; if anything it simply raises intra-abdominal pressure unnecessarily and does little to move the umbilicus centrally. The skin pannus is defatted around the umbilicus inset, which the author prefers to reconstruct using the Avelar umbilicoplasty. Mesh should be used if there is extensive tearing of weak fascial components during closure or if tension seems high. If it is required, I use an inlay technique, suturing the mesh to the linea semilunaris internally within the sheath laterally and medially to the linea alba (Fig. 36.10a, b). The overlying anterior sheath leaflets are then sewn over the top of the mesh to cover about 50–60% of its surface area. Bucky describes excellent results with extensive inlay resulting in attractive abdominal contouring [48].

36.16 Timing of Nipple Reconstruction

It has been our policy to wait 6–8 weeks before performing nipple reconstruction. This allows the flap to settle under the influence of gravity, allowing nipple placement to be more accurately assessed. A C-V flap or modified skate flap is used for nipple reconstruction, creating a nipple some 50% longer than required, as atrophy will cause further slight loss of projection with time. In an effort to maintain nipple projection, I place the reconstructed nipple's free edge on a shelf of de-epithelialized adjacent TRAM flap skin to prevent the nipple from falling back into the donor site. Tattooing is usually performed 6–8 weeks later to minimize the effect of tattoo-induced atrophy of the nipple**.** Immediate nipple reconstruction has been advocated by some and is certainly more cost-effective than staged procedures [56]. The difficulty with using this approach is that settling of the TRAM flap may result in an incorrectly placed nipple reconstruction. The use of a traditional skate flap with surrounding skin graft unquestionably provides the best long-term projection in the author's opinion, but its requirement for a skin graft detracts from its value [57].

36.17 Secondary Shaping and Contralateral Breast Surgery for Symmetry

Secondary shaping is usually not necessary if careful attention to flap shaping and symmetry has been taken at the initial operation. Where possible, it is preferable to match the reconstruction to the unoperated contralateral breast unless this breast is in need of reduction or mastopexy at the patient's request. If secondary shaping is necessary, I prefer to perform it at the time of nipple reconstruction [52]. Careful contouring with 3–4 mm cannulae will help define blunted inframammary folds or lateral breast creases and effectively reduces minor contour defects produced by overfilling with excess flap bulk. Contralateral reduction, mastopexy, or augmentation will be necessary in some patients and can be performed either at the initial operation or subsequently at the time of nipple reconstruction.

36.18 Complications and Outcome Studies in TRAM Flap Reconstruction

The major complications of delayed TRAM flap reconstruction include scarring, skin and fat necrosis, flap loss, hernia formation, deep venous thrombosis, asymmetry, abdominal

tightness, and the psychosexual issues associated with breast reconstruction.

36.19 Skin and Fat Necrosis

Some degree of fat necrosis is common in any TRAM flap reconstruction whether free or pedicled. It should be less prevalent in free tissue transfers. The problem in assessing the available data is that authors differ in their estimate of "clinically significant" fat necrosis. Furthermore, many perforator flap surgeons only use ipsilateral tissue and discard any cross midline tissue. In our series at the Emory Clinic, we used a definition of 10% or more of the flap surface containing palpable firmness and included cross midline tissue in most of our reconstructions. This definition yielded a "significant fat necrosis" rate of 10.6% [32]. Risk factors associated with fat necrosis included prior radiation ($p < 0.001$), abdominal scarring ($p < 0.01$), and obesity ($p < 0.02$). Two or more risk factors increased the fat necrosis rate to 24.7% compared with 8.3% in patients without risk factors ($p < 0.002$). Patients with multiple risk factors having bipedicled flaps did not have an increased risk for fat necrosis suggesting that the bipedicled procedure eliminated the impact of the risk factors by boosting flap blood supply. Our review of bilateral unipedicled TRAM flap reconstructions demonstrated no increased risk of fat necrosis or flap loss among bilateral patients [31]. Bilateral procedures showed a very slight increase in general complications such as atelectasis. Abdominal complications were not increased significantly. Kroll compared clinical and radiologic evidence of fat necrosis between 49 free and 67 pedicled TRAM flaps. The size of the lesions was not clear but all lesions were visible mammographically. Predictably, free TRAM flaps demonstrated an 8.2% incidence of detectable fat necrosis compared with 26.9% in pedicled TRAM flaps ($p < 0.01$). While fat necrosis was more common in obese patients and smokers, this did not attain statistical significance [58]. Elliott confirmed similar findings for their series of patients, but in all of these studies, measurement of the amount of fat necrosis has been very subjective [59].

Radiation impacts TRAM flaps causing both fibrosis and fat necrosis. In 1997, Williams reported the Emory experience with radiation administered either before or after TRAM flap reconstruction. Fibrosis within the reconstruction was found in 31.6% of radiated TRAM flaps but not in patients who received preoperative therapy. Fat necrosis was similar in both radiated groups at 17.6% and 10% in the nonradiated patients. Not surprisingly, obesity further compounded fat necrosis rates when coupled with radiation therapy [42]. Rogers found a similar trend when free deep inferior epigastric perforator flaps were exposed to postoperative radiation [60]. By contrast, Zimmerman reviewed 21 patients with free TRAM flap reconstruction and claimed little negative impact in the majority of patients [61]. The question of whether or not it is worthwhile performing a microsurgical turbocharged anastomosis to reduce fat necrosis has been addressed in a small series of patients by El-Mrakby [62]. Turbocharged pedicled flaps had almost twice the rate of fat necrosis of free flaps although the fact that these patients required turbocharging suggests sample bias. Their conclusion is that free flaps are superior to turbocharged pedicled flaps.

36.20 Abdominal Wall Strength and Contour After Pedicled TRAM Flaps

There has been considerable debate about the impact of pedicled versus free TRAM and DIEP flaps on abdominal wall function. It would seem intuitive that a free flap would have far less impact on abdominal wall function than pedicled flaps with bipedicled flaps demonstrating the worst outcome. In practice, this is not strictly true, particularly when activities of daily living are evaluated by the patients themselves. It appears that there is considerable recruitment of adjacent muscle power, and this tends to improve with time. Furthermore, it appears that even with free flap harvest, the residual rectus muscle tends to atrophy significantly and hernia rates are not that much less than with pedicled flaps. Hartrampf [11] reported a 1.5% hernia rate in 351 unipedicled TRAM flap reconstructions, while the Emory group reported a hernia rate of 8.8%, a figure strongly skewed by one surgeon's use of small inlay mesh repairs; this figure has since been reduced to approximately 3.9% [31, 32]. This is similar to the data presented by Petit from Milan reporting 251 TRAM flap reconstructions with a hernia rate averaging 7% now reduced to 2% [63, 64]. Paige's review of the Emory experience with 257 bilateral versus unilateral pedicled reconstructions over a 7-year period revealed no significant difference between the two groups in terms of abdominal morbidity. In a review of 268 patients who had undergone either free TRAM (FTRAM) or conventional pedicled TRAM (CTRAM) flap reconstructions at least 6 months before, Kroll found similar hernia rates whether unipedicled or bilateral flaps were harvested (3.8% vs. 2.6%, not statistically significant). Single pedicle free TRAM flap patients were more likely to perform sit-ups than conventional unipedicled flaps which in turn were more likely to be able to do sit-ups than bilateral free or bipedicled patients. The conclusion was that the abdominal hernia or bulge rate is independent of the type of TRAM flap used and the number of muscle pedicles harvested. By contrast, measured abdominal strength was affected by these factors as far out as 6 months postoperatively. Nahabedian evaluated 108 women with free TRAM flaps, 37 women with pedicled flaps, and 10 women

with DIEP flaps. Lower abdominal contour defects were far more common after bilateral free TRAM flaps than with DIEP flaps [65]. Blondeel found that free TRAM flaps impacted far more negatively on abdominal strength than did free DIEP flaps [66, 67], but even free DIEP flaps create abdominal weakness to some extent [68]. To further confound the issue, Suominen has performed several elegant studies to accurately measure abdominal strength and function up to 12 months postoperatively [23, 24, 69]. In a magnetic resonance imaging study of the residual rectus muscles left after free and pedicled flaps, the donor rectus muscle on the free flap side had atrophied by at least 25% when compared with the non-operated side, and fatty degeneration was significantly higher in the donor muscle. No hernias were detected in either group [24]. In another study by the same author, long-term follow-up of the pedicled and free TRAM flap groups was performed with a mean follow-up of 23 months. By this time, there were no significant differences in abdominal flexion/extension strengths between either group [23]. In a prospective study of 19 free versus 23 pedicled TRAM flap patients, Edsander-Nord assessed strength at 3, 6, and 12 months postoperatively. Apart from an initial transient decrease in strength (worse in pedicled than free flap patients), the strength differences resolved almost entirely by 12 months. What is interesting is that free TRAM flap patients experienced a greater incidence of lower abdominal bulging (82%) than their pedicled counterparts at 48% [70]. In a meta-analysis of previously published data, Reece and Kroll attempted to collate the evidence concerning abdominal wall morbidity after TRAM flap reconstruction. The data is interesting, but firm conclusions are difficult to arrive at given the widely disparate data collected [30]. In conclusion, it appears that the more muscle one harvests, the greater the initial impact on abdominal strength. As time progresses, pedicled and free TRAM flap patients develop very similar functional outcomes with little impact on the activities of daily living. Abdominal bulge and hernia rates appear to be independent of the type of flap harvested and may relate to the care with which repair has been undertaken as well as the quality of the fascia to be repaired. The exact mechanism for these observed differences has yet to be explained satisfactorily.

36.21 Total and Partial Flap Loss

While complete flap loss is extremely rare in pedicled TRAM flap reconstruction (2 of 350 unipedicled and 0 of 39 bipedicled TRAM flaps in Hartrampf's series) [11], partial flap loss is more common. Hartrampf reported an 8.5% incidence in his series, while Kroll reported a 15.4% incidence in slim patients increasing to 41.7% in obese patients [71]. Elliott reported a 10% incidence in a series of 128 cases of unipedicled TRAM flaps [59], and Trabulsy noted a 6% incidence of partial flap loss and 4% complete flap loss in their series of 99 patients [1]. By comparison, Chang reporting on over 700 free TRAM flap breast reconstructions found total flap loss in 5.1% with a 6.2% partial flap loss [72]. This pushes total flap necrosis-related complications to over 11% in a center of excellence. These figures should be borne in mind when occasional microsurgeons are tempted to embark on complex free flap procedures in higher-risk patients. Given the high patient satisfaction with pedicled TRAM flaps compared with DIEP flaps [73], this may also explain why many surgeons who are comfortable with microsurgery are reluctant to convert to performing free TRAM or DIEP flaps routinely in their practices, given the time and cost restraints of these complex procedures.

36.22 The Impact of Obesity on TRAM Flap Viability

The most comprehensive study to date detailing the impact of obesity on human flap viability is that presented by Chang et al. [72]. In this study alluded to above, free TRAM flap results were evaluated based on the patient's body mass. Normal-weight patients ($n = 442$) had no total flap losses and a 1.6% partial flap necrosis rate. Overweight patients ($n = 212$) experienced 1.9% total flap loss with a 1.4% partial flap necrosis rate. By contrast, 64 obese patients had a 3.2% total flap necrosis rate and 3.2% partial flap necrosis. Fat necrosis rates were 6.1% in normal patients, 9% in the overweight group, and 7.8% in the obese category. Abdominal bulges were three times more common in overweight patients compared with normal, and seromas were ten times more common in obese patients. In the Emory University study of 556 patients, obesity correlated with both fat necrosis and general complications at the $p < 0.02$ level [32].

36.23 Smoking and TRAM Flap Viability

Watterson's study demonstrated a significant correlation between smoking and general complications ($p < 0.002$), but interestingly smoking did not correlate strongly with fat necrosis [32]. Hartrampf accorded heavy smoking a moderate risk in his scoring system for TRAM flap patient selection criteria [11]. Chang found a significant risk for both the reconstruction and the donor site in smokers compared with non-smokers, with those having more than a ten-pack-year history faring worse than those with shorter histories. Former smokers and non-smokers had similar complication rates [72]. In another study, Padubidri found overall complications to be greater in smokers at 39.4% versus 25% in ex-smokers and non-smokers [74].

36.24 The Timing of Reconstruction in Relation to Radiation Therapy

In the past, radiation therapy had been reserved for those patients with more advanced breast cancers and more than three positive axillary lymph nodes. The publication of two papers, one from Denmark and the other from Canada, initiated a major swing toward treating early breast cancer patients with adjunctive radiation in an effort to improve survival [75, 76]. The result has been that more and more patients with TRAM flap reconstructions are now facing postoperative radiotherapy and then facing the consequences of radiation's impact on the flap. Add to this the dramatic impact of skin-sparing mastectomy on breast reconstruction and one can see what a dilemma the reconstructive surgeon now faces. Should the patient who faces radiotherapy in her future proceed with mastectomy first and then have delayed reconstruction, or should we go ahead with a skin-sparing mastectomy with all of its benefits, reconstruct the breast with a TRAM flap, and then proceed to radiation accepting its negative consequences? This dilemma is the subject of constant debate at national and international meetings. All of us who frequently perform TRAM flaps are aware of radiation's impact on these flaps, whether pedicled or free. TRAM flaps tolerate radiation better than expander-implant reconstructions and with fewer complications [77]. Williams reviewed the Emory experience with radiation and found it to increase fibrosis as well as fat necrosis depending on the timing of treatment in relation to surgery [78]. Flap loss was not increased per se, a finding corroborated by Kroll's review of 428 flaps (of 1384 free flaps total) transferred to previously radiated beds [79]. It was Kroll's belief that radiation significantly impacts the feel and shape of TRAM flaps when administered after reconstruction as evidenced by William's data. His conclusion was that patients in whom radiotherapy is likely post-mastectomy should complete their radiation and then proceed to TRAM flap reconstruction, forgoing the benefits of skin-sparing mastectomy and immediate reconstruction. In this manner, the final reconstruction may be spared the deleterious effects of radiation injury in the long term even though there is a greater likelihood that such patients may need free or bipedicled TRAM flap procedures. There is certainly merit in this argument given the possible prospect of fibrosis, distortion, and fat necrosis that may supervene in a radiated TRAM flap.

36.25 Pregnancy Following Pedicled TRAM Flaps

Despite the loss of muscle function after pedicled TRAM flap harvest, it is still possible for patients to conceive and carry a pregnancy to term as well as achieve normal vaginal delivery [80]. Johnson described the successful vaginal delivery of monozygotic twins after bilateral pedicled TRAM flap reconstruction [81] indicating that patients can be reassured that their abdomens will in all likelihood perform satisfactorily even under the considerable stress of twin pregnancy. Parodi cautions against patients becoming pregnant within 12 months after TRAM flap surgery, reporting a single case of a woman becoming pregnant at 4 months postoperatively and developing a hernia. She delivered vaginally at term [82].

36.26 Patient Satisfaction Outcomes

A patient's emotional outcome after breast reconstruction is unpredictable and highly individual [83]. Several factors influence the aesthetic outcome [84]. In a study of 125 women diagnosed with breast cancer, Keith found that 49.6% of his respondents desired breast reconstruction if available. Young women and depressed women favored reconstruction more than older patients. In Keith's study, marital status, tumor size, extrovertism, neuroticism, and tough-mindedness were not independently predictive of the desire for reconstruction [85]. Of patients requesting reconstruction, 63% were concerned that reconstruction might mask recurrence, but 94% felt that it would greatly benefit their self-esteem. Age does not appear to be a significant risk factor for pedicled TRAM flap usage as evidenced by a study of 84 patients aged 65 years or older in whom successful reconstruction was achieved [86]. In another study evaluating patient acceptance of the procedure, Nissen found that while women were highly satisfied with their reconstruction, their greatest anxiety remained the fear of recurrence as well as a desire to be as informed as possible about complications and recovery [87]. This was reinforced in a study by Tykka who found most women were highly satisfied with their TRAM flap reconstructions, all of which in this study had been performed to replace inconvenient bra prostheses [88]. The patients were particularly pleased with the autologous nature of the reconstructions but had been surprised by the extent of the surgery and length of the recovery process. This highlights the importance of warning patients that recovery will take a minimum of 3 months before patients start to feel as if life is returning to normal once more. It appears that patients are more accepting of the quality of their reconstruction than are their surgeons as evidenced by a study of 20 patients whose level of satisfaction was much higher than that of their surgeons [89]. In another study of 60 inner city women undergoing breast reconstruction, demographic studies failed to show any differences in education, economic status, or insurance status in women undergoing reconstruction. In this study, reconstructed women had a higher satisfaction with their sex lives and body image than did non-reconstructed women [90]. While these trends are culled from relatively

small patient populations, it is apparent that breast reconstruction can be an immensely satisfying procedure for both patient and surgeon and can have a positive impact on a patient's daily life and convenience.

Conclusion

Pedicled TRAM flap breast reconstruction remains a common choice for autologous reconstruction and is readily learned by any competent surgeon. It provides excellent contour and softness in most patients and abdominal complications are few. Given the potential for free flap failure and the added cost involved in additional operating time for microsurgical procedures [91], pedicled TRAM flaps remain the most cost-effective method of autologous breast reconstruction in most surgeons' hands [91]. Although TRAM flap reconstruction is a major operative procedure, it provides both patient and surgeon with a unique tool to achieve a natural, soft, warm, well-integrated reconstruction after mastectomy.

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References

1. Trabulsy PP, Anthony JP, Mathes SJ (1994) Changing trends in post mastectomy breast reconstruction: a 13 year experience. Plast Reconstr Surg 93(7):1418–1427
2. Carlson GW et al (1996) Preservation of the inframammary fold: what are we leaving behind?[comment]. Plast Reconstr Surg 98(3):447–450
3. Carlson GW (1996) Skin sparing mastectomy: anatomic and technical considerations. Am Surg 62(2):151–155
4. Bostwick J 3rd, Carlson GW (1997) Reconstruction of the breast. Surg Oncol Clin N Am 6(1):71–89
5. Millard DR Jr (1976) Breast reconstruction after a radical mastectomy. Plast Reconstr Surg 58(3):283–291
6. Robbins TH (1979) Rectus abdominis myocutaneous flap for breast reconstruction. Aust N Z J Surg 49(5):527–530
7. Drever JM (1977) Total breast reconstruction with either of two abdominal flaps. Plast Reconstr Surg 59(2):185–190
8. Dinner MI, Labandter HP, Dowden RV (1982) The role of the rectus abdominis myocutaneous flap in breast reconstruction. Plast Reconstr Surg 69(2):209–215
9. Dinner MI, Dowden RV, Scheflan M (1983) Refinements in the use of the transverse abdominal island flap for postmastectomy reconstruction. Ann Plast Surg 11(5):362–372
10. Sakai S, Takahashi H, Tanabe H (1989) The extended vertical rectus abdominis myocutaneous flap for breast reconstruction. Plast Reconstr Surg 83(6):1061–1067. discussion 1068-9
11. Hartrampf CR Jr (1988) The transverse abdominal island flap for breast reconstruction. A 7-year experience. Clin Plast Surg 15(4):703–716
12. Hartrampf CR Jr, Bennett GK (1987) Autogenous tissue reconstruction in the mastectomy patient. A critical review of 300 patients. Ann Surg 205(5):508–519
13. Scheflan M, Hartrampf CR, Black PW (1982) Breast reconstruction with a transverse abdominal island flap. Plast Reconstr Surg 69(5):908–909
14. Scheflan M, Dinner MI (1983) The transverse abdominal island flap: part I. Indications, contraindications, results, and complications. Ann Plast Surg 10(1):24–35
15. Milloy FJ, Anson B, DK MA (1960) The rectus abdominis muscle and the epigastric arteries. Surg Gynecol Obstet 110:293
16. Taylor GI, Palmer JH (1987) The vascular territories (angiosomes) of the body: experimental study and clinical applications. Br J Plast Surg 40(2):113–141
17. Moon HK, Taylor GI (1988) The vascular anatomy of rectus abdominis musculocutaneous flaps based on the deep superior epigastric system. Plast Reconstr Surg 82(5):815–832
18. Taylor GI, Corlett RJ, Boyd JB (1984) The versatile deep inferior epigastric (inferior rectus abdominis) flap. Br J Plast Surg 37(3):330–350
19. Watterson PA, Taylor GI, Crock JG (1988) The venous territories of muscles: anatomical study and clinical implications. Br J Plast Surg 41(6):569–585
20. Harris NR 2nd, Webb MS, May JW Jr (1992) Intraoperative physiologic blood flow studies in the TRAM flap. Plast Reconstr Surg 90(4):553–558. discussion 559–561
21. Miller LB et al (1988) The superiorly based rectus abdominis flap: predicting and enhancing its blood supply based on an anatomic and clinical study. Plast Reconstr Surg 81(5):713–724
22. Dinner MI, Dowden RV (1983) The value of the anterior rectus sheath in the transverse abdominal island flap. Plast Reconstr Surg 72(5):724–726
23. Suominen S et al (1996) Sequelae in the abdominal wall after pedicled or free TRAM flap surgery. Ann Plast Surg 36(6):629–636
24. Suominen S et al (1997) Magnetic resonance imaging of the TRAM flap donor site. Ann Plast Surg 38(1):23–28
25. Holm C et al (2006) Perfusion zones of the DIEP flap revisited: a clinical study. Plast Reconstr Surg 117(1):37–43
26. Dhar SC, Taylor GI (1999) The delay phenomenon: the story unfolds. Plast Reconstr Surg 104(7):2079–2091
27. Codner MA et al (1995) TRAM flap vascular delay for high-risk breast reconstruction [comment]. Plast Reconstr Surg 96(7):1615–1622
28. Restifo RJ et al (1997) Surgical delay in TRAM flap breast reconstruction: a comparison of 7- and 14-day delay periods. Ann Plast Surg 38(4):330–333. discussion 333-4
29. Ribuffo D et al (1997) A hemodynamic approach to clinical results in the TRAM flap after selective delay. Plast Reconstr Surg 99(6):1706–1714
30. Reece GP, Kroll SS (1998) Abdominal wall complications. Prevention and treatment. Clin Plast Surg 25(2):235–249
31. Paige KT et al (1998) A comparison of morbidity from bilateral, unipedicled and unilateral, unipedicled TRAM flap breast reconstructions. Plast Reconstr Surg 101(7):1819–1827
32. Watterson PA et al (1995) TRAM flap anatomy correlated with a 10-year clinical experience with 556 patients [comment]. Plast Reconst Surg 95(7):1185–1194
33. Slavin SA et al (1998) Skin-sparing mastectomy and immediate reconstruction: oncologic risks and aesthetic results in patients with early-stage breast cancer. Plast Reconstr Surg 102(1):49–62
34. Toth BA, Forley BG, Calabria R (1999) Retrospective study of the skin-sparing mastectomy in breast reconstruction. Plast Reconstr Surg 104(1):77–84
35. Skoll PJ, Hudson DA (2002) Skin-sparing mastectomy using a modified Wise pattern. Plast Reconstr Surg 110(1):214–217

36. Carlson GW et al (1997) Skin-sparing mastectomy. Oncologic and reconstructive considerations. Ann Surg 225(5):570–575. Discussion 575–578
37. Kronowitz SJ et al (2004) Delayed-immediate breast reconstruction. Plast Reconstr Surg 113(6):1617–1628
38. Losken A et al (2002) Importance of right subcostal incisions in patients undergoing TRAM flap breast reconstruction. Ann Plast Surg 49(2):115–119
39. Kroll SS et al (1995) Anticoagulants and hematomas in free flap surgery. Plast Reconstr Surg 96(3):643–647
40. Sharma S et al (2001) Incidence of hematoma associated with ketorolac after TRAM flap breast reconstruction. Plast Reconstr Surg 107(2):352–355
41. Clugston PA et al (2000) Ipsilateral pedicled TRAM flaps: the safer alternative? Plast Reconstr Surg 105(1):77–82
42. Williams JK et al (1995) TRAM flap breast reconstruction after radiation treatment. Ann Surg 221(6):756–764. Discussion 764–766
43. Morris SF, Taylor GI (1995) The time sequence of the delay phenomenon: when is a surgical delay effective? An experimental study. Plast Reconstr Surg 95(3):526–533
44. Hudson DA (1996) The surgically delayed unipedicled TRAM flap for breast reconstruction [comment]. Ann Plast Surg 36(3):238–242. discussion 242–245
45. Taylor GI et al (1992) An anatomic review of the delay phenomenon: II. Clinical applications. Plast Reconstr Surg 89(3):408–416. Discussion 417–418
46. Hartrampf CR Jr, Drazan L, Noel RT (1993) A mechanical leech for transverse rectus abdominis musculocutaneous flaps. Ann Plast Surg 31(2):103–105
47. Kroll SS, Schusterman MA, Mistry D (1995) The internal oblique repair of abdominal bulges secondary to TRAM flap breast reconstruction. Plast Reconstr Surg 96(1):100–104
48. Bucky LP, May JW Jr (1994) Synthetic mesh. Its use in abdominal wall reconstruction after the TRAM. Clin Plast Surg 21(2):273–277
49. Evans GR et al (1995) Reconstruction and the radiated breast: is there a role for implants? Plast Reconstr Surg 96(5):1111–1115. Discussion 1116–1118
50. Wagner DS, Michelow BJ, Hartrampf CR Jr (1991) Double-pedicle TRAM flap for unilateral breast reconstruction. Plast Reconstr Surg 88(6):987–997
51. Lazarus D, Hudson DA (2001) A simple method for determining the weight of the TRAM flap intraoperatively at the time of breast reconstruction. Plast Reconstr Surg 107(3):818–822
52. Maxwell GP, Andochick SE (1994) Secondary shaping of the TRAM flap. Clin Plast Surg 21(2):247–253
53. Kroll SS et al (1995) A comparison of factors affecting aesthetic outcomes of TRAM flap breast reconstructions [comment]. Plast Reconstr Surg 96(4):860–864
54. Carlson GW et al (2001) Results of immediate breast reconstruction after skin-sparing mastectomy. Ann Plast Surg 46(3):222–228
55. Restifo RJ (1999) The “aesthetic subunit” principle in late TRAM flap breast reconstruction. Ann Plast Surg 42(3):235–239
56. Hudson DA, Skoll PJ (2001) Single-stage, autologous breast restoration. Plast Reconstr Surg 108(5):1163–1171. Discussion 1172–1173
57. Jones G, Bostwick J (1993) Nipple-areola reconstruction. Oper Tech Plast Surg 1:35–38
58. Kroll SS et al (1998) Fat necrosis in free and pedicled TRAM flaps [comment]. Plast Reconstr Surg 102(5):1502–1507
59. Elliott LF et al (1993) Immediate TRAM flap breast reconstruction: 128 consecutive cases. Plast Reconstr Surg 92(2):217–227
60. Rogers NE, Allen RJ (2002) Radiation effects on breast reconstruction with the deep inferior epigastric perforator flap. Plast Reconstr Surg 109(6):1919–1924. Discussion 1925–1926
61. Zimmerman RP et al (1998) Radiation tolerance of transverse rectus abdominis myocutaneous-free flaps used in immediate breast reconstruction. Am J Clin Oncol 21(4):381–385
62. El-Mrakby HH, Milner RH, McLean NR (2002) Supercharged pedicled TRAM flap in breast reconstruction: is it a worthwhile procedure. Ann Plast Surg 49(3):252–257
63. Petit JY, Rietjens M (1997) Complications and abdominal wall sequelae in pedicle TRAM breast reconstruction. Ann Chir Plast Esthet 42(2):131–137
64. Petit JY et al (2003) Abdominal complications and sequelae after breast reconstruction with pedicled TRAM flap: is there still an indication for pedicled TRAM in the year 2003? Plast Reconstr Surg 112(4):1063–1065
65. Nahabedian MY et al (2002) Contour abnormalities of the abdomen after breast reconstruction with abdominal flaps: the role of muscle preservation. Plast Reconstr Surg 109(1):91–101
66. Blondeel N et al (1997) The donor site morbidity of free DIEP flaps and free TRAM flaps for breast reconstruction. Br J Plast Surg 50(5):322–330
67. Blondeel N et al (1997) The fate of the oblique abdominal muscles after free TRAM flap surgery. Br J Plast Surg 50(5):315–321
68. Futter CM et al (2000) A retrospective comparison of abdominal muscle strength following breast reconstruction with a free TRAM or DIEP flap. Br J Plast Surg 53(7):578–583
69. Suominen S et al (1997) Abdominal wall competence after free transverse rectus abdominis musculocutaneous flap harvest: a prospective study. Ann Plast Surg 39(3):229–234
70. Edsander-Nord A, Jurell G, Wickman M (1998) Donor-site morbidity after pedicled or free TRAM flap surgery: a prospective and objective study [comment]. Plast Reconstr Surg 102(5):1508–1516
71. Kroll SS, Netscher DT (1989) Complications of TRAM flap breast reconstruction in obese patients. Plast Reconstr Surg 84(6):886–892
72. Chang DW et al (2000) Effect of obesity on flap and donor-site complications in free transverse rectus abdominis myocutaneous flap breast reconstruction [comment]. Plast Reconstr Surg 105(5):1640–1648
73. Chun YS et al (2010) Comparison of morbidity, functional outcome, and satisfaction following bilateral TRAM versus bilateral DIEP flap breast reconstruction. Plast Reconstr Surg 126(4):1133–1141
74. Padubidri AN et al (2001) Complications of postmastectomy breast reconstructions in smokers, ex-smokers, and nonsmokers. Plast Reconstr Surg 107(2):342–349. Discussion 350-1
75. Overgaard M et al (1997) Postoperative radiotherapy in high-risk premenopausal women with breast cancer who receive adjuvant chemotherapy. Danish Breast Cancer Cooperative Group 82b Trial [comment]. N Engl J Med 337(14):949–955
76. Ragaz J et al (1997) Adjuvant radiotherapy and chemotherapy in node-positive premenopausal women with breast cancer.[comment]. N Engl J Med 337(14):956–962
77. Chawla AK et al (2002) Radiotherapy and breast reconstruction: complications and cosmesis with TRAM versus tissue expander/implant. Int J Radiat Oncol Biol Phys 54(2):520–526
78. Williams JK et al (1997) The effects of radiation treatment after TRAM flap breast reconstruction. Plast Reconstr Surg 100(5):1153–1160
79. Kroll SS et al (1998) Does prior irradiation increase the risk of total or partial free-flap loss? J Reconstr Microsurg 14(4):263–268
80. Chen L, Hartrampf CR Jr, Bennett GK (1993) Successful pregnancies following TRAM flap surgery [comment]. Plast Reconstr Surg 91(1):69–71
81. Johnson RM, Barney LM, King JC (2002) Vaginal delivery of monozygotic twins after bilateral pedicle TRAM breast reconstruction. Plast Reconstr Surg 109(5):1653–1654
82. Parodi PC et al (2001) Pregnancy and tram-flap breast reconstruction after mastectomy: a case report. Scand J Plast Reconstr Surg Hand Surg 35(2):211–215
83. Boughton B (2000) Emotional outcome after breast surgery is highly individual [comment]. J Natl Cancer Inst 92(17):1375–1376

84. Caffee HH (1996) A comparison of factors affecting aesthetic outcomes of TRAM flap breast reconstructions [comment]. Plast Reconstr Surg 98(1):182
85. Keith DJ et al (2003) Women who wish breast reconstruction: characteristics, fears, and hopes. Plast Reconstr Surg 111(3):1051–1056. Discussion 1057–1059
86. Lipa JE et al (2003) Breast reconstruction in older women: advantages of autogenous tissue. Plast Reconstr Surg 111(3):1110–1121
87. Nissen MJ, Swenson KK, Kind EA (2002) Quality of life after postmastectomy breast reconstruction. Oncol Nurs Forum Online 29(3):547–553
88. Tykka E, Asko-Seljavaara S, Hietanen H (2002) Patient satisfaction with delayed breast reconstruction: a prospective study. Ann Plast Surg 49(3):258–263
89. Veiga DF et al (2002) Evaluations of the aesthetic results and patient satisfaction with the late pedicled TRAM flap breast reconstruction. Ann Plast Surg 48(5):515–520
90. Zweifler M et al (2001) Breast reconstruction among inner city women with breast carcinoma. Ann Plast Surg 47(1):53–59
91. Kroll SS et al (1996) Comparison of resource costs of free and conventional TRAM flap breast reconstruction [comment]. Plast Reconstr Surg 98(1):74–77