Update on Breast Reconstruction Using Free TRAM, DIEP, and SIEA Flaps

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ABSTRACT

Breast reconstruction using autologous tissue is commonly accomplished using the transverse rectus abdominis myocutaneous (TRAM) flap. The establishment of microvascular surgery led to the development of the free TRAM flap because of its increased vascularity and decreased rectus abdominis sacrifice. The muscle-sparing free TRAM, DIEP, and SIEA flap techniques followed in an effort to decrease abdominal donor site morbidity by decreasing injury to the rectus abdominis muscle and fascia. Data have accumulated over the past decade that show that muscle- and fascia-sparing techniques, such as the use of DIEP flaps, result in measurably better postoperative abdominal strength. However, muscle-sparing techniques do not appear to decrease the risk of abdominal bulging or hernia, and there are no significant differences in patient-reported abdominal weakness or functional impairments. The SIEA flap is presented as a reemerging method that can virtually eliminate abdominal donor site morbidity. Sensory nerve coaptation to improve reconstructed breast sensation is also reviewed.

KEYWORDS: Breast reconstruction, flap, TRAM, DIEP, SIEA

Breast reconstruction using a transverse paddle of skin and subcutaneous tissue from the lower abdomen is an effective, reliable, and popular method. This lower abdominal donor site remains unmatched in tissue quality, texture, and quantity for breast reconstruction and produces superior aesthetic results compared with other popular methods of breast reconstruction such as prosthetic implants or the latissimus dorsi myocutaneous flap.

Use of autologous tissue from the lower abdomen for breast reconstruction was first reported by Holmstrom[1] in 1979 as a free flap and popularized by Hartrampf and colleagues[2] in 1982 as the pedicled transverse rectus abdominis myocutaneous (TRAM) flap. This donor site has the advantages of improved postoperative contour and an easily hidden scar, but it also carries the risks of motor weakness, hernia, and bulge formation. Furthermore, the length of postoperative hospitalization and time to full recovery from TRAM flap surgery are usually determined by healing at the abdominal donor site. Advances in autologous tissue breast reconstruction during the past decade have sought to decrease abdominal donor site morbidity.

The free TRAM flap introduced by Holmstrom[1] in 1979 gained popularity as microvascular surgery became more common. The improved perfusion of the free TRAM flap allows for the transfer of more tissue with less fat necrosis compared with the pedicled TRAM flap. In addition, less rectus abdominis muscle is harvested with the free TRAM flap, presumably decreasing abdominal donor site morbidity. The tradeoff is the increased complexity of the surgery with the attendant increased operative time and the increased risk for total flap loss due to microvascular thrombosis.

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The free TRAM flap has evolved into the free muscle-sparing TRAM (msTRAM) flap. Here, the vascular perforators supplying the flap are individually identified and selected. Because only a subset of perforators are used, often in a single vertical medial or lateral row, less rectus abdominis muscle and fascia are harvested than with a free TRAM flap. The rectus abdominis muscle is not completely transected; typically medial and lateral strips of muscle are preserved. The presumption is that the decreased harvest of muscle and fascia leads to decreased abdominal donor site morbidity compared with a conventional free TRAM flap, in which the full width of muscle is harvested.

Another technical advance made in autologous tissue breast reconstruction was the deep inferior epigastric perforator (DIEP) flap. This was introduced by Koshima and Soeda[3] in a case report in 1989 and followed by a report of a series of 13 patients in 1992.[4] Although Koshima and colleagues did not call these flaps "DIEP flaps" and did not use them for breast reconstruction, they realized that a single perforator could support a surprisingly large amount of skin and subcutaneous tissue. Allen and Treece[5] described the use of the DIEP flap for breast reconstruction in 1994, and Blondeel[6] and Hamdi and associates[7] further popularized this technique in 1999. Harvest of the DIEP flap requires incision of the rectus abdominis muscle and fascia but not excision of these abdominal wall structures. Nevertheless, the rectus abdominis muscle is injured by the removal of its dominant vascular supply with the flap and the division of portions of its motor innervation.

The latest advance in autologous tissue breast reconstruction has been the reemergence of the superficial inferior epigastric artery (SIEA) flap. The anatomy of this fasciocutaneous flap was well documented by Taylor and Daniel in 1975.[8] The SIEA flap was first described for breast reconstruction as a "free abdominoplasty flap" in a case report by Grotting.[9] Since then, other authors have also reported its use.[10–13] The SIEA flap allows for the transfer of lower abdominal tissue for breast reconstruction without excision or incision of the rectus abdominis muscle or fascia, a technique that has the potential to virtually eliminate abdominal donor site morbidity. The SIEA flap transfers the same lower abdominal skin and subcutaneous tissue as the TRAM and DIEP flaps and can be used to reconstruct medium and large breasts with an aesthetic quality similar to that of TRAM and DIEP flaps (Figs. 1 and 2). The disadvantages of SIEA flaps are the smaller pedicle

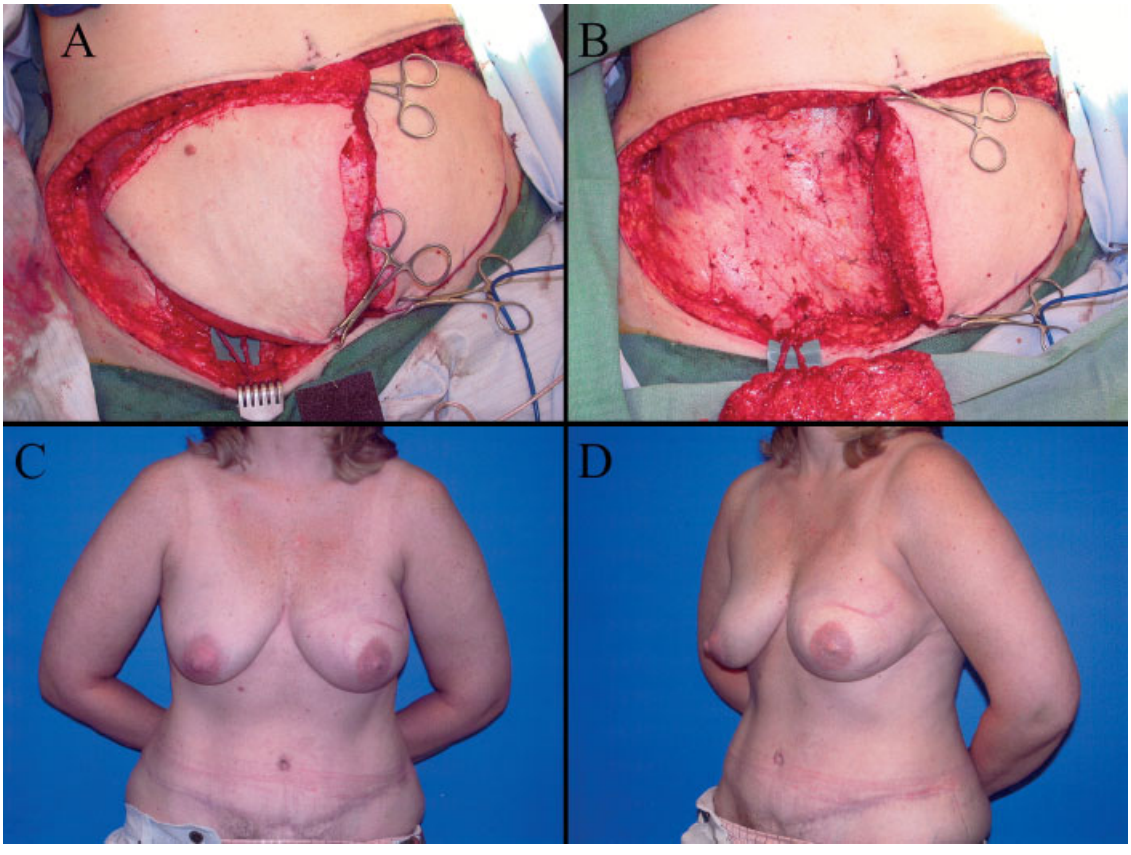

Figure 1 Immediate reconstruction of a medium-sized breast with an SIEA flap. (A) Right SIEA flap with pedicle consisting of medial superficial inferior epigastric vein and lateral SIEA. (B) Abdominal donor site with intact rectus abdominis fascia and muscle. (C) Anterior and (D) oblique views 7 months after surgery.

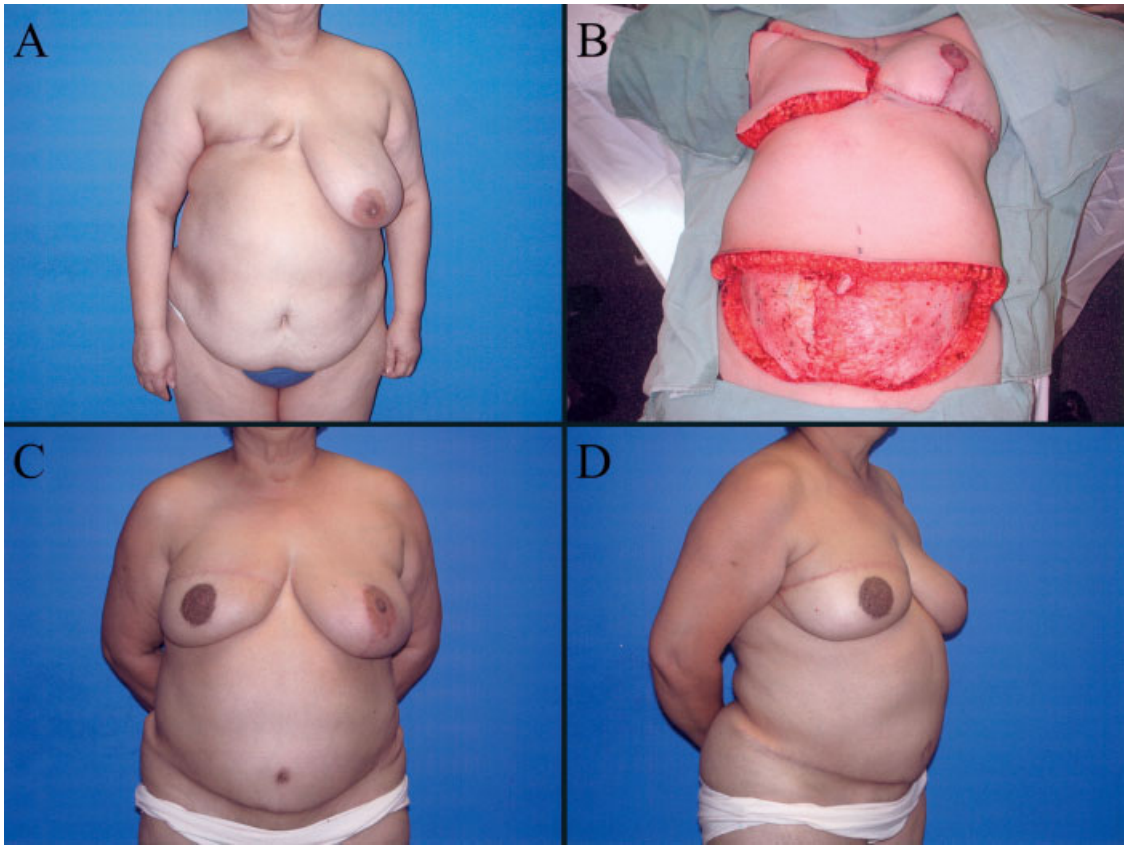

Figure 2 Delayed reconstruction of a large breast with an SIEA flap. (A) Preoperative anterior view. (B) SIEA flap revascularized at right chest, lower abdominal donor site with intact rectus abdominis fascia and muscle, and left breast reduction. (C) Anterior and (D) oblique views 8 months after surgery.

diameter and shorter pedicle length than those found in TRAM and DIEP flaps and the absence or inadequacy of an arterial pedicle in many patients.[8,11,13]

Perforator flaps from the gluteal[14] and anterolateral thigh[15–17] donor sites have also been described for breast reconstruction. These free flaps are much less commonly employed, have significant disadvantages compared with flaps from the abdominal donor site, and will not be reviewed here.

ARE MUSCLE-SPARING OPERATIONS JUSTIFIED?

Breast reconstruction techniques using the lower abdominal donor site include the pedicled TRAM flap, the free TRAM flap, the free msTRAM flap, the DIEP flap, and the SIEA flap. Each successive flap in this list involves the harvest of less rectus abdominis muscle and fascia. The presumption is that less excision or incision of the rectus abdominis muscle and fascia results in less abdominal donor site morbidity. However, the published data reviewed below do not unequivocally support this presumption. Moreover, there are trade-offs. Although the free TRAM flap offers improved flap vascularity, the surgery is more complex and time-consuming, and there is a higher risk of total flap loss compared with the pedicled TRAM flap. The DIEP flap is even more complex and technically exacting, resulting in further increased surgical time. In addition, the DIEP flap has decreased vascularity and a higher risk of venous insufficiency, partial flap loss, and fat necrosis compared with free TRAM flaps.[18–20] Harvest of the SIEA flap does not involve the rectus abdominis muscle or anterior fascia; therefore, it is technically simpler to elevate than TRAM or DIEP flaps. However, the main disadvantage of the SIEA flap is its variable vascular anatomy; the flap is contraindicated in up to 70% of patients because of the absence or inadequacy of an arterial pedicle.[8,11,13] The reconstructive surgeon must weigh the benefits of employing a muscle- and fascia-sparing flap procedure against the disadvantages. Data on the benefits of muscle-sparing abdominal flap breast reconstruction are reviewed below with an emphasis on statistically significant findings.

MUSCLE SPARING AND ABDOMINAL MOTOR FUNCTION

Several studies have compared abdominal motor function following pedicled and free TRAM flap breast reconstruction. Conclusions have varied. The 1995 study by Kroll and colleagues[21] showed a slight but statistically

significant decrease in the ability of patients with unilateral pedicled TRAM flaps to perform a sit-up postoperatively compared with patients with unilateral free TRAM flaps (57 versus 63%, respectively). In addition, patients with bilateral (pedicled and free) TRAM flaps were statistically significantly much less likely to be able to perform a sit-up postoperatively compared with patients with unilateral TRAM flaps (36 versus 62%, respectively). However, the 1996 study by Suominen and coworkers[22] found no significant difference in abdominal motor strength between patients with pedicled or free msTRAM flaps as measured by dynamometry or the ability to perform a sit-up postoperatively. In fact, the postoperative sit-up performance of patients with pedicled or free TRAM flaps was within the normal range for women of their age group. A 1997 prospective study by Kind and colleagues[23] showed no significant difference in the abdominal wall strength of patients with pedicled TRAM flaps and free msTRAM flaps 3 to 12 months after surgery as measured by dynamometry, physical therapist assessments, and activity questionnaires. A 1998 prospective study by Edsander-Nord and associates[24] also found no statistically significant difference in postoperative strength between patients with pedicled TRAM flaps and free msTRAM flaps as measured by dynamometry or the ability to perform a sit-up.

There is clearly no consensus regarding the relative effects of free and pedicled TRAM flap harvest on abdominal wall motor strength. Although differences between pedicled and free TRAM flap patients often did not attain statistical significance in these studies, the trend was usually toward greater weakness and symptoms in the pedicled TRAM flap groups.

Similarly, the DIEP flaps have been compared with free TRAM flaps. In 1997, Blondeel and colleagues[25] compared 18 patients with DIEP flaps and 20 with free TRAM flaps at least 1 year after surgery. They found that patients with free TRAM flaps had significantly less abdominal power performing a "curl-up" test and were significantly weaker than patients with DIEP flaps in two of six isokinetic dynamometer measurements. Furthermore, the abdominal strength of patients with DIEP flaps 1 year after surgery was indistinguishable from that of a control group who did not have surgery. However, on a questionnaire, no significant differences were found between the responses of patients with free TRAM or DIEP flaps concerning abdominal donor site strength, pain, aesthetics, or their ability to perform activities of daily life. Despite the lack of a significant difference, patients with DIEP flaps were less likely than were patients with TRAM flaps to have noticed decreased abdominal power, asymmetric umbilical position, or chronic lower abdominal wall pain. It should be noted that the free TRAM flaps in this study were not muscle sparing.

Using a dynamometer and questionnaires, Futter and colleagues[26] compared the abdominal wall strength of 23 patients with DIEP flaps, 27 patients with free msTRAM flaps, and 32 women who had not undergone breast reconstruction. Patients with free msTRAM flaps were significantly weaker than patients with DIEP flaps in 5 of the 14 dynamometer strength measurements. However, no statistically significant difference was found between patients with free msTRAM flaps and DIEP flaps in their responses to a questionnaire regarding postoperative abdominal function, bulging, pain, and their ability to perform activities of daily living. Despite a lack of statistical significance, patients with DIEP flaps reported fewer functional problems than did patients with free msTRAM flaps.

These two studies comparing DIEP and free TRAM flaps show that an objective measuring tool like a dynamometer can detect the increased abdominal weakness of patients with TRAM flaps but that subjective patient self-assessments are not sensitive enough to detect a difference in abdominal wall strength or function. The motor weakness resulting from unilateral free msTRAM or DIEP flap harvest is probably subclinical in most of the typically middle-aged, sedentary women who undergo breast reconstruction. What is clear is that patients are not disabled following either TRAM or DIEP flap surgery and that bilateral flap harvest has a more negative effect on abdominal motor strength than does any type of unilateral flap harvest.

There are no data addressing the postoperative abdominal motor strength or function of patients with SIEA flaps. However, I found that patients with unilateral SIEA flaps had statistically significantly shorter hospital stays than did patients with unilateral free msTRAM and DIEP flaps.[13] One would expect very little, if any, postoperative weakness or risk of abdominal bulging or hernia after SIEA flap surgery because it is a true abdominoplasty flap that does not result in injury to the rectus abdominis muscle or fascia.

MUSCLE SPARING AND ABDOMINAL CONTOUR

How muscle-sparing flap harvest affects abdominal contour remains unresolved. The 1995 study by Kroll and associates[21] comparing 168 patients with free TRAM flaps with 100 patients with pedicled TRAM flaps found no significant difference in the incidence of abdominal bulges or hernias. Suominen and colleagues[22] reported that only 4% of patients with free msTRAM flaps had minor lower abdominal bulges compared with 44% of patients with pedicled TRAM flaps. In contrast, in a study by Edsander-Nord and coworkers,[24] 82% of patients with free msTRAM flaps reported postoperative lower abdominal bulging, compared with 48% of patients with pedicled TRAM flaps.

Comparing patients with free TRAM and DIEP flaps, Blondeel and colleagues[25] found a statistically significantly lower rate of abdominal bulging and hernia (all cases of which were asymptomatic) in patients with DIEP flaps. However, they also found no significant difference between patients with free TRAM and DIEP flaps in self-assessed postoperative abdominal appearance or silhouette. Futter and associates[26] also reported no difference in patient-reported rates of abdominal bulge following free msTRAM or DIEP flap surgery. Furthermore, Nahabedian and coworkers[27] found no significant difference in the rates of postoperative abdominal bulging or hernia between 85 patients with unilateral free TRAM flaps and 8 patients with unilateral DIEP flaps.

It is not clear from these published reports whether a pedicled TRAM flap, free TRAM flap, or DIEP flap is any less likely to result in abdominal contour abnormalities. Nevertheless, there are no significant differences in patient-reported abdominal contour abnormalities among these flap types.

SENSATE FREE TRAM, DIEP, AND SIEA FLAPS

Reinnervation of TRAM, DIEP, and SIEA flaps to provide sensate reconstructed breasts is another area that has seen recent advancements. Autologous tissue breast reconstructions have been shown to spontaneously recover cutaneous sensation, but the frequency of recovery is unpredictable and the quality of recovered sensation is usually poor.[28–32] Slezak and colleagues[31] were the first to report coaptation of sensory nerves to improve reinnervation of breast reconstructions. Yap and associates[33] recently published an anatomical and neurophysiological study defining the course of intercostal sensory nerves innervating the lower abdominal flap.

Several other studies have shown the effectiveness of sensory nerve coaptation at restoring sensation in breasts reconstructed with pedicled TRAM flaps,[34] free msTRAM flaps (in conversation with L-H Yap, M.D., 2002), and DIEP flaps.[35] A study by Blondeel and colleagues[35] showed statistically significantly better pressure sensation in the central region of innervated DIEP flaps compared with DIEP flaps that did not have a neurorrhaphy. However, even neurotized DIEP flaps were significantly less sensitive than normal breasts. Erogenous sensation was reported in only 30% of the innervated DIEP flaps. Yap and coworkers have shown that breasts reconstructed with innervated free msTRAM flaps have statistically significantly better fine touch and temperature sensation than do breasts reconstructed with nonneurotized free msTRAM flaps. Interestingly, fine touch sensitivity was better throughout the breasts reconstructed with reinnervated flaps, not just in the central zone.

In all of the reported cases of neurotized autologous tissue breast reconstructions, a lower thoracic intercostal nerve from the abdominal flap (Fig. 3A) was coapted to the lateral cutaneous branch of the T3, T4, or T5 intercostal nerve at the lateral mastectomy site. Use of the medial portion of an intercostal nerve or its anterior cutaneous branch as a recipient nerve has not been described. These medial intercostal sensory nerves near the sternum may be preferable when using the internal mammary recipient vessels. The medial end of

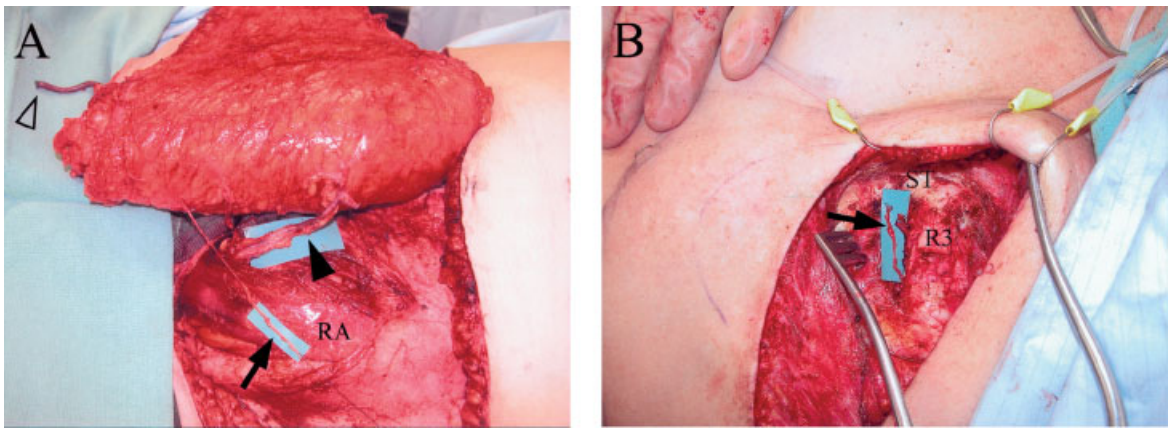

Figure 3 Delayed left breast reconstruction with a neurotized free DIEP flap. (A) Left lateral view of the left DIEP flap reflected medially at the abdominal donor site. Arrow points to the dissected T11 intercostal nerve with its sensory fibers entering the subcutaneous undersurface of the DIEP flap. Note that this nerve, the largest sensory nerve from the flap, is remote from the two dominant perforators. Arrowhead points to the deep inferior epigastric vessels connecting the two DIEP flap perforators. The vessels have been dissected free from the surrounding rectus abdominis muscle. Open arrowhead points to the medial superficial inferior epigastric vein. RA indicates the rectus abdominis muscle. (B) Left anterior-oblique view of the left chest with a portion of the third rib cartilage removed in preparation for exposure of the internal mammary recipient vessels. Arrow indicates the dissected medial portion of the third intercostal nerve just inferior to the rib with adjacent intercostal vessels. Following DIEP flap transfer and revascularization, the T11 intercostal nerve from the flap was coapted to the T3 medial intercostal nerve at the chest recipient site. R3 marks the most medial portion of the third rib. ST marks the left lateral sternal border.

the intercostal nerve is easily identified just inferior and adjacent to the rib cartilage that is resected during exposure of the internal mammary recipient vessels (Fig. 3B). The medial portion of the intercostal nerves can be reliably identified during delayed breast reconstruction when finding a lateral cutaneous branch within the previous operative field of the mastectomy is difficult. Another advantage is that the medial intercostal nerve can be dissected free laterally to increase its mobile length to facilitate coaptation to a short sensory nerve of the flap.

The use of innervated SIEA flaps has also been reported.[12] The sensory nerves exit from the subcutaneous tissue on the undersurface of the SIEA flap and pierce the anterior rectus fascia, usually with a perforating artery and sometimes with a vein as well, exactly as they do in a TRAM or DIEP flap. However, harvesting a sensory nerve longer than several centimeters would necessitate incision of the rectus abdominis fascia and dissection through the muscle; this would partially offset the advantages of the use of the SIEA flap and may not be desirable. A very short sensory nerve from the flap could be used if a long medial intercostal nerve at the anterior chest recipient site could be dissected as described above. Having a shorter nerve from the flap would also decrease the distance nerve fibers would have to regenerate.

In summary, dissection and coaptation of sensory nerves from an abdominal flap to the lateral intercostal nerves at the mastectomy site improve the quality, extent, reliability, and rapidity of return of sensation to the reconstructed breast. Use of the anterior branch or medial portion of an intercostal nerve may be advantageous, especially in delayed breast reconstruction. The sensory nerves from the abdominal flap join motor fibers within the rectus abdominis muscle to become a mixed intercostal nerve that exits the lateral border of the muscle. The intramuscular portion of these nerves rarely tracks exactly with perforating blood vessels being harvested with the flap. Therefore, harvest of these nerves typically results in additional dissection through the rectus abdominis muscle and division of some motor nerve fibers of the rectus muscle. Presumably, this would incrementally increase the risk of abdominal donor site morbidity by reducing the extent of muscle sparing. The surgeon and patient must weigh the advantages of increased sensation of the reconstructed breast against the potential disadvantages at the abdominal donor site and the increased operating time necessary to dissect the nerves and perform the neurorrhaphy.

OBSERVATIONS AND CONCLUSIONS

The lower abdomen is the preferred donor site for the harvest of autologous tissue for breast reconstruction. Rectus abdominis muscle and fascia are excised for a TRAM flap or incised for a DIEP flap to maintain a vascular pedicle for transfer of the flap. This leads to the risk of donor site morbidity including abdominal motor weakness, bulging, herniation, and chronic pain. The SIEA flap does not involve injury to the rectus abdominis muscle and fascia, therefore presumably virtually eliminating the risk of abdominal donor site morbidity.

It makes intuitive sense that techniques such as the free msTRAM or DIEP flap that decrease the amount of rectus abdominis muscle and fascia that is excised or incised would decrease the risk of donor site morbidity. However, data have not shown that these procedures significantly reduce the rate of abdominal bulging and herniation. Objectively measured abdominal strength is higher after muscle-sparing techniques such as the DIEP flap. However, postoperative abdominal strength and function do not improve significantly with muscle-sparing techniques according to subjective patient assessments. One explanation for this is that the typical patient undergoing breast reconstruction is a middle-aged, sedentary woman. Such a patient may not require full strength of both rectus abdominis muscles to perform her activities of daily living; therefore, she may not notice the partial loss of abdominal strength following unilateral TRAM or DIEP flap surgery. The SIEA flap may virtually eliminate the risk of postoperative abdominal weakness and herniation, but it is possible only in a minority of patients undergoing breast reconstruction.

Sensory nerve coaptation to improve reconstructed breast sensation is a refinement that may gain popularity. Neurotization of the flap unfortunately increases the complexity of the procedure, lengthens operative time, and often leads to additional rectus abdominis injury. This technique may have more benefit in delayed breast reconstructions, in which a large area of otherwise insensate flap skin is exposed. Flap neurotization may be less beneficial in immediate reconstructions of skin-sparing mastectomy defects, in which the mastectomy skin flaps often spontaneously recover some sensation.

My own approach to autologous tissue breast reconstruction is to attempt to use an SIEA flap, then a DIEP flap, and finally a free msTRAM flap,[13] an approach that is similar to the algorithm advocated by Arnez and colleagues.[36] I will use an SIEA flap if a hemi-lower abdominal flap will provide sufficient tissue, if an SIEA with an external diameter of 1.5 mm or more exists on the side opposite the breast to be reconstructed, and if internal mammary recipient vessels are available.[13] If the SIEA flap is contraindicated, I will attempt to use a DIEP flap. A DIEP flap requires at least one large or two medium-sized perforators in the lateral row. Medial row perforators must be very large or originate from a medial branch of the deep inferior epigastric artery that is immediately beneath the perforators; otherwise, the

dissection can be very time-consuming. Tissue across the midline (zone 2) of DIEP flaps based on lateral row perforators is usually not well perfused, and therefore not used. DIEP flaps are usually not used in patients who smoke unless the perforators are exceptionally large. If a DIEP flap is not used, I will use a free msTRAM flap. Following this algorithm, I use an SIEA flap in ~25% of autologous tissue breast reconstructions, a DIEP flap in 25%, and a free msTRAM flap in 50%.

Informal patient questioning at follow-up visits 6 months or more postoperatively indicates that patients who have undergone unilateral breast reconstruction with msTRAM, DIEP, or SIEA flaps generally do not notice or complain of abdominal motor weakness. However, patients do seem to notice less postsurgical pain[37] and more rapid recovery when muscle-sparing techniques are used.[13]

In summary, there is a lack of consistent and convincing data that DIEP or SIEA flaps significantly decrease the rate of abdominal donor site contour abnormalities. Objective data show measurably better abdominal strength in patients with DIEP flaps than in those with free TRAM flaps, but accumulated data indicate that patients themselves are unaware of the abdominal strength differences resulting from free TRAM, free msTRAM, or DIEP flaps. Given that the type of muscle-sparing flap used may not result in a difference in abdominal function that patients can detect, I advocate employing the most expeditious flap that will reliably provide a sufficient volume of tissue for breast reconstruction.

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