Review Article

Abdominal perforator *vs*. muscle sparing flaps for breast reconstruction

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Abstract: Abdominally based free flaps have become the mainstay for women that desire to use their own tissue as a means of breast reconstruction after mastectomy. As the techniques have evolved, significant effort has been invested in finding the best means of minimizing morbidity to the abdominal donor site while ensuring a viable reconstructed breast that is aesthetically pleasing. This manuscript reviews and compares the muscle sparing free transverse rectus abdominis myocutaneous (MsfTRAM), the deep inferior epigastric artery perforator (DIEP), and the superficial inferior epigastric artery (SIEA) flaps, regarding flap success rate, operative times, abdominal donor site morbidity and residual functionality, hospital lengths of stay and associated costs, impact of co-morbid conditions, and resilience after adjuvant radiation treatment.

Keywords: Muscle sparing free transverse rectus abdominis myocutaneous (MsfTRAM) flap; deep inferior epigastric artery perforator (DIEP) flap; superficial inferior epigastric artery (SIEA) flap; free flap breast reconstruction

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Over the last 40 years, breast reconstruction has been widely considered a significant component of the comprehensive treatment and management of breast cancer patients. This was heightened by the passage of the Women's Health and Cancer Rights Act (WHCRA) of 1998, that mandated insurance plans to provide breast cancer patients with coverage for reconstructive surgery and other benefits related to a mastectomy (1). With its initial description in 1979, the free transverse rectus abdominis myocutaneous (TRAM) flap became a pillar of autologous breast reconstruction (2). The concept of reconstructing the breast with reliable autologous tissue, that was soft, robust, and resulted in an aesthetically pleasing reconstruction lead to its widespread adoption. With the intent to reduce abdominal donor site morbidity, the original free TRAM flap has undergone numerous modifications resulting in the modern day muscle-sparing free TRAM (MsfTRAM), deep inferior epigastric perforator (DIEP), and superficial inferior epigastric artery (SIEA) flaps (3-13). Both the MsfTRAM and the DIEP flaps are based off of the same axial blood supply and arguably yield the same amount of abdominal subcutaneous tissue and skin; however, the DIEP flap technique has received further notoriety as it spares the rectus abdominis muscle and anterior rectus fascia (6,14). In an effort to further reduce abdominal wall morbidity, the SIEA flap is based on a more superficially located blood supply obviating the need to violate the anterior rectus fascia or its underlying muscle all together (11-14).

Despite its presumed benefit of decreased donor site morbidity and pain, the DIEP flap technique has been slow to be collectively embraced due to initial concerns for increased flap loss, heightened rates of fat necrosis, more complex dissection, and skepticism over its reduction in donor site hernia or bulge. Although it is universally agreed upon that SIEA flaps limit donor site morbidity compared to MsfTRAM and DIEP flaps, it too has had detractors secondary to concerns about its reliability and heightened rates of fat necrosis. There have been numerous contributions to the literature comparing outcomes, complications, donor site functionality, and even cost differences between the

MsfTRAM, DIEP, and SIEA flap techniques. Most of these studies contain data from single institutions and admittedly none have been performed in a truly randomized fashion. Although all three reconstructive techniques have proven to be relatively reliable, safe, and yielding of good aesthetic results, we felt that it would be of value to review the most recently cited differences. Factors considered in this comparison of MsfTRAM, DIEP, and SIEA flaps include flap success rates, rates of fat necrosis, operative time, abdominal donor site morbidity and residual functionality, hospital lengths of stay and associated costs, impact of co-morbid conditions, and resilience after adjuvant radiation treatment.

Muscle sparing free transverse rectus abdominis myocutaneous (MsfTRAM)

Both MsfTRAM and DIEP flaps rely on the deep inferior epigastric vascular system as their axial blood supply. Both flaps require that the anterior rectus sheath and rectus abdominis muscle are incised; however, the MsfTRAM involves procurement of some of the muscle as a part of the flap while the DIEP flap contains no muscle. In 2002, Nahabedian *et al*. described a classification system for MsfTRAM flaps, employing the nomenclature MS-0 thru MS-3. They are described in the following manner: MS-0, the full width of the rectus abdominis muscle is procured with the overlying subcutaneous tissue and skin; MS-1, the lateral segment of the rectus abdominis muscle is preserved; MS-2, both medial and lateral segments of rectus abdominis muscle are spared; and MS3, the entire rectus abdominis muscle is preserved (DIEP flap) (15). The intended preservation of an increased amount of rectus abdominis muscle was twofold. It would ensure greater integrity of the abdominal wall as well as preserve the lateral intercostal nerve innervations that are theoretically as important, or even more vital, to the strength of the abdominal wall than the muscles themselves.

By procuring some of the rectus abdominis muscle with the overlying subcutaneous tissue and skin, the MsfTRAM flap has the benefit of preserving some of the small intramuscular perforators from the deep inferior epigastric artery and vein that would otherwise be lost (16). The clinical relevance of these small perforators continues to be debated, but remains one of the reasons that some surgeons prefer this technique over the DIEP flap.

Deep inferior epigastric perforator (DIEP)

The DIEP flap relies on 1-4 perforating vessels from the deep inferior epigastric artery and vein, sparing procurement of the rectus abdominis muscle and anterior rectus fascia (14,17). Viable DIEPs are those said to have a visible artery, an accompanying visible vein, and a palpable pulse. The decision on how many of the perforators to procure with the flap is based on perforator size, location (medial or lateral row), and proximity to each other, all in an attempt to minimize the extent of intramuscular dissection. By minimizing the intramuscular dissection and basing the flap on medial row perforators only, disruption of the lateral intercostal innervations can be avoided leaving behind not only an intact rectus abdominis muscle but also one that has not been denervated.

The DIEP flap involves a more technically demanding dissection and there is an undeniable learning curve pertaining to perforator identification, preservation, and successful transfer of these flaps (18). The theoretical benefit of complete muscle preservation and reduced donor site morbidity is what has led many to endorse the DIEP flap over the MsfTRAM, however the lack of confidence in depending on one or two, small diameter perforators to perfuse a relatively large flap has posed the greatest barrier to its universal adoption (19,20).

Superficial inferior epigastric artery (SIEA)

First described as a viable autologous breast reconstructive option in 1991, the SIEA flap yields the advantage of leaving the abdominal fascia completely intact as its vascular supply travels superficial to the rectus abdominis fascia. The SIEA and vein originate from the common femoral vessels while the external iliac vessels supply the deep inferior epigastric artery and vein (11). Despite its diminished donor site advantage, the SIEA flap has not been universally adopted for several key reasons. The first is due to significant anatomic variability as several studies cite the SIEA being absent in upwards of 30% of patients (13,21,22). The second is that the SIEA consistently is smaller in diameter that the traditional recipient vessels for autologous free flap breast reconstruction (internal mammary and thoracodorsal) leading to the anastomoses being more technically demanding. Lastly, there have been significant concerns about the ability of the SIEA to adequately perfuse all four, historical zones of the abdominal wall skin and subcutaneous tissue (21). When used it has been documented that an SIEA >1.5 mm in diameter be used to improve the likelihood of flap viability (12,23).

Flap viability and fat necrosis

Comparing rates of total or partial flap loss and frequency of the occurrence of fat necrosis between MsfTRAM, DIEP, and SIEA flaps have been popular topics in the last 15 years. With full disclosure the authors of these published rates recognize that their data lack the scientific vigor of randomization and also that they are frequently reporting on a single institution, and many times a single surgeon's, experience. That being said, the most recently published rates of complete and partial flap loss for MsfTRAM flaps range from 0.3% to 3.6% and 2.2% to 7%, respectively (15,19,24-29). The most recently published rates of complete and partial flap loss for DIEP flaps are slightly higher than MsfTRAM flaps ranging from 0.5% to 6% and 2.5% to 8.7%, respectively (24,26,29-33). Undoubtedly contributing to the reluctance of the routine use of SIEA flaps, the published rates of SIEA total flap loss range from 1.9% to 12.6% (12,14,21-23,34,35). These heightened flap loss rates even in the most experienced of hands are 3-4 times higher than reported rates of MsfTRAM and DIEP flaps causing some to suggest that SIEA flaps may not be worth the risk despite its reduced donor site insult (21). The majority of recent studies comment that there is marginal difference in flap loss between MsfTRAM and DIEP flaps as both are safe and reliable; however, the DIEP flap also poses a slightly greater risk of fat necrosis over more muscle inclusive options (24).

Kroll *et al*. in 2000 was one of the first studies that specifically compared rates of fat necrosis between MsfTRAM and DIEP flap breast reconstruction. This single institution and single surgeon study reported that of their 310 reconstructed breasts, fat necrosis occurred in 12.9% of their MsfTRAM flaps compared to a significantly higher 29.0% in their DIEP flaps (25). More recently in a series of 130 flaps at another institution, they also cited a statistically significant (P=0.001) increased rate of fat necrosis in DIEP flaps compared to MsfTRAM flaps (33). In contrast, and highlighting institutional variability, several other recent single institution studies reported no statistically significant difference in rates of fat necrosis between their MsfTRAM and DIEP flaps (19,24,26). Fewer studies have assessed SIEA flaps rate of fat necrosis with limited reports ranging from 5.7% to 14% (35,36).

The variability of these findings suggests not only that these outcomes are surgeon or institutionally dependent, but also presume an inconsistency in how fat necrosis is defined. Kroll *et al*. was very specific in defining fat necrosis as any palpable firmness greater than 1cm in diameter present 3 months after surgery and proven to not be a cancer recurrence (25), while other studies either gave a vague explanation or failed to define their definition of fat necrosis all together. Aware of the variability in reported rates of fat necrosis, Baumann *et al*. recently assessed how the number of perforators predicts fat necrosis in abdominally based free flap breast reconstruction. Their single institution, prospective study concluded that as the number of perforators supplying the flap diminishes, the amount of fat necrosis increases. The MsfTRAM flaps with ≥3 perforators had significantly less fat necrosis than the DIEP and SIEA flaps that rely on ≤2 perforators (36). Undeniably to more accurately answer this question with more scientific rigor, a multi-institutional, prospective study with strict guidelines defining fat necrosis would need to be employed.

Operative time

Historically there have been some reservations by surgeons to adopt the DIEP flap technique due to concerns of it being a more technically challenging and potentially time consuming procedure than the MsfTRAM. There have been no recent studies directly comparing operative times for MsfTRAM, DIEP, or SIEA flap techniques. With the early advent of MsfTRAM flaps, operative times for bilateral procedures were reported to take around 8.6 hours (37). One of the first reported large series of DIEP flaps revealed an average operative time of 9.2 hours for a bilateral procedure (38). One could reasonably speculate that without the need for an intramuscular dissection, SIEA flaps would yield shorter operative times. Once again there is a paucity of published data on this topic; however, one study contrarily found there to be no statistically significant difference between SIEA flap operative times compared to MsfTRAM and DIEP flaps (P=0.67) (12).

With refinements in techniques, and the availability of venous coupling devices, implantable dopplers, and efficient preoperative imaging modalities there has been a significant reduction in DIEP flap operative times (38,39). Recent studies report unilateral DIEP flaps being performed in less than 4.5 hours (39,40). A unifying theme throughout the literature is the undeniable learning curve involved with all three techniques. Acosta *et al*. reported over a 9-year experience that their unilateral DIEP operative times have reduced from an initial 7.3 hours to a current 4.1 hours, with a much lower complication rate (39).

Abdominal donor site morbidity

The much lauded benefit of the DIEP and SIEA flaps compared to the MsfTRAM flap is the presumed reduction in donor site morbidity. Ensuring a robust flap while minimizing the abdominal donor-site morbidity such as pain, weakness, bulges, and hernias has been the impetus for the evolution of these procedures. Abdominal wall discomfort, strength, and functionality after MsfTRAM, DIEP, and SIEA flap breast reconstruction is dependent on numerous factors inclusive of the amount of rectus abdominis muscle and fascia that remains after the flap has been raised, the prevailing blood supply to the rectus abdominis muscle, the integrity of the lateral intercostal innervations to the *in situ* rectus abdominis muscle, and the amount of scar tissue that develops as a result of the flap dissection and procurement (8,26,41).

The first to describe differences in donor site pain between MsfTRAM and DIEP flaps came from the British literature as they speculated that their DIEP flap patients had reduced amounts of pain secondary to the diminished amount of tension on their rectus abdominis fascia repair (9,32,42). These findings were confirmed and extrapolated upon by Kroll *et al*. when they correlated the amount of subjective pain patients reported to a more objective assessment of amount of narcotic used between MsfTRAM patients and DIEP patients. They found on average that patients with MsfTRAM flaps used on average over twice the amount of narcotic (1.65 mg/kg) than the patients with DIEP flap reconstruction (0.74 mg/kg), which was statistically significant (P<0.001) (43). The literature further reveals that SIEA flap patients report nearly statistically significant less abdominal pain than both MsfTRAM and DIEP flap patients (P=0.06) (44).

Contour abnormalities that can occur with abdominally based free flap breast reconstruction has been thoroughly assessed and described in the literature (3,8,10,15,19,24,26). These studies have all demonstrated that there is no statistically significant difference in contour between MsfTRAM (MS-2) DIEP, and SIEA flaps; however, several of the more recent studies confirm a heightened risk of bulge in the MsfTRAM flap reconstructions compared to DIEP and SIEA flaps (21,24,26,41,45). Interestingly, Egeberg *et al*. recently revealed that although there was a 20% greater risk of developing a physician identified bulge in the MsfTRAM cohort compared to the DIEP cohort, when bulge rates were self-reported via survey by patients there was no significant difference in bulge rates between the two groups (45). This points to the clinical significance, if any, are of a post-operative bulge. Regardless, most authors encourage maximal preservation of the anterior rectus sheath, in conjunction with a strong suture closure, to minimize the development of any abdominal contour abnormalities.

No theoretical risk of hernia formation exists with SIEA flaps which have been corroborated in a few studies (13,21). However, comparison of hernia rates after MsfTRAM and DIEP flaps have been readily evaluated by many of the aforementioned studies (3,8,10,15,19,24,26). Although most reveal a slightly higher rate of abdominal wall hernias after unilateral MsfTRAM flaps than DIEP flaps, the difference does not meet the level of statistical significance (P<0.05). For example, Nelson *et al*. reported a hernia rate of 2.6% in MsfTRAM flaps compared to 0% in their DIEP flaps (P=0.15) (24). Nahabedian *et al*. reported an abdominal hernia rate of 1.5% in their unilateral DIEP flaps and a comparable 4.7% in their unilateral MsfTRAM flaps (P=0.36) (26).

Notably this same study by Nahabedian *et al*., as well as others, have revealed a statistically significantly greater risk of bulge and or hernia formation in the setting of bilateral MsfTRAM flaps (21%) compared to bilateral DIEP flaps (5%) (26,45). At this point it is universally accepted that bilateral MsfTRAM flaps pose a greater risk of hernia formation than bilateral DIEP flaps; however, there is growing evidence that when fascial preservation techniques are employed during MsfTRAM flaps, hernia or bulge formation are further reduced (41). The amount of muscle removed is proving less important as long as the vast majority of the fascial integrity remains intact.

The importance of a meticulous closure of the abdominal donor site to prevent the occurrence of hernia or bulge cannot be overstated. Wan *et al*. advocate that MsfTRAM flaps still very much have their utility as the hernia risk can be effectively addressed with mesh (46). They suggest that by reinforcing the abdominal wall defect with permanent mesh, hernia rates for bilateral MsfTRAM flaps can be reduced to that of bilateral DIEP flaps. They join several other studies that encourage the routine use of mesh in the donor site repair to reduce abdominal wall morbidity for both unilateral and bilateral MsfTRAM flaps (15,24,26,41,46). Further pointing to the significance of fascial preservation techniques, recent studies from the general and plastic surgery literature are advocating for primary fascial coaptation with mesh reinforcement as the most ideal repair of abdominal wall defects to prevent either hernia recurrence or occurrence, respectively (47,48).

Assessment of abdominal strength after abdominally based breast free flap reconstruction remains controversial. This is primarily due to the lack of consistency and consensus on how best it should be evaluated. Some surgeons believe that isolated testing of the rectus abdominis should be performed using isokinetic dynamometry, electromyography, or myosonography (9,26,49-51). Other physicians advocate for a more practical assessment such as sit-ups or surveying the patients to determine if they can carry out the activities of daily living that they subscribed to preoperatively (3,26,44,51-53).

Futter *et al*. compared patients that had undergone DIEP flaps, MsfTRAM flaps, and non-operated controls after assessment of their abdominal and back extensor strength on an isokinetic dynamometer (9). The DIEP flap and control groups displayed statistically significant better abdominal and back extensor strength than the MsfTRAM flap group. Additionally, patients from the MsfTRAM group reported greater rates of abdominally related functional difficulty and discomfort compared to the DIEP flap and control groups (9). Bottero *et al*. revealed through electromyography that the function of the rectus abdominis muscle after DIEP flap procurement was reduced only 30% after a follow-up of over a year (50). The authors advocate that their finding implies superiority of the DIEP flap over the MsfTRAM although they admittedly failed to compare MsfTRAM in the same fashion. Similarly without having a MsfTRAM flap comparison group, Kässmann *et al*. pre- and post-operatively examined DIEP flap patients using myosonography (49). Comparing unilateral DIEP flap patients operative side to their contralateral, non-operated side as a control, they reported almost identical rectus muscle function on both sides just 2 months postoperatively. The absolute muscle thickness at maximum contraction and the difference of muscle thickness between relaxation and contraction were also found to be almost identical on both sides (49).

Looking specifically at bilateral reconstruction and using a manual muscle function test, Selber *et al*. found muscle impairment to be consistent with theoretical predictions. The greatest amount of impairment was seen by patients with MsfTRAM/MsfTRAM, followed by MsfTRAM/DIEP, DIEP/DIEP, DIEP/SIEA, and finally SIEA/SIEA patients revealed the least functional impairment (53). Only the level of impairment of the bilateral MsfTRAM cohort relative to the functional preservation of the bilateral SIEA cohort reached the level of statistical significance (P=0.04) (53).

Patient surveys have been the most frequently employed model of assessing abdominal wall functionality after abdominally based free flap breast reconstruction. Even the most recent of studies reveal mixed results. Some report that DIEP and SIEA flap patients perceive their core strength to be better or that they can more readily carry out prior activities, such as performing sit-ups, than patients that have undergone MsfTRAM flap reconstruction (8,9,26,44). Two studies reported no significant difference in patient perceived abdominal wall function after DIEP or MsfTRAM flap reconstruction (3,54). Fittingly, other recent studies have described that despite objective evidence of greater decline in abdominal function of MsfTRAM flap patients, this difference has not translated to significant detriments in the ability to carry out activities of daily living for MsfTRAM flap patients compared to their DIEP flap counterparts (53,55). The most recent meta-analysis on this topic agrees that the only way to legitimately answer the question of abdominal wall functionality comparing abdominally based free flaps will require a multicenter, longitudinal study, that employs consistent and valid measures (55). With that being said, there is a relatively universal consensus that both MsfTRAM, DIEP, and SIEA flaps yield far less donor site morbidity than its pedicle TRAM predecessor, particularly in the setting of bilateral reconstruction (51,56).

Hospital length of stay (LOS) and cost

Relative to the aforementioned topics, hospital LOS and cost comparisons between patients undergoing MsfTRAM, DIEP, and SIEA flaps have been less frequently assessed. Kroll *et al*. published that on average their DIEP flap patients remained in the hospital for a shorter duration (4.73 days) than their MsfTRAM patients (5.21 days) (43). Although this did reach statistical significance (P=0.026), it amounted to less than a full day (43). Kaplan *et al*. reported that on average, TRAM patients stayed in the hospital 4 days longer than perforator flap patients (57,58). Unfortunately, the study fails to disclose how many of the TRAM flaps were pedicled *vs.* free, and additionally non-abdominally based gluteal flaps were included in their perforator flap cohort which further confounds the results.

Several studies have included SIEA flaps in their assessment of hospital LOS. Vega *et al*. reported a significantly shorter hospital LOS in their DIEP and SIEA flap patients compared to their MsfTRAM patients (59). Chevray *et al*. also revealed a significantly shorter LOS for their SIEA flap patients (4.2 days) compared to their DIEP and MsfTRAM patients (5.1 days; P=0.04), but once again

this equated to less than 1 day (12). These studies conclude that the etiology of the LOS discrepancy is multifactorial but that donor site pain is likely a contributing factor. As surgeons become more facile with all three techniques and post-operative courses become more protocol driven, it is likely that even these small discrepancies in hospital LOS will further dissipate as is evident by one group's experience where no difference in LOS was identified between DIEP and MsfTRAM groups, 4.1 and 4.0 days, respectively (P=0.10) (24).

There are contradictory reports regarding the cost comparison of MsfTRAM, DIEP, and SIEA flaps. The aforementioned Kaplan *et al*. study originally published that the $9,625 average cost for perforator flap breast reconstruction was far less expensive than the $18,070 average TRAM reconstruction cost (57,58). Once again this study was confounded by the fact that there is no identification of how many of the TRAM flaps were pedicled *vs.* free, the perforator flap group included gluteal flaps; and although some cost adjustments were made, the perforator flaps were performed by one institution in Louisiana, while the TRAM flaps were performed by a separate institution in Texas.

Using a national database, Pien *et al*. recently published that DIEP flaps were associated with significantly higher charges and costs than pedicled TRAM and MsfTRAM flaps (60). The average cost of a DIEP flap was $23,616 compared to $15,538 and $20,756 for pedicled TRAM and MsfTRAM flaps, respectively (60). The authors cited that the only potential cost determinant that significantly differed among the groups was that more of the DIEP patients were privately insured. There was no statistically significant difference in LOS between the groups.

The only cost-effectiveness data that specifically includes SIEA flaps comes from the Canadian literature. Although their initial data was promising regarding the cost effectiveness of SIEA flaps compared to DIEP flaps, there remains some caution due to the SIEA flaps high rate of re-exploration and conversion to a DIEP flap (61). Of note, the Canadians have also found that DIEP flaps are associated with a higher cost than MsfTRAM flaps ($7,026 *vs.* $6,058) (62).

Co-morbid conditions and post-operative radiation therapy

It is well described that regarding abdominally based free flap breast reconstruction, obesity [body mass index (BMI) ≥30] and smoking have higher rates of mastectomy skin flap necrosis, flap complications, and abdominal wall donor-site complications than patients with a normal BMI or nonsmokers (63-66). There remains to be published studies that directly compare MsfTRAM, DIEP, and SIEA flaps in smokers or obese patients, but the historic teaching has been to include as many perforators as possible in the flaps of these two high risk groups (67). That philosophy would then favor MsfTRAM over DIEP or SIEA flaps. Without substantial evidence to the contrary, it is difficult to fault this approach; however, there is mounting evidence that DIEP and SIEA flaps are equally as safe and reliable in the obese and smokers as MsfTRAM flaps.

Garvey *et al*. found no difference in rates of flap loss or fat necrosis among obese, overweight, or normal weight patients that underwent DIEP flap reconstruction (68). Ochoa *et al*. found that although obesity predisposed DIEP flap patients to delayed wound healing of both the flap and the donor site, the overall flap complications were not significantly different in the obese compared to the normal weight patients (69). In a meta-analysis, Lee and Mun showed that compared to conventional free TRAM flaps, MsfTRAM, DIEP, and SIEA flaps showed a lower pooled incidence of flap loss, fat necrosis, and donor site hernias/bulges in obese patients (64). Most recently using a propensity score analysis, Zhong *et al*. compared MsfTRAM flaps to DIEP flaps in both obese patients and smokers and found no statistically significant difference in rates of flap loss or fat necrosis (70). This study did however find a greater risk of abdominal donor site complications in the MsfTRAM flaps compared to the DIEP flaps. So although it is still advised that all patients planning to have DIEP or SIEA flaps should stop smoking at least 4 weeks prior and after the operation as well as have a BMI of <30 to avoid a higher risk of complications, this is becoming less of a hard and fast rule.

Although it has been well documented that adjuvant radiation therapy after free flap breast reconstruction yields high rates of fat necrosis, fibrosis, contracture, and atrophy of the flap, there has been limited evidence favoring one form of free flap breast reconstruction over another (71-74). A more historical study suggested that MsfTRAM flaps should be employed rather than DIEP flaps to minimize the deleterious radiation side-effects (75). Their reasoning that MsfTRAM flaps have a more robust blood supply than DIEP flaps parallels the explanation for its preferential use in smokers and the obese. Some recent studies are bringing that philosophy into question. Garvey *et al*. followed free flap breast reconstruction patients over 5 years. They revealed that although both MsfTRAM and DIEP flaps had

Table 1 Comparisons of muscle sparing *vs.* abdominal perforator flaps for breast reconstruction

Variable	MsfTRAM flaps (Refs.)	DIEP flaps (Refs.)	SIEA flaps (Refs.)	Advantage
Total flap loss	0.3-3.6% (15,19,24-29)	0.5-6% (24,26,29-33)	1.9-12.6% (12,14,21-23,34,35)	MsfTRAM
Flap fat necrosis	4.6-12.9% (24,25,36)	5.9-29% (24,25,36)	5.7-14% (35,36)	MsfTRAM
Operative time (bilateral)	8.6-9.9 hours (37,57,58)	8.5-9.2 hours (37,57,58)	NP	Equivalent
Donor site pain*	211 (44)	195 (44)	165 (44)	SIEA
Donor site bulge/contour deformity (unilateral)	3-5% (24,26)	0-2% (24,26)	0% (21,23)	Equivalent
Donor site bulge/contour deformity (bilateral)	6-21% (24,26)	5-6% (24,26)	0% (21,23)	DIEP and SIEA
Donor site hernia (unilateral)	1.9-5% (21,24,26)	0-2% (24,26)	0% (21,23)	Equivalent
Donor site hernia (bilateral)	6-21% (24,26)	0-5% (24,26)	0% (21,23)	DIEP and SIEA
Residual abdominal functionality (unilateral)†	4.0 (52)	4.4 (52)	4.3 (52)	Equivalent
Residual abdominal functionality (bilateral)†	3.7 (53)	4.7 (53)	5.0 (53)	DIEP and SIEA
Hospital LOS	4.1-5.2 days (24,43)	4.0-4.7 days (24,43)	NP	Equivalent
Cost per flap ($)	20,756 (60)	23,616 (60)	NP	Undetermined

*, according to weighted pain score: the lower the score, the lower the amount of pain reported; †, according to Upper Rectus Abdominis Manual Muscle Function Test: 0 (least function)-5 (best function). MsfTRAM, muscle sparing free transverse rectus abdominis myocutaneous; DIEP, deep inferior epigastric perforator; SIEA, superficial inferior epigastric artery; NP, not published in a comparative fashion; LOS, length of stay.

high rates of fat necrosis after adjuvant radiation therapy, MsfTRAM flaps fared no better than DIEP flaps and were not protective against radiation induced changes (74). Findings like these will likely warrant further investigation in a more prospective manner.

Conclusions

Abdominally based free flap breast reconstruction using MsfTRAM, DIEP, or SIEA flaps can be used safely and reliably with a relatively low risk of flap loss or major complications. Head to head comparisons of various factors pertaining to these flaps remains a challenge due to the paucity of randomized controlled studies; however, a very general summary using the currently available data is provided in *Table 1*. The existing data continues to reveal that DIEP flaps have a slightly increased rate of flap loss and fat necrosis than MsfTRAM, while SIEA flaps have 3-4 times the rate of immediate postoperative complications of DIEP and MsfTRAM flaps, respectively. There appears to be no significant difference in operative times among the three techniques and increased experience results in improved expediency for the entire group. SIEA flaps continue to reveal the least amount of donor site morbidity, but must be balanced with the confirmed heightened risk of flap survival. Donor site morbidity comparisons between MsfTRAM and DIEP flaps remains debatable, although the objective measures give DIEP flaps the advantage. Hospital LOS appears to be comparable among all three flaps; however, early evidence reveals that DIEP flaps are the most expensive option. Despite further evidence that obesity poses a heightened risk of free flap complications and smoking yields greater mastectomy skin flap necrosis, DIEP flaps appear to be gaining credibility as a viable option in these high risk patients that were previously relegated to only pedicled or MsfTRAM flaps. The historical thinking that MsfTRAM flaps are more resilient to the deleterious effects of adjuvant radiation is being challenged as the amount of fat necrosis found in MsfTRAM flaps and perforator flaps appears to be comparable. Most current studies agree that ultimately, the choice of flap should be determined by the intra-operative anatomic findings, the patient's health status, the potential need for adjuvant therapy, and the surgeons' confidence in creating a viable breast flap at the least detriment to the donor site.

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