OPEN

PRS GLOBAL OPEN

ORIGINAL ARTICLE
Breast

Not All Deep Inferior Epigastric Artery Perforator Flaps Are Created Equal: A Review of Donor-site Morbidity in Abdominally Based Autologous Breast Reconstruction

Robert G. DeVito, MD
Jesse Chou, MD
Benjamin G. Ke, BA
Eileen Wen, BS
Chris A. Campbell, MD

Background: Breast reconstruction after mastectomy is one of the most common procedures performed in plastic surgery. Autologous reconstruction is associated with better long-term patient satisfaction than implant-based reconstruction but with the requisite donor site and potential for associated morbidity.
Methods: The authors review the literature regarding the technical evolution of abdominally based autologous breast reconstruction and the effect of these changes as well as patient morbidities on bulge, hernia, and all-cause donor-site morbidity.
Results: The impact of patient risk factors on surgical outcomes is evaluated in the context of constantly improving technical surgical innovation. Patients' premorbid abdominal condition and prior abdominal procedures along with traditional complicating factors such as age, obesity, and smoking are associated with increased rates of donor-site complications. Conversely, shorter fascial incisions with or without robotic and laparoscopic assistance are associated with lower rates of abdominal weakness and healing complications than traditional abdominal free flap harvest. Perforator selection and abdominal closure techniques also play a key role.
Conclusions: There are contributions of both patient factors and technical aspects that when optimized can help minimize the risk of donor-site morbidity in deep inferior epigastric artery perforator flap breast reconstruction. *(Plast Reconstr Surg Glob Open 2025;13:e6519; doi: 10.1097/GOX.0000000000006519; Published online 11 February 2025.)*

INTRODUCTION

Breast reconstruction after mastectomy remains one of the most common and critically important procedures plastic surgeons offer patients, where form and function are restored after cancer extirpation.[1] Roughly half of patients undergoing mastectomy proceed with reconstruction with either implants or autologous breast reconstruction.[2–5] Although roughly three-quarters of women electing reconstruction in the continental United States undergo implant-based breast surgery, patient-reported outcome studies suggest that autologous breast reconstruction provides a more durable result with higher satisfaction.

From the Department of Plastic Surgery, Maxillofacial and Oral Health, University of Virginia, Charlottesville, VA.

Received for publication August 5, 2024; accepted December 12, 2024.

DOI: 10.1097/GOX.0000000000006519

METHODS

This review assesses current evidence on donor-site morbidity in abdominally based autologous breast reconstruction, focusing on transverse rectus abdominis muscle (TRAM) and deep inferior epigastric artery perforator (DIEP) flaps. Articles were primarily sourced from *Plastic and Reconstructive Surgery*, *Plastic and Reconstructive Surgery Global Open*, *Annals of Plastic Surgery*, and other reputable journals. Studies from the past 10 years were prioritized to ensure relevance, but high-quality foundational articles were also included as needed. Selection criteria focused on studies that examined patient factors, surgical techniques, and outcomes related to abdominal morbidity, including hernia, bulging, and patient well-being. The findings were synthesized to provide a comprehensive overview of the factors that influence donor-site outcomes in autologous breast reconstruction.

Disclosure statements are at the end of this article, following the correspondence information.

PEDICLED TRAM VERSUS FREE DIEP FLAP

The abdomen is the most frequently used donor site for autologous breast reconstruction. This approach began with Hartrampf et al[6] in 1982, who described the pedicled TRAM flap, utilizing the superior epigastric artery for blood supply. To enhance perfusion and reduce fat necrosis, the free TRAM flap was later developed, incorporating microvascular techniques to connect to the deep inferior epigastric artery and vein.[6,7]

In 1994, Allen and Treece[8] introduced the DIEP flap, designed to minimize donor-site morbidity by preserving the rectus abdominis muscle while selectively sacrificing inferior epigastric perforating vessels. This technique offered a balance between adequate flap perfusion to prevent fat necrosis and rectus muscle preservation to reduce postoperative bulge.[8]

Studies comparing pedicled and free TRAM flaps with DIEP flaps have highlighted differences in abdominal morbidity. Knox et al[9] found significantly higher rates of hernia and bulge in pedicled TRAM flap patients than in DIEP flap patients (21.2% versus 3.1%, $P = 0.001$). Additionally, 12.7% of pedicled TRAM flap patients required further surgical intervention for abdominal wall morbidity compared with 0.0% for DIEP flap patients ($P < 0.001$).[9]

The economic impact of abdominal morbidity is also considerable. Shubinets et al[10] analyzed more than 8000 cases of pedicled TRAM, free TRAM, and DIEP reconstructions, estimating that each hernia repair costs roughly $40,000 per hospital encounter.

Given the variations reported in abdominal wall morbidity outcomes between the 2 techniques, the American Society of Plastic Surgeons (ASPS) in 2017 commissioned a work group to examine the differences between autologous breast reconstruction with free DIEP and pedicled TRAM abdominal flaps. Their analysis showed a higher hernia probability in pedicled TRAM versus DIEP (3.50% versus 0.74%) that approached significance but similar bulge rates between the 2 surgical techniques (4.62% versus 3.50%). The ASPS recommended that surgeons base their choice on experience and available resources, as both techniques show comparable donor-site complication risks.[11]

Although surgical outcomes vary based on technique, patient satisfaction is equally or more important to evaluate. Using the BREAST-Q survey, Atisha et al[12] reported that unilateral DIEP flap patients had significantly higher abdominal well-being scores than those with unilateral pedicled TRAM flaps (+9.5 points, $P < 0.001$). Bilateral free flap patients similarly scored higher than bilateral pedicled TRAM flap patients by an average of 6.8 points ($P = 0.04$).[12]

FREE TRAM VERSUS FREE DIEP FLAP

Following the development of free autologous breast reconstruction techniques, classification systems were created to facilitate communication and outcome reporting among surgeons. In 2002, Nahabedian et al[13] utilized a system categorizing flaps based on the amount of muscle harvested, from a full TRAM to a DIEP flap. They found no functional differences in sit-up performance among patients with full TRAM (MS-0), muscle-sparing free TRAM (MS-1 and MS-2), and DIEP (MS-3) flaps. However, abdominal bulges were more common in bilateral free TRAM reconstructions compared with unilateral free TRAM reconstructions (16% versus 4.4%, $P < 0.001$). None of the 17 patients undergoing DIEP flap reconstruction developed an abdominal bulge.[13]

Takeaways

Question: Are there best practices to consider in avoiding donor-site morbidity in deep inferior epigastric artery perforator flap breast reconstruction?

Findings: This article is an in-depth wholistic literature review of donor-site morbidity after abdominally based autologous breast reconstruction and reviews flap selection, patient factors, and technical factors that are related to donor-site morbidity. Optimized health comorbidities and limited fascial incisions seem to potentially pose the most benefit in reducing donor-site morbidity.

Meaning: There are contributions of both patient factors and technical aspects that when optimized can help minimize the risk of donor-site morbidity in deep inferior epigastric artery perforator flap breast reconstruction.

Other clinical comparisons between free TRAM and DIEP flaps following these initial reports have described differences in donor-site outcomes. Nelson et al[14] found a higher, though not statistically significant, incidence of hernia and bulge in free TRAM flaps (5.2% versus 1.0% for DIEP; $P = 0.09$) and a higher rate of immediate complications including arterial or venous thrombosis and flap loss in DIEP flaps (3.9% versus 0.0%, $P < 0.05$). Similarly, a meta-analysis observed higher hernia (3.9%) and bulge (5.9%) rates for TRAM (MS-0 to MS-2) flaps compared with DIEP (hernia 0.8%; bulge 3.1%) that approached significance ($P = 0.57$).[14]

To further evaluate the abdominal donor site, functional studies were performed to measure abdominal recovery. Uda et al[15] examined functional preoperative and postoperative abdominal strength, bulge, pain, and stiffness in MS-2 TRAM and DIEP patients. Both groups experienced reduced flexion strength at 3 months postoperatively; however, they returned to baseline by 6 months, with no significant differences in bulge or stiffness.[15] Nelson et al[16] also reported similar long-term outcomes between MS-2 TRAM and DIEP flap patients, noting that functional recovery generally returned to baseline after an initial decline, regardless of flap type or laterality.

Acknowledging differences in abdominal flap harvest techniques, the performance of prophylactic mesh with muscle harvest has been reported. Wan et al[17] found that inlay polypropylene mesh significantly reduced abdominal bulge rates in bilateral free TRAM and muscle-sparing TRAM reconstructions, achieving results comparable to DIEP (3.7%). Chang et al[18] reported that free MS-0 TRAM flap patients had higher hernia rates than MS-2 TRAM or DIEP flap patients, with mesh reinforcement reducing hernia/bulge odds by 70% compared with primary fascial closure.

Despite advances from pedicled TRAM to DIEP flaps, early reported outcome comparisons did not consistently

show differences in abdominal wall morbidity as reported in the ASPS work group in 2017.[11] Subsequent technique comparisons found only a trend favoring DIEP flaps in minimizing donor morbidity, whereas functional studies showed no significant difference based on available evidence. MS-2 TRAM and DIEP flaps had comparable morbidity in unilateral cases. Meta-analyses favored DIEP flaps over muscle-sparing and full TRAM flaps, with significant donor-site benefits evident when combining studies.[19]

PATIENT FACTORS

Recent studies have underscored the significance of patient factors in optimizing outcomes and reducing abdominal donor-site morbidity in breast reconstruction.[11,20] Historically, overall complication rates including the breast and the abdomen for free and pedicled TRAM and DIEP flaps have ranged from 24% to 49%.[4–6] Mehrara et al[21] reported a major complication rate of 7.7% in 1195 autologous breast reconstructions, with obesity (odds ratio = 3, $P < 0.01$) and neoadjuvant chemotherapy (odds ratio = 2.9) as key predictors of donor-site complications. Patient selection is important when considering abdominally based autologous breast reconstruction, as literature can suggest no significant difference in abdominal morbidity between DIEP and muscle-sparing free TRAM flaps in properly selected patients.[22,23] Patient satisfaction and function, however, can be impacted, as Stone et al[24] found using the physical well-being of the abdomen domain from the BREAST-Q. Over half of the patients undergoing flap-based reconstruction experienced a clinically significant decline in abdominal well-being postoperatively, with autologous reconstruction patients scoring lower than those who had implant-based reconstruction.[24]

Preoperative Abdominal Condition

The preoperative abdominal condition of the patient has been demonstrated to potentially impact donor-site morbidity. Kappos et al[25] used preoperative computed tomography to assess rectus muscle surface area and diastasis, finding that each 1 cm^2 increase in the area of the rectus abdominis muscle represented an 88% risk reduction in abdominal bulge/hernia formation ($P < 0.01$) and each 1-mm decrease in the interrectus muscle distance represented an 86% risk reduction ($P < 0.01$).[25] Tokumoto et al[26] reported that preoperative abdominal bulge correlated with prior pregnancies, smaller rectus muscles, and diastasis, as evidenced by patients with postoperative abdominal bulge showing significantly thinner rectus muscles (8.6 versus 10.5 mm, $P < 0.001$) and higher diastasis incidence (78.1% versus 32.3%, $P < 0.001$).[26]

Prior Abdominal Surgery

Prior abdominal surgery is linked to a higher risk of donor-site complications. Scars from previous procedures can impair blood flow, weaken fascia, and reduce tissue flexibility, leading to complications such as wound healing issues (OR = 2.3), hernia/laxity (OR = 2.5), and fat necrosis (OR = 2.0).[21,27,28] Losken et al[29] found that subcostal incisions increased donor-site complications 5-fold in pedicled TRAM flap patients. Takeishi et al[28] also reported that subcostal and multiple abdominal scars increased risks of bulge (6% versus 1.5%, $P = 0.003$), hernia/bulge (7.4% versus 2%, $P = 0.002$), and delayed wound healing (8.4% versus 1.8%, $P < 0.05$).

Age

Increasing age may impact breast-related outcomes but did not consistently impact abdominal donor-site complications. In a study by Torabi et al,[30] older patients (≥65 years) had higher rates of breast wound dehiscence but showed no differences in abdominal donor-site complications compared with younger patients. Similarly, Seidenstuecker et al[31] reported no differences in donor-site complications, including wound healing, hernia, and bulging, between patients older than and younger than 65 years of age. However, Mennie et al[32] found that patients older than 61 years of age had an increased hernia repair risk after DIEP, pedicled TRAM, or free TRAM flaps (HR = 1.73, $P < 0.05$).

Obesity

Obesity's impact on abdominal delayed wound healing and seroma formation is evident in multiple studies, but was not associated with increased rates of bulge or hernia. Ochoa et al[33] found that morbidly obese patients (body mass index [BMI] ≥ 40 kg/m^2) had increased rates of delayed wound healing but no significant differences in hernia, bulging, infection, or seroma compared with those with lower BMI. Similarly, Jandali et al[34] found that morbid obesity was associated with delayed wound healing but not hernia or bulge. However, Seidenstuecker et al[31] observed that obese patients (BMI ≥ 30 kg/m^2) were more likely to develop seroma but showed no differences in hernia, bulging, or delayed wound healing. Srinivasa et al[35] found that class II or III obesity (BMI ≥ 35 kg/m^2) was linked to higher complication rates in autologous reconstruction, although BMI did not correlate with lower BREAST-Q scores.

History of Massive Weight Loss

Weight loss history can be associated with other medically confounding conditions and elevated BMI and is often accompanied by excess skin burden. With regard to the breast free flap population, Sinik et al[36] found that patients with a history of major weight loss had increased donor-site wound healing delays and more frequent revision procedures. Major weight loss was also linked to higher complication rates at the recipient site and decreased BREAST-Q psychosocial and sexual well-being scores.[36]

Smoking

Smoking is similarly associated with poorer donor-site outcomes. Seidenstuecker et al[31] reported that active smokers experienced higher rates of donor-site complications (12% versus 4.3%, $P = 0.007$) and higher rates of donor-site delayed wound healing (6.4% versus 0.6%, $P = 0.001$). Similarly, Klasson et al[37] found that smoking correlated with a roughly doubled risk of donor-site complications in DIEP flap breast reconstruction (OR = 2.12, $P = 0.025$). On a historical note, the series by Spear et al[38] found no statistically significant differences in donor-site complications among active, former, and nonsmokers in

Table 1. Summary of Patient Factors' Contribution to Donor-site Morbidity

Patient Factors	Impacted Outcomes
Abdominal wall morbidity: diastasis recti, prior pregnancy	Bulge, hernia
Prior abdominal surgery	Bulge, wound healing
Age	None identified
BMI	Wound healing, seroma
Massive weight loss	Wound healing, revision surgery
Smoking	Wound healing

pedicled TRAM flap patients, although recipient-site complications were more common in smokers. A summary of patient factors as they relate to donor-site morbidity is represented in Table 1.

SURGICAL TECHNICAL FACTORS

As evidenced by the classification systems reported in the prior section, there are differing techniques used for harvesting abdominally based free flaps for breast reconstruction. Even within the different muscle-sparing and perforator flap designations, technical factors related to dissection and closure can significantly impact abdominal donor-site outcomes. Reported technical flap harvest variables include the laterality of harvest, length of fascial incision, perforator selection, nerve preservation, and the use of minimally invasive techniques. Aesthetically guided closure techniques, such as progressive tension sutures, are more commonly performed with the intent of improving patient satisfaction while reducing dead space.

Laterality

Bilateral reconstruction has been associated with increased abdominal morbidity compared with unilateral procedures. Allen et al[39] reviewed 405 patients, finding lower patient-reported abdominal well-being scores in bilateral reconstructions at 1, 2, and 3 years postsurgery, along with a higher risk of delayed wound healing (8.8% versus 2.1%, $P = 0.01$). However, bulge rates were comparable between bilateral and unilateral reconstructions (6.4% versus 5.1%, $P = 0.36$).[39] Atisha et al[12] showed in their 2019 study that unilateral abdominal free flap reconstruction patients had BREAST-Q abdominal well-being scores roughly 12 points higher than bilateral free flap breast reconstruction patients ($P < 0.001$).

Perforator Selection

Perforator selection is critical for balancing flap perfusion with donor-site morbidity. Garvey et al[40] hypothesized that lateral row perforators, due to their association with intercostal nerves, might increase bulge or hernia rates. In a 10-year analysis of 501 free TRAM and DIEP flaps, they found no significant differences between medial and lateral row perforators regarding donor-site complications (bulge, hernia, or delayed healing). However, muscle-sparing free TRAM flaps with medial row perforators showed a trend toward higher bulge rates compared with DIEP flaps ($P = 0.0806$).[40] Hembd et al[41] reported that medial row perforators in DIEP flaps had the lowest bulge rates ($P = 0.05$), whereas lateral row perforators minimized fat necrosis.

Fascial Incision Length

As abdominal morbidity is the result of abdominal wall dissection, musculofascial incision length has been studied extensively, comparing standard incision length, short fasciotomy, and laparoscopic and robotic techniques. A short fascial incision can be performed with dissection continued submuscularly to the takeoff of the deep inferior epigastric vessels or a shorter pedicle dissection may be used. In a cadaveric and clinical evaluation, Colohan et al[42] showed that deep inferior epigastric arterial and venous diameters demonstrated preserved vessel size to the lateral edge of the rectus and only slightly narrower at the bifurcation, supporting utilization of shorter pedicle lengths without compromising clinical outcomes.

Kim et al[43] compared "short" (fasciotomy only over intramuscular course) and standard fasciotomy in 304 patients, finding a lower bulge rate with the "short" fasciotomy with a mean length of 6.7 cm when compared with a mean length of 11.4-cm fascial incision (0.0% versus 3.3%, $P < 0.05$). Hilven et al[44] further supported this approach in a cohort of 27 patients using a limited 4-cm fascial incision, reporting fewer electromyography changes and fewer abdominal symptoms compared with standard incisions ($P = 0.005$).

Robotic and Laparoscopic Assistance

Robotic and laparoscopic techniques have shown promise in reducing anterior rectus sheath and muscle dissection as the extramuscular portion of the dissection can be used in either an intra- or extraperitoneal plane, lessening the amount of muscle division. Selber[45] pioneered robotic DIEP harvest, limiting fascial disruption to the pedicle exit site. Chang Gung University compared robotic with conventional DIEP flaps, finding shorter fascial incisions in the robotic group (2.67 cm versus 8.14 cm, $P < 0.001$) and also found no differences among the cohorts in flap loss, length of stay, or postoperative pain.[46] Additionally, Choi et al[47] reported that a single-port robotic system enabled a completely extraperitoneal approach, potentially shortening the learning curve.

Delay procedures have been used to enlarge a selected inferior epigastric perforator without significant intramuscular course to improve candidacy for laparoscopic techniques. Shakir et al[48] used a laparoscopic approach for 57 DIEP flaps after initial flap delay, achieving mean fascial incisions of 2.0 cm, with 60% of patients recovering without narcotics and an average hospital stay of 2.5 days. However, 2 flaps sustained pedicle injuries requiring additional anastomoses.[48]

Superficial Inferior Epigastric Artery Flap

The superficial inferior epigastric artery (SIEA) flap avoids fascial incisions entirely by using the superficial system, helping reduce donor-site morbidity. Park et al[49] reviewed 119 patients (145 flaps), reporting a 0% rate of hernia or bulge, though flap loss (4.8%) and fat necrosis (10%) rates were relatively high when compared with the reported performance of the DIEP flap. Wu et al[50] found that unilateral SIEA flap patients scored higher on postoperative lifting ability, and those with bilateral SIEA flaps

Table 2. Summary of Technical Factors' Contribution to Donor-site Morbidity

Intervention	Rate of Bulge, %	Notable Benefits or Requirements
Standard fascial incision DIEP flap	3.3–6	• Wide exposure, increased visibility during pedicle dissection
Short fascial incision DIEP flap	0–2	• Fewer large electromyography changes • Decreased incidence of abdominal tingling, spasms, or abnormal sensations
Laparoscopic-assisted or robotic-assisted DIEP flap	0	• Reduced rectus sheath and muscle dissection • Potentially advantageous in high-risk patient populations • Requires resources and expertise
Alternative flaps (SIEA)	0	• Improved postoperative functional status • Increased seroma risk, increased flap loss rate, and increased fat necrosis

showed better outcomes in functional surveys. Erdmann-Sager et al,[51] using the Mastectomy Reconstruction Outcomes Consortium, a prospective, multicenter cohort study that examines outcomes in common breast reconstruction, noted lower hernia/bulge rates in SIEA flaps compared with DIEP flaps (0.0% versus 1.7%), but higher seroma (30.7%) and wound (27.4%) rates.

Abdominal Closure Techniques

Advancements in abdominal closure techniques help minimize donor-site morbidity while improving donor-site aesthetics. The addition of superficial fascial system closure to the abdominal closure did not improve healing outcomes or aesthetic evaluation in a comparison of 103 cases with and without superficial fascial system closure.[52] Visconti et al[53] adapted the "CALP" technique—cannula-assisted limited undermining and progressive high-tension sutures—showing reduced seroma rates and improved skin sensibility with better abdominal scar quality ($P = 0.002$), though satisfaction scores for abdominal appearance were similar to traditional closure techniques. In 2016 Eom et al[54] introduced the concept of a low DIEP flap, using a lower incision concealed by underwear, suited for small to moderate breast sizes and indicated when perforators are located more than 4 cm below the umbilicus on preoperative imaging. A summary of technical factors as they relate to donor-site morbidity is represented in Table 2.

SUMMARY

Surgical innovation has brought autologous breast reconstruction from pedicled TRAM flaps to short incision perforator flaps with minimal muscular dissection. Comparisons of DIEP and muscle-sparing TRAM flaps have varying accounts of abdominal wall morbidity. Smoking, obesity, and massive weight loss portend abdominal delayed wound healing, whereas prior abdominal surgery, pregnancy, and diastasis are associated with an increased rate of bulge. Data on perforator location are conflicting, except for the SIEA flap in patients with suitable superficial anatomy. However, the SIEA flap as an alternative to the DIEP flap is associated with increased donor-site seroma and flap loss. Shorter length fascial incisions can be 2–3 cm involving only the anterior fascia above the arcuate line and may pose the most significant technical maneuver to minimize hernia or bulge with or without robotic/laparoscopic assistance. Robust, highly powered studies evaluating abdominal wall morbidity after short fascial incision abdominal free flap harvest will be important forthcoming contributions to this topic of study.

CONCLUSIONS

This review highlights key factors influencing donor-site morbidity in abdominally based autologous breast reconstruction. Patient-specific factors such as BMI, smoking, and prior abdominal surgery significantly impact outcomes, as do surgical techniques such as perforator selection, fascial incision length, and minimally invasive approaches such as robot-assisted and laparoscopic-assisted techniques. These findings underscore the importance of individualized patient assessment and technique refinement to optimize both functional and aesthetic results in breast reconstruction.

Robert G. DeVito, MD
Department of Plastic Surgery, Maxillofacial and Oral Health
University of Virginia
Charlottesville, VA
E-mail: znm9gq@uvahealth.org

DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

REFERENCES

1. American Society of Plastic Surgeons. 2023 Plastic Surgery Statistics. Available at https://www.plasticsurgery.org/news/plastic-surgery-statistics. January 1, 2024. Accessed August 5, 2024.
2. Tanna N, Sultan DL, Minasian RA, et al. Contemporary microsurgical breast reconstruction: abdominally based flaps. *Plast Reconstr Surg*. 2024;154:199e–214e.
3. Campbell CA, Losken A. Understanding the evidence and improving outcomes with implant-based prepectoral breast reconstruction. *Plast Reconstr Surg*. 2021;148:437e–450e.
4. Carlson GW, Losken A, Moore B, et al. Results of immediate breast reconstruction after skin-sparing mastectomy. *Ann Plast Surg*. 2001;46:222–228.
5. Chang EI. Latest advancements in autologous breast reconstruction. *Plast Reconstr Surg*. 2021;147:111e–122e.
6. Hartrampf CR, Scheflan M, Black PW. Breast reconstruction with a transverse abdominal island flap. *Plast Reconstr Surg*. 1982;69:216–225.
7. Elliott LF, Beegle PH, Jr, Hartrampf CR, Jr, et al. Breast reconstruction following mastectomy: an update. *J Med Assoc Ga*. 1991;80:607–615.
8. Allen RJ, Treece P. Deep inferior epigastric perforator flap for breast reconstruction. *Ann Plast Surg*. 1994;32:32–38.
9. Knox ADC, Ho AL, Leung L, et al. Comparison of outcomes following autologous breast reconstruction using the DIEP and pedicled TRAM flaps: a 12-year clinical retrospective study and literature review. *Plast Reconstr Surg*. 2016;138:16–28.

10. Shubinets V, Fox JP, Sarik JR, et al. Surgically treated hernia following abdominally based autologous breast reconstruction: prevalence, outcomes, and expenditures. *Plast Reconstr Surg.* 2016;137:749–757.
11. Lee BT, Agarwal JP, Ascherman JA, et al. Evidence-based clinical practice guideline: autologous breast reconstruction with DIEP or pedicled TRAM abdominal flaps. *Plast Reconstr Surg.* 2017;140:651e–664e.
12. Atisha DM, Tessiatore KM, Rushing CN, et al. A national snapshot of patient-reported outcomes comparing types of abdominal flaps for breast reconstruction. *Plast Reconstr Surg.* 2019;143:667–677.
13. Nahabedian MY, Momen B, Galdino G, et al. Breast reconstruction with the free TRAM or DIEP flap: patient selection, choice of flap, and outcome. *Plast Reconstr Surg.* 2002;110:466–475; discussion 476.
14. Nelson JA, Guo Y, Sonnad SS, et al. A comparison between DIEP and muscle-sparing free TRAM flaps in breast reconstruction: a single surgeon's recent experience. *Plast Reconstr Surg.* 2010;126:1428–1435.
15. Uda H, Kamochi H, Sarukawa S, et al. Clinical and quantitative isokinetic comparison of abdominal morbidity and dynamics following DIEP versus muscle-sparing free TRAM flap breast reconstruction. *Plast Reconstr Surg.* 2017;140:1101–1109.
16. Nelson JA, Tecci MG, Lanni MA, et al. Function and strength after free abdominally based breast reconstruction: a 10-year follow-up. *Plast Reconstr Surg.* 2019;143:22e–31e.
17. Wan DC, Tseng CY, Anderson-Dam J, et al. Inclusion of mesh in donor-site repair of free TRAM and muscle-sparing free TRAM flaps yields rates of abdominal complications comparable to those of DIEP flap reconstruction. *Plast Reconstr Surg.* 2010;126:367–374.
18. Chang EI, Chang EI, Soto-Miranda MA, et al. Comprehensive analysis of donor-site morbidity in abdominally based free flap breast reconstruction. *Plast Reconstr Surg.* 2013;132:1383–1391.
19. Man LX, Selber JC, Serletti JM. Abdominal wall following free TRAM or DIEP flap reconstruction: a meta-analysis and critical review. *Plast Reconstr Surg.* 2009;124:752–764.
20. Kroll SS, Baldwin B. A comparison of outcomes using three different methods of breast reconstruction. *Plast Reconstr Surg.* 1992;90:455–462.
21. Mehrara BJ, Santoro TD, Arcilla E, et al. Complications after microvascular breast reconstruction: experience with 1195 flaps. *Plast Reconstr Surg.* 2006;118:1100–1109.
22. Schusterman M, Kroll SS, Miller MJ, et al. The free transverse rectus abdominus musculocutaneous flap for breast reconstruction: one center's experience with 211 consecutive cases. *Ann Plast Surg.* 1994;32:234.
23. Watterson PA, Bostwick J III, Hester TR, Jr, et al. TRAM flap anatomy correlated with a 10-year clinical experience with 556 patients. *Plast Reconstr Surg.* 1995;95:1185–1194.
24. Stone JP, Bello RJ, Siotos C, et al. Patient-related risk factors for worsened abdominal well-being after autologous breast reconstruction. *Plast Reconstr Surg.* 2020;145:475e–480e.
25. Kappos EA, Jaskolka J, Butler K, et al. Preoperative computed tomographic angiogram measurement of abdominal muscles is a valuable risk assessment for bulge formation after microsurgical abdominal free flap breast reconstruction. *Plast Reconstr Surg.* 2017;140:170–177.
26. Tokumoto H, Akita S, Kubota Y, et al. Relationship between preoperative abdominal wall strength and bulging at the abdominal free flap donor site for breast reconstruction. *Plast Reconstr Surg.* 2022;149:279e–286e.
27. Roostaeian J, Yoon AP, Sanchez IS, et al. The effect of prior abdominal surgery on abdominally based free flaps in breast reconstruction. *Plast Reconstr Surg.* 2014;133:247e–255e.
28. Takeishi M, Shaw WW, Ahn CY, et al. TRAM flaps in patients with abdominal scars. *Plast Reconstr Surg.* 1997;99:713–722.
29. Losken A, Carlson GW, Jones GE, et al. Importance of right subcostal incisions in patients undergoing TRAM flap breast reconstruction. *Ann Plast Surg.* 2002;49:115–119.
30. Torabi R, Stalder MW, Tessler O, et al. Assessing age as a risk factor for complications in autologous breast reconstruction. *Plast Reconstr Surg.* 2018;142:840e–846e.
31. Seidenstuecker K, Munder B, Mahajan AL, et al. Morbidity of microsurgical breast reconstruction in patients with comorbid conditions. *Plast Reconstr Surg.* 2011;127:1086–1092.
32. Mennie JC, Mohanna PN, O'Donoghue JM, et al. Donor-site hernia repair in abdominal flap breast reconstruction: a population-based cohort study of 7929 patients. *Plast Reconstr Surg.* 2015;136:1–9.
33. Ochoa O, Chrysopoulo M, Nastala C, et al. Abdominal wall stability and flap complications after deep inferior epigastric perforator flap breast reconstruction: does body mass index make a difference? Analysis of 418 patients and 639 flaps. *Plast Reconstr Surg.* 2012;130:21e–33e.
34. Jandali S, Nelson JA, Sonnad SS, et al. Breast reconstruction with free tissue transfer from the abdomen in the morbidly obese. *Plast Reconstr Surg.* 2011;127:2206–2213.
35. Srinivasa DR, Clemens MW, Qi J, et al. Obesity and breast reconstruction: complications and patient-reported outcomes in a multicenter, prospective study. *Plast Reconstr Surg.* 2020;145:481e–490e.
36. Sinik LM, Elver AA, Egan KG, et al. Autologous breast reconstruction after massive weight loss: understanding risks in a growing population. *Plast Reconstr Surg.* 2023;152:503–512.
37. Klasson S, Nyman J, Svensson H, et al. Smoking increases donor site complications in breast reconstruction with DIEP flap. *J Plast Surg Hand Surg.* 2016;50:331–335.
38. Spear SL, Ducic I, Cuoco F, et al. The effect of smoking on flap and donor-site complications in pedicled TRAM breast reconstruction. *Plast Reconstr Surg.* 2005;116:1873–1880.
39. Allen RJ, Jr, Sobti N, Patel AR, et al. Laterality and patient-reported outcomes following autologous breast reconstruction with free abdominal tissue: an 8-year examination of BREAST-Q data. *Plast Reconstr Surg.* 2020;146:964–975.
40. Garvey PB, Salavati S, Feng L, et al. Abdominal donor-site outcomes for medial versus lateral deep inferior epigastric artery branch perforator harvest. *Plast Reconstr Surg.* 2011;127:2198–2205.
41. Hembd A, Teotia SS, Zhu H, et al. Optimizing perforator selection: a multivariable analysis of predictors for fat necrosis and abdominal morbidity in DIEP flap breast reconstruction. *Plast Reconstr Surg.* 2018;142:583–592.
42. Colohan S, Maia M, Langevin CJ, et al. The short- and ultrashort-pedicle deep inferior epigastric artery perforator flap in breast reconstruction. *Plast Reconstr Surg.* 2012;129:331–340.
43. Kim J, Lee KT, Mun GH. Short fasciotomy-deep inferior epigastric perforator flap harvest for breast reconstruction. *Plast Reconstr Surg.* 2023;152:972e–984e.
44. Hilven PH, Vandevoort M, Bruyninckx F, et al. Limiting the fascia incision length in a DIEP flap: repercussion on abdominal wall morbidity. *J Plast Reconstr Aesthet Surg.* 2022;75:1108–1116.
45. Selber JC. The robotic DIEP flap. *Plast Reconstr Surg.* 2020;145:340–343.
46. Tsai CY, Kim BS, Kuo WL, et al. Novel port placement in robot-assisted DIEP flap harvest improves visibility and bilateral DIEP access: early controlled cohort study. *Plast Reconstr Surg.* 2023;152:590e–595e.
47. Choi JH, Song SY, Park HS, et al. Robotic DIEP flap harvest through a totally extraperitoneal approach using a single-port surgical robotic system. *Plast Reconstr Surg.* 2021;148:304–307.

48. Shakir S, Spencer AB, Kozak GM, et al. Laparoscopically assisted DIEP flap harvest minimizes fascial incision in autologous breast reconstruction. *Plast Reconstr Surg*. 2020;146:265e–275e.
49. Park JE, Shenaq DS, Silva AK, et al. Breast reconstruction with SIEA flaps: a single-institution experience with 145 free flaps. *Plast Reconstr Surg*. 2016;137:1682–1689.
50. Wu LC, Bajaj A, Chang DW, et al. Comparison of donor-site morbidity of SIEA, DIEP, and muscle-sparing TRAM flaps for breast reconstruction. *Plast Reconstr Surg*. 2008;122:702–709.
51. Erdmann-Sager J, Wilkins EG, Pusic AL, et al. Complications and patient-reported outcomes after abdominally based breast reconstruction: results of the Mastectomy Reconstruction Outcomes Consortium Study. *Plast Reconstr Surg*. 2018;141:271–281.
52. Johnson AC, King BBT, Colakoglu S, et al. The influence of closing the abdominal donor-site superficial fascial system in deep inferior epigastric perforator flap breast reconstruction. *Plast Reconstr Surg*. 2021;148:357e–364e.
53. Visconti G, Tomaselli F, Monda A, et al. Deep inferior epigastric artery perforator flap donor-site closure with cannula-assisted, limited undermining, and progressive high-tension sutures versus standard abdominoplasty: complications, sensitivity, and cosmetic outcomes. *Plast Reconstr Surg*. 2015;135:1–12.
54. Eom JS, Kim DY, Kim EK, et al. The low DIEP flap: an enhancement to the abdominal donor site. *Plast Reconstr Surg*. 2016;137:7e–13e.