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Characterizing Outcomes of Medial and Lateral Perforators in Deep Inferior Epigastric Perforator Flaps

Ashlie A. Elver, BS[1] Stephanie A. Matthews, BS[1] Katie G. Egan, MD[1] Eva L. Bowles, BS[1] Niaman Nazir, MD, MPH[2] Mitchell Flurry, MD[3] Julie Holding, MD[1] Eric C. Lai, MD, FACS[1] James A. Butterworth, MBBCh, FACS[1]

[1] Department of Plastic Surgery, University of Kansas Medical Center, Kansas City, Kansas
[2] Department of Population Health, University of Kansas Medical Center, Kansas City, Kansas
[3] Plastic & Cosmetic Surgery, Ascension Medical Group, Wichita, Kansas

Address for correspondence James A. Butterworth, MBBCh, FACS, 4000 Cambridge Blvd Mailstop 3015, Kansas City, KS 66160 (e-mail: jbutterworth@kumc.edu).

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Abstract

Background Perforators are typically found in rows in the deep inferior epigastric perforator (DIEP) flap. As methods to assess flap perfusion continue to improve, surgeons may be more likely to select perforators traditionally avoided. The purpose of this article is to describe clinical outcomes based on row and number of perforators to reevaluate flap and abdominal donor site morbidity.

Methods A retrospective analysis was performed on patients who underwent breast reconstruction with DIEP flaps by four microsurgeons from 2013 to 2020. The row and number of perforators were determined from operative reports. Chi-square and *t*-test or nonparametric Fisher's exact test and Wilcoxon two-sample test were used for discrete and continuous variable, respectively, as applicable. Logistic regression was used for multivariable analyses.

Results Of 628 flaps, 305 were medial row (58.7%), 159 were lateral row (30.6%), and 55 had both rows (10.6%). Partial flap loss was higher in both rows ($p = 0.003$). Fat necrosis was higher with medial ($p = 0.03$) and both rows ($p = 0.01$) when compared with lateral using multivariable analysis. Hernia or bulge was higher in lateral row flaps (lateral: 8/157, 5.1%; medial, 5/299, 1.7%; both, 0/55; $p = 0.05$); however, mesh was more commonly used in both row flaps ($p = 0.05$). There was no difference in fat necrosis or abdominal morbidity between single and multiple perforators.

Conclusion There was no difference in fat necrosis based on the number or row of perforators. The lateral row provides adequate perfusion but may be associated with an elevated risk of hernia or bulge. Patients may benefit from mesh, especially when both rows are dissected.

Keywords
- fat necrosis
- abdominal wall
- perforator flap
- autologous reconstruction

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The deep inferior epigastric perforator (DIEP) flap is commonly used in breast reconstruction and is based on the perforating branches of the deep inferior epigastric artery (DIEA). Selecting perforators is a balance of achieving adequate perfusion while minimizing abdominal wall morbidity from the dissection. The location and number of perforators is commonly discussed as a topic for microsurgical optimization.

Perforator location is related to branch patterns described by Moon and Taylor of the DIEA coursing within the rectus sheath superior to the arcuate line. Type I branch patterns contain a single medial trunk, which is always present. Type II branching patterns are most commonly found, where the DIEA bifurcates into a medial and lateral trunk. Rarely, the DIEA will trifurcate as a type III branching pattern.[1] Medial or lateral row perforators correspond to the originating trunk. Although technically an easier dissection due to a shorter intramuscular course,[2] the lateral row is traditionally avoided to prevent abdominal wall morbidity related to its anatomical proximity to motor nerves supplying the abdominal wall.[3–7] On the other hand, recent data suggests the lateral row confers a benefit to decrease fat necrosis, with one author recommending the addition of lateral perforators to medial-based flaps.[8,9]

Advancing methods to assess perfusion will allow a more precise selection of the optimal perforator. For this reason, surgeons may be interested in venturing away from strict algorithms and selecting perforators traditionally avoided. The purpose of this article is to describe clinical outcomes based on the number and row of perforators selected. The primary outcomes will examine flap morbidity, including fat necrosis, as well as abdominal donor site morbidity based on perforator row. The secondary outcome will examine outcomes based on the number of perforators. We aim to reevaluate existing ideas in the literature and provide clinical insight for surgeons to utilize when selecting optimal perforators.

Methods

Following approval by the institutional review board, a retrospective chart review was conducted on patients who underwent autologous breast reconstruction with DIEP flaps at an academic center from 2013 to 2020. Data was collected from the electronic medical record and stored using REDCap (Research Electronic Data Capture) tools hosted by the study institution.[10] Unilateral and bilateral hemi-abdominal flaps by four fellowship trained microsurgeons were reviewed. Information regarding number and location of perforators was extracted from description in the operative reports. Records with missing documentation were excluded from respective analyses. Perforator location was determined to be medial row, lateral row, or both. Perforator utilization from a mid or type III branch was rarely encountered in analysis and were excluded. The total number of perforators harvested per hemi-abdominal side was recorded.

Demographics assessed were age, body mass index (BMI), smoking status, and history of chemotherapy. The timing of immediate or delayed reconstruction was noted. Operative duration was compared between groups and in a subanalysis of unilateral and bilateral reconstructions. Injury to the pedicle requiring repair during flap harvest was noted. Difficult donor dissection was defined as a clear statement by surgeon dictation that dissection was more technically difficult than would be expected. Synthetic mesh is not routinely used at the study institution and is used by discretion of the surgeon. In cases with concerns for fascial weakness or with BMI > 35 kg/m^2, macroporous polypropylene mesh was placed in an underlay fashion. Patients were evaluated preoperatively with computed tomography angiography. Fluorescent angiography was routinely used intraoperatively to aid in perforator selection by evaluation after isolation of planned dominant perforator(s). Based upon the results of fluorescent angiography, planned perforators/rows may be adjusted or additional perforators may be added. Final perforator selection was made intraoperatively based on the surgeon's clinical judgment.

Postoperative variables included length of stay (LOS) and acute complications before discharge including flap arterial thrombosis, venous congestion, hematoma, partial or total flap loss, and return to the operating room (OR). Partial flap loss was defined as a portion of the flap remaining viable.

Late complications occurred after discharge and were collected in from review of clinic documentation and subsequent procedure notes. Flap-related complications were delayed wound healing, fat necrosis, seroma, and partial flap loss. Fat necrosis was documented through clinical exam or imaging. Bulge or hernia at the abdominal donor site was recorded by evidence on abdominal exam or identified on imaging.

Data management and statistical analyses were performed using SAS software (version 9.4) (Copyright (c) 2002–2012 by SAS Institute Inc., Cary, NC. All Rights Reserved). Categorical variables were summarized with percentages and continuous variables were summarized by means and standard deviations. Instances where 50% of the cells had expected counts of less than 5, Fisher's exact test was used to make global comparisons of categorical continuous variables across groups. Analysis of variance and independent samples *t*-test were used to compare means of continuous variables across groups and if the data were skewed, nonparametric Wilcoxon two-sample test was used to compare medians across groups. Multivariable logistic regression models were run for outcome of interest controlling for independent variables. Two-sided *p*-values less than 0.05 were considered statistically significant.

Results

Perforator Row

There were 628 DIEP flaps, 519 were included for analysis of anatomical perforator row. There were 305 flaps with medial row (58.7%), 159 flaps with lateral row (30.6%), and 55 flaps with both rows (10.6%). There was no difference in demographic variables including age ($p = 0.25$), BMI ($p = 0.35$), smoking status ($p = 0.83$), and history of chemotherapy ($p = 0.65$) (►**Table 1**).

Table 1 Patient characteristics

	Medial row N = 305	Lateral row N = 159	Medial and lateral N = 55	*p*-Value
Demographics	**Mean (SD)**			
Age, y	50 (10.6)	49.4 (10.3)	52.2 (9.3)	0.25
BMI, kg/m^2	30.6 (4.9)	31.4 (5.1)	31 (5)	0.35
	***n* (%)**			
Nonsmokers	197 (65)	101 (63.5)	39 (70.9)	0.83
History of chemotherapy	185 (61.1)	102 (65)	32 (59.3)	0.65
Operative variables	**Mean (SD)**			
Operative duration	512.2 (130.4)	537 (128.4)	524.6 (111)	0.26
No. of veins	1.3 (0.5)	1.1 (0.4)	1.2 (0.4)	0.05[a]
	***n* (%)**			
Difficult donor dissection	21 (6.9)	18 (11.3)	9 (16.4)	0.05[a]
Donor pedicle injury	7 (2.3)	2 (1.3)	1 (1.8)	0.90
Mesh	14 (4.6)	9 (5.7)	7 (13)	0.05[a]

Abbreviations: BMI, body mass index; SD, standard deviation.
[a]$p \leq 0.05$.

Operative Variables

There was no difference in operative duration ($p = 0.26$). This was maintained when comparing unilateral ($p = 0.55$) and bilateral reconstructions ($p = 0.96$) alone between groups. Timing of reconstruction (immediate vs. delayed) was not statistically different between groups ($p = 0.28$). Difficult donor dissections were more common when both rows were harvested (9/55, 16.4%, $p = 0.05$) compared with when only the medial (21/305, 6.9%) or lateral row was harvested (18/159, 11.3%). There was no difference in donor pedicle injuries ($p = 0.90$). The number of veins per hemi-abdomen side was higher in medial row flaps (mean 1.3 ± 0.5; $p = 0.05$) than lateral row flaps (mean 1.1 ± 0.4). Surgeons were less likely to use single vessel lateral row flaps (medial: 58.9% single vessel; lateral 44.7% single vessel; $p < 0.001$) and more likely to include two perforators ($p < 0.001$). Synthetic mesh was used more commonly in flaps with both rows (7/55, 3%; $p = 0.05$) compared with the medial (14/305, 4.6%) and lateral rows (9/159, 5.7%).

Acute complications

In the acute period, there was no difference between groups in rate of arterial thrombosis ($p = 0.63$), venous congestion ($p = 0.37$), flap hematoma ($p = 0.21$), returns to the OR ($p = 0.42$), or early partial or total flap loss ($p = 1.0$). LOS was significantly longer in lateral row flaps (mean 4.6 ± 2.6; $p = 0.01$) compared with medial row flaps (mean 4.1 ± 1.4) (►**Table 2**).

Late Complications

The lowest rate of fat necrosis was in lateral row flaps (20/159, 12.6%) compared with medial row (55/305, 18%) and both rows (13/55, 23.6%). With logistic regression models predicting fat necrosis using BMI, perforator row, perforator number, unilateral/bilateral reconstruction, number of veins, reconstruction timing, and operative duration as independent variables, the odds of fat necrosis were significantly higher in medial row flaps (odds ratio [OR] 2.0, 95% confidence interval [CI] 1.1–3.7, $p = 0.03$) and flaps with both rows (OR 3.1, 95% CI 1.3–7.6, $p = 0.01$). Fat necrosis was also significantly associated with BMI of 30 to 35 (OR 3.3, 95% CI 1.1–9.5, $p = 0.03$) and BMI > 35 (OR 6.9, 95% CI 2.3–20.5, $p < 0.001$). Partial flap losses were significantly higher in both rows (5/55, 9.1%; $p < 0.003$) compared with medial row (4/305, 1.3%) and lateral row (1/159, 0.6%). There was no difference in delayed wound healing ($p = 0.49$) or flap seromas ($p = 0.32$). Hernia or bulge was higher in the lateral row (8/159, 5.1%; $p = 0.05$) compared with medial row (5/305, 1.7%). There were no occurrences of hernia in both row flaps; however, mesh was used more commonly in this group. The primary outcomes are displayed in ►**Fig. 1**.

Number of Perforators

There were 233 single perforator flaps (47.8%) and 254 multiple perforator flaps (52.2%). There were no differences in demographic variables.

Operative Variables

Operative duration was significantly higher in multiple perforator flaps (multiple: mean 529.7 ± 114; single: mean 496.9 ± 130.7; $p = 0.004$); however, significance was not maintained in isolated comparisons of unilateral ($p = 0.47$) and bilateral reconstructions ($p = 0.50$). There was no difference in difficult donor dissections ($p = 0.12$), donor pedicle injuries ($p = 0.90$), or number of veins used per hemi-abdomen ($p = 0.46$). Synthetic mesh was used similarly in both groups ($p = 0.11$).

Acute Complications

There were no differences in venous congestion ($p = 0.88$), arterial thrombosis ($p = 0.06$), flap hematomas ($p = 0.57$), or

Table 2 Complications

	Medial row $N = 305$	Lateral row $N = 159$	Medial and lateral $N = 55$	*p*-Value
Acute complications	**Mean (SD)**			
LOS, d	4.1 (1.4)	4.6 (2.6)	4.1 (1.2)	0.01[a]
	***n* (%)**			
Flap venous congestion	9 (3)	2 (1.3)	2 (3.6)	0.37
Flap arterial thrombosis	3 (1)	1 (0.6)	1 (1.8)	0.63
Flap site hematoma	9 (3)	4 (2.5)	4 (7.3)	0.21
Return to operating room	32 (10.5)	11 (6.9)	6 (10.9)	0.42
Early partial or total flap loss	3 (1)	2 (1.3)	0	1.0
Late complications	***n* (%)**			
Fat necrosis	55 (18)	20 (12.6)	13 (23.6)	0.13
Partial flap loss	4 (1.3)	1 (0.6)	5 (9.1)	0.003[a]
Delayed flap wound healing	24 (7.9)	10 (6.3)	2 (3.6)	0.49
Flap seroma	10 (3.3)	9 (5.7)	1 (1.8)	0.32
Hernia or bulge	5 (1.7)	8 (5.1)	0	0.05[a]

Abbreviations: LOS, length of stay; SD, standard deviation.
[a]$p \leq 0.05$.

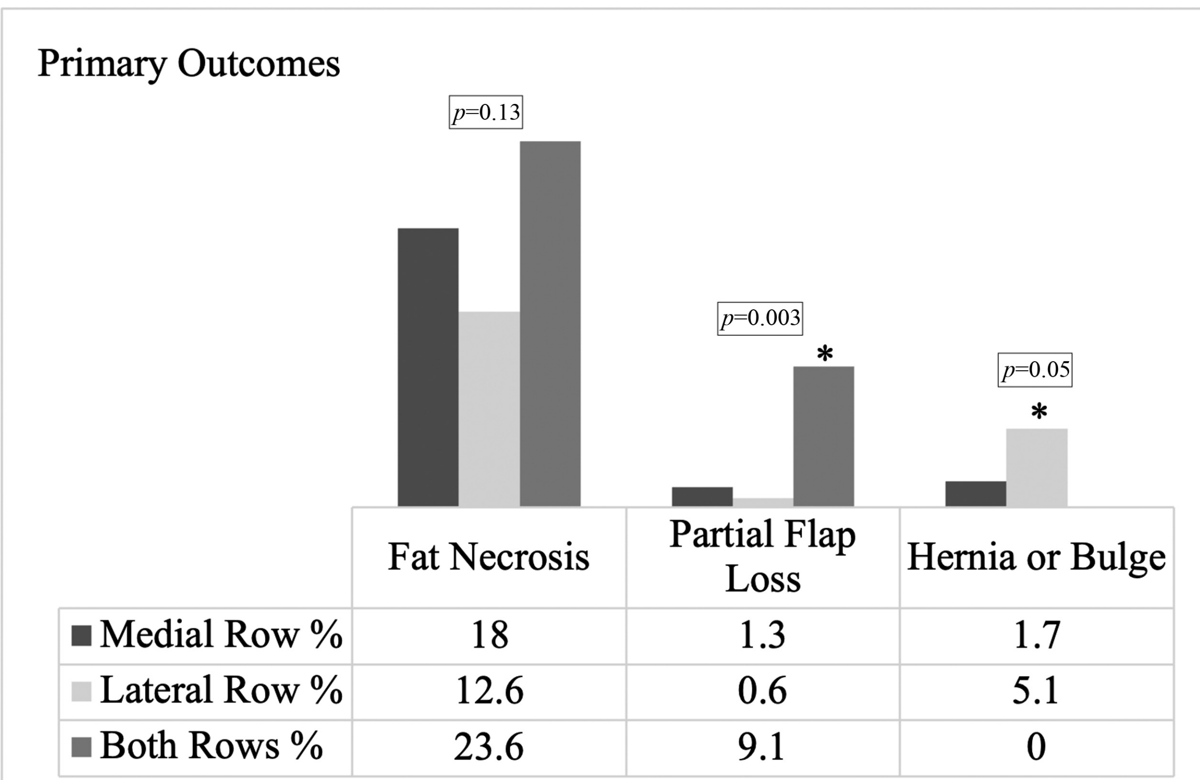

Fig. 1 The incidence of primary outcomes in 305 medial row flaps, 159 lateral row flaps, and 55 flaps with both rows. There was no difference in rate of fat necrosis. Partial flap loss was significantly higher in flaps with both rows. Abdominal morbidity was significantly higher in lateral row flaps.

early flap loss ($p = 0.35$). There was a trend toward higher returns to the OR when multiple perforators were used (30/254, 11.8%) compared with single perforators (18/233, 7.7%; $p = 0.13$). There was no difference in LOS ($p = 0.78$).

Late Complications

There was no difference in rate of delayed wound healing ($p = 0.66$), flap seroma ($p = 0.36$), fat necrosis (single: 18.5%; multiple: 16.1%; $p = 0.50$), or partial flap losses (single: 1.3%;

multiple: 2.8%; $p = 0.34$). Hernia or bulge occurred in 3.5% of single perforator flaps (8/228) and in 2% of multiple perforator flaps (5/251) and was not statistically significant ($p = 0.31$). This was maintained in a subgroup analysis comparing 1, 2, 3, and > 4 perforators ($p = 0.63$).

Discussion

Recent studies advocate for the use of lateral row perforators to reduce fat necrosis. Kamali et al reviewed 728 DIEP hemi flaps and showed significantly higher fat necrosis in medial row flaps compared with lateral row flaps, as well as when compared with both rows. The authors suggested adding a lateral perforator to medial-based flaps.[8] Similarly, Hembd et al showed in a multivariate analysis of 409 DIEP flaps the lateral row independently decreased odds of fat necrosis.[9] In our study, although not significant, lateral row flaps had the lowest rate of fat necrosis. The rate of partial flap loss was also lowest in the lateral row and doubled in medial row flaps. Benefits were not seen in both row flaps which had the highest rate of fat necrosis and significantly higher partial flap losses. Both row flaps were rarely performed in this study population, and a second row may have been added due to intraoperative concerns about flap perfusion or viability.

While the lateral row may be advantageous, important considerations of abdominal wall morbidity must be addressed. The lateral row is in close proximity to motor nerves supplying the abdominal wall; this anatomic relationship is well established.[4,5,7] These nerves are at risk for denervation from dissection and harvest is associated with abdominal laxity postoperatively.[3] Conflicting data are reported regarding the true significance of developing hernia or bulge. Garvey et al reported no difference in hernia or bulge rates of the lateral row in a retrospective analysis of 617 abdominal flaps.[11] This study included muscle-sparing free transverse rectus abdominis musculocutaneous (ms-TRAM) flaps, which may confound the advantage of reduced abdominal morbidity caused by structural disruption with DIEP flap harvest.[12] In an analysis of only DIEP flaps, Hembd et al reported 3.2 times higher odds of abdominal bulge in lateral row flaps compared with the medial row.[9] Similarly, we found a trend toward higher rates of hernia or bulge associated with the lateral row. This is a notable finding to elucidate the suspected risk of dissecting the lateral row. ►**Fig. 2** displays the tradeoff between improved perfusion and abdominal wall morbidity in lateral row flaps.

Although Kamali et al recommend adding lateral perforators to medial-based flaps to improve perfusion, they do not report the incidence of hernia or bulge. There are two reasons patients have a higher likelihood to develop hernia or bulge when both rows are dissected. The first is denervation by the lateral row, and the second is structural disruption from dissection across the muscle. We were unable to reproduce perfusion benefits in flaps with both rows, which had the highest rate of fat necrosis and significantly more partial flap loss, likely related to intrinsic flap perfusion abnormalities. Other authors have expressed concerns related to higher complications rates seen in flaps with both rows.[13] Therefore, the authors recommend limiting the use of both rows only when necessary for concerns of flap viability or perfusion, given the risk for abdominal morbidity. Obesity has been reported as an independent risk factor for flap complications such as fat necrosis.[14] Our multivariable analysis supported these findings and revealed higher odds of fat necrosis with BMI of greater than 30. Perfusion may also be affected by previous abdominal surgeries, which have been shown to increase risk of fat necrosis and was not evaluated in the current study.[15,16]

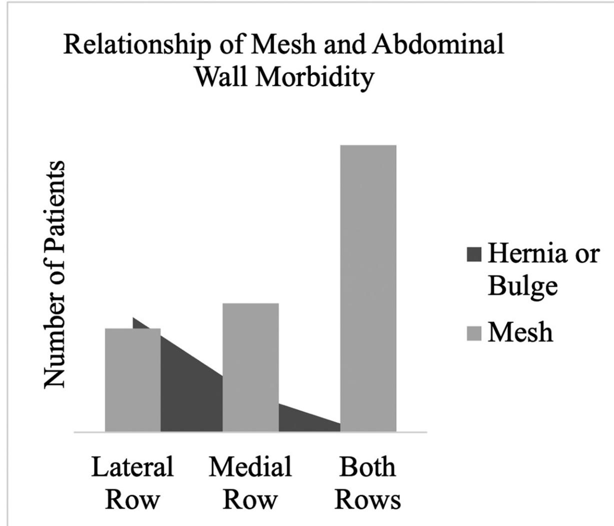

Fig. 2 The number of patients who experienced fat necrosis and abdominal hernia or bulge in 305 medial row flaps and 159 lateral row flaps.

The use of mesh in patients with elevated risk for hernia or bulge should be considered. In our study, the use of mesh may have decreased the risk of hernia or bulge when used appropriately in high-risk patients. Although expected to have the highest risk of hernia or bulge, there were zero occurrences reported when both rows were harvested. This group had the statistically highest rate of prophylactic mesh placement. This trend is displayed in ►**Fig. 3**. Further prospective research is needed to evaluate patient selection and outcomes following donor site mesh placement. Others have found use for mesh in ms-TRAM flaps to reduce abdominal morbidity equivalent to DIEP flaps.[17] Further exploration of the utility of mesh in lateral or both row flaps may help prevent patients from incurring donor site morbidity. Another strategy to mitigate abdominal morbidity is using abdominal perforator exchange flaps. In this technique, full rectus preservation is accomplished by using pedicle disassembly and vascular rerouting to create desired anatomy.[18] Our institution recently initiated this technique but was not included in the study sample and thus not evaluated in this study.

The role of the number of perforators and the relationship to fat necrosis is debated in the literature. While some conclude more perforators are protective against fat necrosis, most studies fail to produce convincing evidence based on statistically significant data.[9,13,19–22] Our study found no

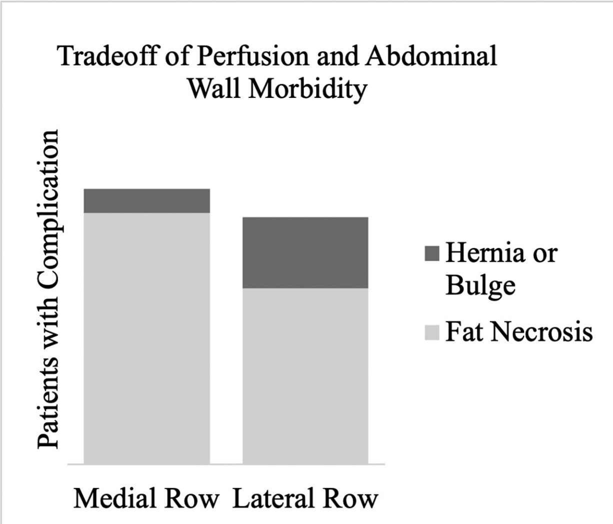

Fig. 3 The use of mesh is overlayed with the incidence of hernia or bulge in 305 medial row flaps, 159 lateral row flaps, and 55 flaps with both rows. A trend of decreasing abdominal complications is seen with increased use of mesh.

difference in the rate of fat necrosis, partial flap loss, or abdominal morbidity between single and multiple perforators.

Many emphasize the importance of vessel caliber and palpable pulse instead of using more perforators to improve perfusion.[13,23] In fact, Mohan et al describes a stepwise approach to improve surgeon confidence to select single-perforator flaps.[13] We found surgeons were less likely to have single-vessel flaps with the lateral row. Garvey et al also found surgeons harvested more perforators from the lateral row.[21] This may be related to its vertical course, allowing dissection of more perforators without damaging the muscle. There may be potential drawbacks to including more perforators even if easily accessed. The importance of vessel caliber is supported by Poiseuille's law which has a more significant effect on flow than adding additional perforators. Additionally, higher filling pressures recruit linking vessels and is reduced when more vessels are added.[24] We found trends of higher arterial thrombosis and more unplanned returns to the OR when multiple perforators were used compared with single vessels. The evidence does not strongly support fat necrosis benefits based on the number of perforators alone, and thus the minimal number of perforators demonstrating satisfactory perfusion should be selected.

This study was limited by retrospective design and generalizability may be limited to high-volume academic centers. Indocyanine green-based fluorescent angiography is shown to decrease fat necrosis significantly and was used intraoperatively at this institution.[9,25–27] Perforator selection is widely variable and dependent on subjective intraoperative judgment impossible to assess in a retrospective study. We could not assess vessel caliber, perforator location, flap weight, and pedicle length, which influence perforator selection. Our analysis and conclusions drawn related to hernia and abdominal wall morbidity are limited by the retrospective nature and low number of reported hernias. Information regarding nerve preservation was not collected in this study and may have affected morbidity. However, the purpose of this article was not to influence existing algorithms for selection but to provide clinical insight for the surgeon's intended selection.

Conclusion

Strict algorithms for selecting perforators based on row or number of perforators are less relevant as methods to assess perfusion continue to advance, and decisions should instead be based on a balance of optimizing perfusion and maximizing flap and donor site outcomes. There is no difference in fat necrosis based on the number or row of perforators. Surgeons should be aware of the possibility of an elevated risk for abdominal wall morbidity that may be associated with the lateral row. More research is needed to fully elucidate this risk and strategies for mitigation.

Conflict of Interest
None declared.

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