Revisiting Anastomosis to the Retrograde Internal Mammary System in Stacked Free Flap Breast Reconstruction: An Algorithmic Approach to Recipient-Site Selection

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Background: The authors present their stacked flap breast reconstruction experience to facilitate selection of either caudal internal mammary vessels or intraflap vessels for the second recipient anastomosis.

Methods: A retrospective review was conducted of multiflap breast reconstructions (double-pedicled deep inferior epigastric perforator, stacked profunda artery perforator, and stacked profunda artery perforator/deep inferior epigastric perforator) performed at the authors' institution from 2011 to 2018. Data collected included demographics, recipient vessels used, and intraoperative/postoperative flap complications. Complications were compared between cranial, caudal, and intraflap anastomoses.

Results: Four hundred stacked flaps were performed in 153 patients. Of 400 arterial anastomoses, 200 (50 percent) were to cranial internal mammary vessels, 141 (35.3 percent) were to caudal internal mammary vessels, and 59 (14.8 percent) were to intraflap vessels. Of 435 venous anastomoses, 145 (33.3 percent) were to caudal internal mammary vessels, 201 (46.2 percent) were to cranial internal mammary vessels, and 89 (20.5 percent) were to intraflap vessels. Intraoperative revision for thrombosis occurred in 12 of 141 caudal (8.5 percent), 14 of 20 cranial (7 percent), and seven of 59 intraflap (11.9 percent) arterial anastomoses ($p = 0.373$), and in none of caudal, three of 201 cranial (1.5 percent), and two of 89 intraflap (2.2 percent) venous anastomoses ($p = 0.559$). Postoperative anastomotic complications occurred in 12 of 400 flaps (3 percent) and were exclusively attributable to venous compromise; seven of 12 (58.3 percent) were salvaged, and five of 12 (41.7 percent) were lost. More lost flaps were caused by caudal [four of five (80 percent)] versus cranial [one of five (20 percent)] or intraflap (zero of five) thrombosis ($p = 0.020$).

Conclusion: If vessel features are equivalent between the caudal internal mammary vessels and intraflap vessels, intraflap vessels should be used for second site anastomosis in stacked flap reconstructions. (*Plast. Reconstr. Surg.* 145: 880, 2020.)

CLINICAL QUESTION/LEVEL OF EVIDENCE: Therapeutic, III.

The use of stacked flaps has expanded the reconstructive options for patients with either insufficient abdominal tissue to achieve adequate volume or abdominal scarring.[1–9] In contrast to single-pedicle reconstructions, where the cranial internal mammary vessels are most commonly used as a recipient site, the stacked flaps require a second anastomosis. The thoracodorsal vessels are an option as a second recipient site[4] but are less frequently used because of the additional dissection field needed and increased difficulty of flap inset.[6,10,11] The caudal internal mammary vessels[6,8,10,12–15] and the intraflap vasculature[4,7,9,11,16] are both commonly

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used as second recipient sites. Larger scale studies that detail anastomotic complications and provide guidance as to second recipient vessel selection strategy are lacking. Only one study looking at 25 deep inferior epigastric perforator (DIEP) flaps performed in a double-pedicled fashion (50 arterial anastomoses) provided an algorithm to guide decision-making between intraflap anastomosis and extraflap anastomosis using caudal internal mammary vessels by looking at pedicle configuration and internal mammary vessel anatomy.[17]

We seek to further clarify the choice between caudal internal mammary vessels and intraflap vessels as second recipient sites by presenting the largest series published to date on our multiflap experience for breast reconstruction. We detail and compare intraoperative and postoperative anastomotic complications and their management between anastomotic types, describe inset techniques to minimize anastomotic complications, and analyze whether the presence of risk factors that specifically affect the internal mammary vessels increase the risk of anastomotic complications with their use compared with use of intraflap vasculature.

PATIENTS AND METHODS

After institutional review board approval, a retrospective review of a prospectively collected database of all free flap breast reconstructions performed at the University of Texas Southwestern from January of 2011 to October of 2018 by the two senior surgeons was conducted. Data were collected for all multiflap patients [double-pedicled DIEP flaps, stacked profunda artery perforator (PAP) flaps, and stacked PAP/DIEP flaps] and included patient demographics, history of prereconstruction radiation therapy and expander complications, left versus right breast reconstruction, flap type, recipient vessels used for anastomosis, donor-recipient vessel mismatch, and all intraoperative and postoperative flap complications. Factors that specifically affect the internal mammary vessels and potentially increase the risk of anastomotic compromise with their use (versus use of the intraflap vasculature) were defined according to the existing literature as follows:

1. Preoperative radiation therapy to the chest wall.
2. Preoperative tissue expander complication requiring return to the operating room or intravenous antibiotics.
3. Left internal mammary vessels as recipients.
4. Presence of donor/recipient vessel mismatch over 50 percent.

The internal mammary vessels were exposed to allow for cranial/caudal anastomoses by partial removal of the third rib cartilage and all intercostal musculature between the second and fourth ribs.[18] All arterial anastomoses were hand-sewn, and all venous anastomoses were performed using a venous coupler. For each breast, one flap was always anastomosed to the cranial internal mammary vessels, and the caudal internal mammary vessels or the intraflap vasculature were used as the second anastomotic site. Direct vessel inspection, vessel caliber (≥1 mm for arteries and ≥2 mm for veins), vessel quality (presence of delamination or friable vessel), vessel flow (spurt test), and donor-recipient vessel size match were factors considered when deciding between caudal internal mammary vessels and intraflap vessels. For all flap dissections, the side branches (either PAP or DIEP) and the cranial extension of the pedicle (DIEP) were examined and preserved if suitable as a potential "intraflap" second recipient site for anastomosis.

Complication rates of cranial, caudal, and intraflap anastomoses were compared using IBM SPSS (IBM Corp., Armonk, N.Y.). The binary dependent variables were analyzed using chi-square tests, and the continuous dependent variables were analyzed using univariate analysis of variance. For all statistical tests, values of $p < 0.05$ were considered significant. Multivariable analysis was attempted, but because of the rarity of flap complications, we were unable to estimate the association between outcomes of interest and the independent variables.

RESULTS

A total of 400 free flaps (400 arterial anastomoses) were performed in a multiflap fashion using the internal mammary vessels as at least one recipient site in 153 patients from 2011 to 2018 by the authors. Of these flaps, 198 of 400 (49.5 percent) were combined as double-pedicled (DIEP/DIEP or DIEP/superficial inferior epigastric artery), 168 of 400 (42 percent) as stacked DIEP/PAP flaps, and 34 of 400 (8.5 percent) as stacked PAP flaps. There were no differences in patient comorbidities between groups (Table 1). Stacked DIEP/PAP flap patients had a higher rate of previous tissue expander placement compared with the double-pedicled DIEP group, but there were no differences in history of tissue expander complications between groups (Table 1). To determine whether experience bias impacted our results, we looked at the number of intraoperative

Table 1. Patient Demographics

Characteristic	Double-Pedicled DIEP/DIEP (%)	Stacked DIEP/PAP (%)	Stacked PAPs (%)	SIEA (%)*	*p*
No. of patients	82	42	17	17	
Mean age, yr	54.79	49.07	51.12	57.18	0.005†
Mean BMI, kg/m^2	27.23	27.48	26.45	28.49	0.281
Active smoking	27/82 (33)	14/42 (33)	4/17 (24)	5/17 (29)	0.879
Diabetes mellitus	6/82 (7)	3/42 (7)	0/17 (0)	2/17 (12)	0.594
Coagulopathy	0/82 (0)	1/42 (2)	0/17 (0)	1/17 (6)	0.205
Radiation therapy	48/82 (58)	26/42 (61)	10/17 (59)	4/17 (24)	0.044‡
Previous tissue expander	46/82 (56)	39/42 (93)	12/17 (71)	11/17 (65)	0.001§
Previous tissue expander complication	18/46 (39)	10/39 (26)	3/12 (25)	4/11 (36)	0.543

SIEA, superficial inferior epigastric artery; BMI, body mass index.
*DIEP/SIEA, SIEA/SIEA, and PAP/SIEA.
†SIEA patients significantly older than stacked DIEP/PAP patients.
‡SIEA significantly lower rates of radiation therapy compared with other groups.
§Stacked DIEP/PAP patients had a significantly higher rate of previous tissue expansion than double-pedicle DIEP patients.

(p = 0.177) and postoperative anastomotic complications (p = 0.565) requiring revision per year from 2011 to 2018 and found no significant difference. Of the 400 arterial anastomoses, 200 of 400 (50 percent) were to the cranial internal mammary artery, 141 of 400 (35.3 percent) were to the caudal internal mammary artery, and 59 of 400 (14.8 percent) were parasitic to the dominant flap by means of intraflap anastomoses. There were 435 venous anastomoses performed for the 400 flaps. Of these, 145 of 435 (33.3 percent) were to the caudal internal mammary vein, 201 of 435 (46.2 percent) were to the cranial internal mammary vein, and 89 of 435 (20.5 percent) were to the intraflap veins. We do not routinely supercharge our flaps, and the additional 35 veins were primarily used in the context of intraflap anastomoses (26 of 35), where the additional vena comitans is added if of appropriate caliber to counter twisting at the anastomosis.

Intraoperative Anastomotic Compromise

Intraoperative arterial events (thrombosis or avulsion) requiring intervention occurred in 36 of 400 of all arterial anastomoses (9 percent) and did not significantly differ between groups, where specifically 12 of 141 caudal anastomoses (8.5 percent), 14 of 200 cranial anastomoses (7 percent), and seven of 59 intraflap anastomoses (11.9 percent) required intraoperative revision for thrombosis (p = 0.373) (Table 2). Intraoperative venous events requiring intervention (thrombosis or avulsion) occurred in eight of 435 venous anastomoses (1.8 percent). Of these, five required revision for thrombosis [caudal anastomoses, 0 percent; cranial anastomoses, three of 201 (1.5 percent); intraflap anastomoses, two of 89 (2.2 percent); p = 0.559]. On univariate analysis, the only predictor for an intraoperative event was use of the intraflap artery and vein. All flaps were salvaged intraoperatively. For nine of 12 thrombosed arterial caudal anastomoses (75 percent), salvage was achieved by redoing the original anastomosis; in two of 12 (16.7 percent), the recipient vessel was converted to an intraflap anastomosis, and in one of 12 (8.3 percent), an interpositional graft was added. For the thrombosed arterial cranial anastomoses, 13 of 14 (92.9 percent) were salvaged by redoing the original anastomosis, with the remaining one of 14 (7.1 percent) salvaged by conversion to intraflap anastomosis. All arterial intraflap anastomoses were salvaged by redoing the original anastomosis. For salvage of the two thrombosed cranial veins, one was simply redone, and one was redone and supercharged with anastomosis to the caudal internal mammary vein. For salvage of the

Table 2. Intraoperative and Postoperative Anastomotic Complications

Location of Thrombus	Intraoperative Arterial Thrombus (%)	Intraoperative Venous Thrombus (%)	No. of Flaps Lost Intraoperatively (%)	Postoperative Arterial Thrombus (%)	Postoperative Venous Thrombus (%)	No. of Flaps Lost Postoperatively (%)
Cranial internal mammary vessels	14/201 (7%)	3/204 (1.5)	0	0	4/204 (2)	1/204 (0.5)
Caudal internal mammary vessels	12/142 (8.5)	0	0	0	6/147 (4.1)	4/147 (2.7)
Intraflap*	7/60 (11.7)	2/92 (2.2)	0	0	1/92 (1.1)	0
p	0.373	0.559	n/a	n/a	0.283	0.077

*Cranial extension of DIEP pedicle or side branch of DIEP or PAP pedicle.

thrombosed intraflap veins, one was redone, and the other was converted to the caudal internal mammary vein with the use of an interpositional graft. There were three avulsions (both arterial and venous) that occurred intraoperatively, where one intraflap anastomosis was avulsed on transfer to the chest and the other on inset, and one caudal anastomosis was avulsed on inset. All were repaired without further compromise.

Postoperative Flap Compromise

Postoperative flap compromise requiring emergent return to the operating room occurred in 12 of all 400 flaps (3 percent), where specifically six of 200 cranial flaps (3 percent), five of 141 caudal flaps (3.5 percent), and one of 59 intraflap flaps (1.7 percent) had complications ($p = 0.778$). Of these complications, 11 of 12 (91.7 percent) were attributable to venous compromise: four of 201 cranial veins (2 percent), six of 145 caudal veins (4.1 percent), and one of 89 intraflap veins (1.1 percent) ($p = 0.283$); one of 12 (8.3 percent) was attributable to a hematoma (Table 2). Of the compromised flaps, seven of 12 (58.3 percent) were salvaged by redoing the anastomosis or repositioning the pedicle, and five of 12 (41.7 percent) were lost despite attempted salvage with thrombectomy and tissue plasminogen activator. The majority of flap losses were attributable to the caudal vein [four of five (80 percent)] rather than the cranial [one of five (20 percent)] or intraflap vein (zero of five); however, this did not reach significance, likely because of the rarity of postoperative flap loss.

Subgroup Analysis

For the most common multiflap configurations (double-pedicled DIEP/DIEP and stacked DIEP/PAP), intraoperative and postoperative anastomotic complications were analyzed by subgroup. Within both the double-pedicled DIEP/DIEP and stacked DIEP/PAP subgroup, there were no differences in intraoperative or postoperative arterial or venous compromise between the different anastomotic configurations (Tables 3 and 4).

Internal Mammary Vessel Risk Factor Analysis

Of the flaps anastomosed to the internal mammary vessels (341 of 400 arterial anastomoses, 336 of 435 venous anastomoses), 143 of 341 arteries (41.9 percent) and 146 of 336 veins (43.5 percent) were anastomosed to irradiated internal mammary vessels. Arteries and veins that were irradiated had equivalent rates of intraoperative complications when compared to nonirradiated arteries ($p = 0.279$) and veins ($p = 0.674$). Donor-recipient mismatch of over 50 percent was present

Table 3. Double-Pedicled DIEP/DIEP Anastomotic Complications

Double-Pedicled DIEP/DIEP Anastomotic Configuration	No. of Double-Pedicled Flaps	Intraoperative Arterial Thrombus (%)	Intraoperative Venous Thrombus (%)	No. of Flaps Lost Intraoperatively	Postoperative Arterial Thrombus	Postoperative Venous Thrombus (%)	No. of Flaps Lost Postoperatively
Cranial*/caudal*	47	9/94 (9.6)	0/104 (0)	0	0	1/104 (1)	0
Cranial*/intraflap†	34	6/68 (8.8)	2/88 (2.3)	0	0	0	0
p		0.871	0.122	n/a	n/a	0.356	n/a

n/a, not applicable.
*Internal mammary vessels.
†Cranial extension or side branch of DIEP pedicle.

Table 4. Stacked DIEP/PAP Anastomotic Complications

Stacked DIEP/PAP Anastomotic Configuration	No. of Stacked Flaps	Intraoperative Arterial Thrombus (%)	Intraoperative Venous Thrombus	No. of Flaps Lost Intraoperatively	Postoperative Arterial Thrombus	Postoperative Venous Thrombus (%)	No. of Individual Flaps Lost Postoperatively (%)
DIEP cranial*/PAP caudal*	46	7/92 (7.6)	0	0	0	4/92 (4.3)	2/92 (2.2)
DIEP caudal*/PAP cranial*	29	2/58 (3.4)	0	0	0	1/60 (1.7)	1/92 (1.1)
DIEP cranial*/PAP intraflap†	7	1/14 (7.1)	0	0	0	0	0
DIEP intraflap†/PAP cranial*	1	0%	0	0	0	0	0
p		0.742	n/a	n/a	n/a	0.695	0.937

n/a, not applicable.
*Internal mammary vessels.
†Cranial extension of DIEP pedicle or side branch of DIEP or PAP pedicle.

in 104 of 341 arterial anastomoses (30.5 percent), and had equivalent rates of intraoperative arterial complications [seven of 104 (7 percent)] when compared to flaps without mismatched vessels [29 of 296 (9.8 percent); $p = 0.361$]. Of the flaps anastomosed to the internal mammary vessels, 61 of 34 arteries (117.9 percent) and 61 of 336 veins (18.2 percent) had a history of an overlying tissue expander complication requiring return to the operating room or intravenous antibiotics, but had equivalent rates of intraoperative events [10 of 61 (16 percent)] compared with those without a history of tissue expander complications [22 of 178 (12 percent); $p = 0.425$]. There was no difference in intraoperative venous complications between left anastomoses [four of 435 (0.9 percent)] and right anastomoses [three of 435 (0.7 percent); $p = 0.486$].

We looked at the number of risk factors for anastomotic complications present for caudal ($n = 142$) versus intraflap anastomoses ($n = 60$) to determine whether increased risk factors for internal mammary vessel use swayed the authors toward intraflap anastomosis. There was no difference between number of risk factors present for caudal internal mammary vessel anastomoses versus intraflap vessel anastomoses (average caudal risk factors, 1.61; average intraflap risk factors, 1.52; $p = 0.498$). There was no difference in the average number of risk factors when comparing flaps without any postoperative events to those with postoperative events (average risk factors, 1.57 for no postoperative events and 2 for postoperative events; $p = 0.306$), and those without intraoperative events to those with intraoperative events (average risk factors, 1.61 for no intraoperative events and 1.36 for postoperative events; $p = 0.233$).

DISCUSSION

As autologous breast reconstruction evolves, stacked or bipedicled flaps are being used for certain patients to optimize breast volume and aesthetic outcome. Despite recent publications touting the reliability of the caudal internal mammary vessels for second-site anastomosis,[10,12,13,17] their use is not without difficulties because of the quality of the retrograde blood flow and added inset challenges, and may lead to increased flap loss and salvage procedures.[14,19] These issues lead to the consideration of intraflap anastomosis as an alternative, and the pros and cons of intraflap versus extraflap (cranial-caudal internal mammary vessels) anastomosis have been described.[4,17] "Extraflap" anastomosis allows independent perfusion to both flaps and ensures that anastomotic problems in one system do not lead to loss of both flaps. Intraflap anastomosis permits cranial, antegrade flow exclusively; however, the reliance on one main source vessel can lead to both flaps failing should issues arise in one.

To determine the high-risk situations for internal mammary vessel use where the benefits of intraflap anastomosis may be increased, we looked to the literature surrounding anastomotic site failure risk factors.[20–26] Las et al.[21] demonstrated that preoperative radiation therapy increased the risk for flap loss nearly 3-fold, and intraoperative revision of the anastomosis increased the odds of partial flap loss 6-fold. In addition, Fracol et al.[27] compared irradiated and nonirradiated breast reconstructions and noted a statistically significant increase in intraoperative vascular complications and need for anastomotic revision in the irradiated breast. Chang et al.[25] demonstrated a significantly smaller internal mammary vein on the left compared with the right, accompanied by a significant increase in venous thrombosis on the left compared with the right side. The use of two-stage autologous breast reconstruction, with a tissue expander placed at the time of the mastectomy, followed by free flap reconstruction after expansion is routinely performed at our institution to preserve the skin envelope.[28,29] The use of expanders leads to a 5-fold increase in scarring and fibrosis surrounding the recipient vessels compared with patients without a tissue expander.[30] If expander insertion is complicated by a seroma or cellulitis, despite salvage of the expander with the use of antibiotics, the additional inflammatory process leads to increased fibrosis surrounding the recipient vessels.[30]

Despite evidence that these risk factors could increase anastomotic complications with the use of the internal mammary vessels, we did not find a difference in the number of risk factors in patients who had internal mammary vessel complications, nor did we note an increased number of risk factors for internal mammary vessel use in patients who had intraflap vessels rather than caudal internal mammary vessels used as recipients for the second flap. Although these risk factors are known to often negatively impact the internal mammary vessel quality, they do not always, and given that their presence alone did not seem to impact anastomotic complications in our study, direct vessel examination likely remains the most important aspect in recipient-site selection.

Intraoperative complications occurred in 8 percent of arterial anastomoses and 1 percent of venous anastomoses, demonstrating the increased complexity of multiflap procedures. Thoughtful sequencing of the case is crucial to the success of these cases. We use a cosurgeon model, which allows ongoing flap dissection as microsurgical anastomosis of the other flap(s) are performed. When faced with second-site arterial compromise, we will attempt one repeated anastomosis but will convert to the alternative (intraflap or caudal vasculature) if available, as repeated attempts at revision of the same anastomosis lead to prolonged ischemia and reperfusion times and ultimately increases in flap loss.[31,32] This technique has yielded high success rates, with all 33 thrombosed arteries successfully salvaged intraoperatively, without need for conversion to the thoracodorsal system. For the venous anastomoses, we note that pedicle position plays a crucial role in preventing venous compromise. The 1 percent of intraoperative venous anastomoses requiring repeated anastomosis does not represent the undocumented venous issues related to pedicle compression that often occur at the time of flap inset and are immediately addressed by pedicle and flap repositioning. When using the cranial and caudal internal mammary vessels, we anastomose the pedicles of the stacked flaps in a crossed fashion, where the flap used for the inferior pole of the breast is anastomosed to the cranial internal mammary vessels and the flap used for the superior pole is anastomosed to the caudal internal mammary vessels (Fig. 1). When using the intraflap vasculature as the second site of anastomosis, preference between use of the cranial extension versus the side branches of the pedicle was based, first, on the best quality vessels, and second, on which offered the most suitable flap positioning for anastomosis and inset (Fig. 2).

To address the kink that occurs as the pedicle leaves the site of anastomosis to lie on the chest wall, we routinely create a trough in the pectoralis major muscle and place a fat graft under the pedicle to ease its transition. This is thought to be especially important in the irradiated chest, where the rigid, noncompliant chest wall and musculature seems to increase pressure on the pedicle. Although the attending surgeons are those most intimately involved in flap inset, to avoid avulsion of an anastomosis in these multiflap procedures, clear communication to all scrubbed team members is required advising caution when manipulating the flap at every moment following completion of the initial anastomosis. To further reduce the risk of avulsion, when necessary, we sew flaps into their folded position to remove tension off of the anastomosis, and perform the majority of deepithelialization before initial flap inset to reduce any subsequent flap manipulation.

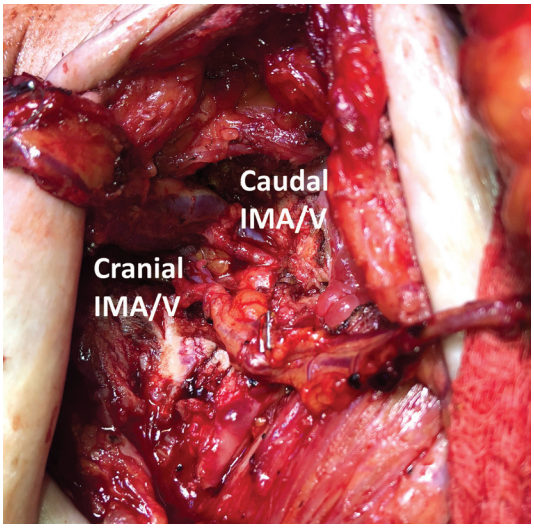

Fig. 1. Cranial/caudal internal mammary vessel anastomotic configuration. *IMA/V*, internal mammary artery/vein.

Fig. 2. Cranial internal mammary vessel/intraflap anastomotic configuration. *IMA/V*, internal mammary artery/vein.

In contrast to the intraoperative vascular events that were primarily attributable to arterial compromise (83.7 percent), postoperative anastomotic issues were exclusively attributable to venous compromise. Caudal venous anastomosis as a secondary recipient site had a higher chance of leading to postoperative venous thrombus and flap loss. Studies have demonstrated that caudal

flow is adequate for flap perfusion,[12–14] and we agree, believing that the postoperative venous issues are more likely attributable to flap and pedicle positioning, with compression and kinking of the caudal vein occurring in response to postoperative swelling and inferior pedicle migration as the patient moves. We speculate that the position of the intraflap anastomosis is at decreased risk for venous kink and compression compared with the position of the caudal anastomosis. In addition to the inset maneuvers described above, we ensure that the inset is not too tight to allow for postoperative swelling and have begun to use surgical bras, ensuring placement is snug at the inframammary fold but slightly loose over the remainder of the flap to counteract inferior flap migration and compression of the caudal anastomosis postoperatively.

This study confirms that both the caudal internal mammary vessels and the intraflap vessels are good options for secondary recipient anastomosis, and is the first large-scale series that demonstrates an increased incidence of intraoperative vascular events using the intraflap vessels along with a trend toward increases in postoperative flap loss using the caudal internal mammary vein. Given the higher flap loss rate using the caudal internal mammary vessels, we now use the intraflap vessels as the first-line option in the absence of significant differences between caudal and intraflap vessel characteristics. A limitation of this study is the retrospective nature of the review, which leads to lack of certain intraoperative details such as pedicle compression necessitating varied inset attempts and key decision-making features for recipient vessel selection that would not have been documented in the operative note.

CONCLUSIONS

The caudal internal mammary vessels and the intraflap vessels are both viable options for second-site anastomosis in stacked flap procedures. Use of the intraflap vessels leads to more intraoperative issues, but use of the caudal internal mammary vein potentially leads to increased postoperative flap loss. Direct vessel observation for quality, caliber, size match, and flow are the most important considerations for recipient-site selection.

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