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ORIGINAL ARTICLE

Breast

Evidence-based Algorithms for Free Deep Inferior Epigastric Perforator Flap Salvage in Autologous Breast Reconstruction

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Background: Breast reconstruction with the deep inferior epigastric perforator (DIEP) free flap has become the gold standard for autologous breast reconstruction. Flap take-back to the operating room (OR) is an uncommon but difficult situation, requiring prompt and accessible resources. We conducted a literature review and independent expert review to inform evidence-based perioperative algorithms in the event of DIEP flap compromise.

Methods: A review of the literature was conducted, including MEDLINE, Embase, Google Scholar, and Cochrane Controlled Register of Trials. Publications examining free flap re-exploration in breast reconstruction were used to inform evidence-based clinical algorithms. The algorithms then underwent expert review and revisions from 6 international experts in microsurgery.

Results: Three evidence-based management algorithms were created. The first algorithm outlines perioperative management strategies to optimize patient care and prompt return to the OR. Nonconstricting flap inset after take-back, salvage medical strategies and postoperative management following flap failure were additionally included. Algorithms 2 (venous congestion) and 3 (vascular thrombosis) provide specific intraoperative strategies surrounding mechanical decompression, pedicle exposure, assessment and extraction of thrombosis, identification and use of alternative recipient vessels, and the usage of intraoperative thrombolytics.

Conclusions: A coherent and stepwise approach to DIEP flap compromise in breast reconstruction was developed. These expert-reviewed algorithms provide an approachable and evidence-based structure to support return to the OR and serve as readily available resources. *(Plast Reconstr Surg Glob Open 2025; 13:e6477; doi: 10.1097/GOX.0000000000006477; Published online 21 January 2025.)*

INTRODUCTION

Postoperative free flap compromise is an infrequent and challenging complication of microvascular breast reconstruction that requires a prompt, systematic response.[1–10] Free flap failure, or total flap loss, is reported at approximately 1%–3% in large microsurgical centers.[4,5,8,10–16] Venous compromise is the most common cause of return to operating room (OR).[4,5,17–21] After return to the OR, salvage rates reported in the literature range widely.[8,10,12–14,22] Timely surgical intervention and number of surgical attempts are significant contributors to successful flap salvage.[10,13–15,23] In addition to being uncommon, urgent take-back procedures are technically difficult, stressful, and highly variable. Readily available resources to guide these procedures are invaluable, particularly in early career stages.

Stepwise approaches to free flap salvage have been previously published, although most are reflective of surgeon or institution experience and practice patterns. We performed a literature review to create an evidence-based, accessible tool to support timely intervention in free flap compromise and direct perioperative management. This review aimed to (1) examine critical opinion and literature on free flap salvage, (2) identify and review existing

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salvage protocols, and (3) propose a systematic approach to breast free flap compromise from initial bedside assessment to intraoperative decision-making.

METHODS

A comprehensive search of MEDLINE (Ovid SP), Embase (Ovid SP), Google Scholar, and Cochrane Controlled Register of Trials (1946 to December 2023) was conducted. A combination of MeSH terms and free text were used. A manual search of references screened for relevance and inclusion (Fig. 1). Articles were included if they described management strategies to free flap compromise in autologous breast reconstruction, including observational studies, cohort studies, case reports, reviews, letters, and studies in which breast cases comprised a portion of the sample size. Inclusion criteria identified English studies utilizing free transverse rectus abdominis myocutaneous, deep inferior epigastric perforator (DIEP), and superficial inferior epigastric artery perforator (SIEA) flaps.

Studies were excluded if they focused only on rates of flap compromise, algorithms guiding flap selection, preventative measures to avoid flap compromise, or studies without breast reconstruction (ie, solely focused on head and neck or lower extremity flap reconstruction).

Three reviewers (A.R.T., M.A., and K.S.) performed the search of title and abstract, and selection of abstracts after deletion of duplicates. The full text of each relevant article was reviewed for final inclusion. We identified 94 studies examining vascular compromise in free flap breast reconstruction. Data were abstracted to populate flow sheets on perioperative management, and organized using Microsoft Excel for Mac 2020, version 16.44. The specific management approaches reviewed included identification of flap compromise, preoperative management, use of imaging or clinical adjuncts, consultations, venous augmentation technique, intraoperative decision points, novel surgical technique, alternate vessel selection, use of thrombolytics, indications, and dosage and administration method. Due to heterogeneity of study protocols and outcome data, statistical meta-analysis of the data was not possible. Instead, qualitative and descriptive analyses were performed; for quantitative values such as medication dosing, we provided a range of outcomes. Data were organized thematically based on presentation (venous congestion, vascular thrombosis) and abstracted to inform our stepwise algorithms (Figs. 2–4).

The algorithms provided a stepwise approach assuming the use of the internal mammary system as the initial recipient vessels.

The draft algorithms were presented to 6 experts who had previous academic, clinical, or fellowship experience in the topic. They represented various national and international institutions in an effort to recognize differences in practice patterns. They provided individualized feedback and input in a series of in person sessions. The expert panel commented on ease of use and accessibility of the algorithms, as well as content. Feedback was consolidated and reviewed, and the algorithms were modified based on this feedback.

Takeaways

Question: Surgeons performing breast reconstruction require stepwise, easily accessible resources to reference in the event of free flap compromise.

Finding: A review of the literature and expert consultation was used to create three evidence-based algorithms that include stepwise guidance to (1) the perioperative management in flap take-back, (2) approach to venous congestion, and (3) vascular thrombosis in autologous breast flap reconstruction.

Meaning: These expert-reviewed algorithms provide an approachable and evidence-based structure to support return to the operating room and serve as readily available resources.

RESULTS

Perioperative Management

Perioperative management and early detection of flap compromise is paramount to successful flap salvage. Clinical assessment of color, turgor, temperature, capillary refill, and Doppler signal may indicate the etiology of flap compromise even before surgical re-exploration.[16] Hand-held Doppler is commonly used at bedside, typically hourly within the initial 24 hour postoperative period.[16,25]

Free flap take-back procedures should be initiated immediately following identification of flap compromise. Nil per os status and time from the last dose of anticoagulant medication should be noted. Assessment of patient clinical status must be examined, including vital signs and hemodynamic stability, and basic laboratory values (complete blood count, platelets, electrolytes, type/group and screen).[25] Systemic factors should be controlled to prevent further vasospasm, such as maintaining normal blood pressure, euvolemia, and euthermia.[8,10] Attention must be paid to patient positioning and dressings; sutures and flap inset should be examined to ensure that they are not excessively tight or causing vascular constriction or compression. The goal of bedside measures is to address reversible causes, minimize further propagation of tissue injury, and optimize the patient while preparing for prompt operative exploration.

Once identified, patient consent must be completed and return to the OR should be organized within the hour as timely intervention is critical to successful salvage.[12,14,15,25–28] Consent will include re-exploration, possible vein graft, debridement, possible flap removal and closure (primary, negative pressure dressing, skin graft, or local flap). Preoperative discussions with anesthesia and other consulting services, if needed, should be initiated.

Upon return to the OR, the entire flap, pocket, and pedicle course are methodically examined.[10,18,22,29] Warm saline irrigation and gentle evacuation of hematoma, if present, should be performed. All points of bleeding, compression, torsion or kinking should be addressed.[9,17,18] There may be areas of compression from the surrounding tissue which may be released by further dissecting the vessels from the intercostal muscles, resecting rib cartilage,

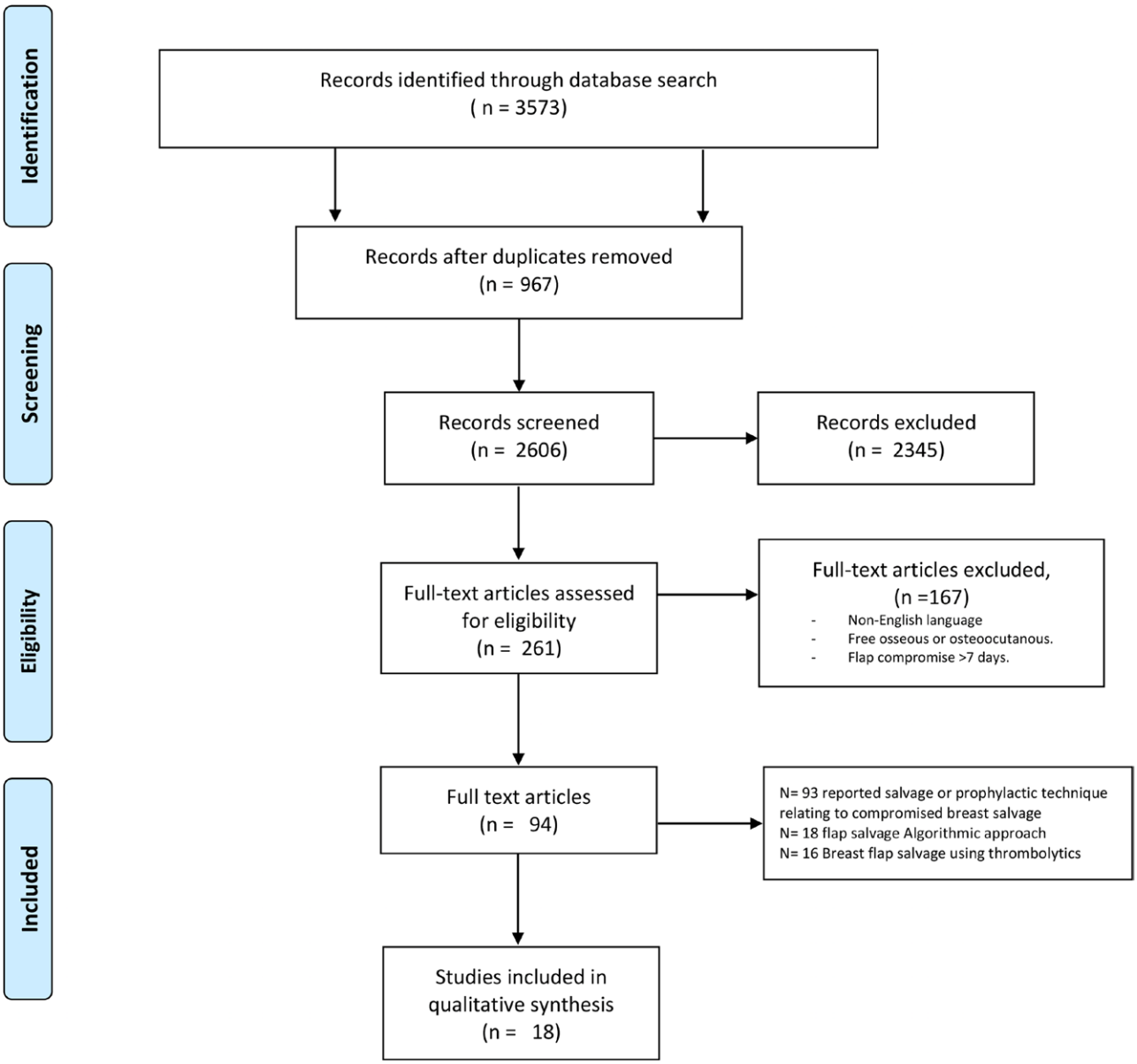

Fig. 1. PRISMA diagram.[24]

and releasing the medial insertion of pectoralis major.[17] Flap bulk can be trimmed to reduce the venous burden.

If these initial measures beget improvement, the flap can be re-inset in a tension-free manner, extending incisions as necessary.[10] If unable to inset without undue tension, a skin graft may be considered to cover an exposed edge.

Vascular Compromise

Once the anastomoses have been exposed and points of compression addressed, if clinical concern for poor perfusion remains, the etiology must be further assessed. If no thrombosis is seen within the pedicle, a gentle "strip test" is performed with a pair of Jeweler forceps to confirm patency across the anastomosis.[9,17] Stripping a visible thrombus could result in distal migration of thrombus and should be avoided. Sterile hand-held Doppler directly on the vessels may also be used to assess patency.[9,17]

Heparin is used in microsurgery as both topical irrigation (100 U/mL) and systemic anticoagulant.[7,8,15,16,30–32] Many protocols recommend the use of a systemic heparin bolus, with ranges of 2500–5000 U (or 50 U/kg), at the beginning of the salvage procedure or at the time that anastomosis is performed.[9,10,15,16,25,30,33]

Venous Congestion

The leading cause of DIEP flap failure is venous outflow insufficiency.[4,5,17–19,29] Identifying the cause and appropriately augmenting venous egress are critical in rectifying congestion (Fig. 3). If there is no thrombus visible when the pedicle and anastomosis are examined, and the flap demonstrates clinical signs of congestion (purple-blue

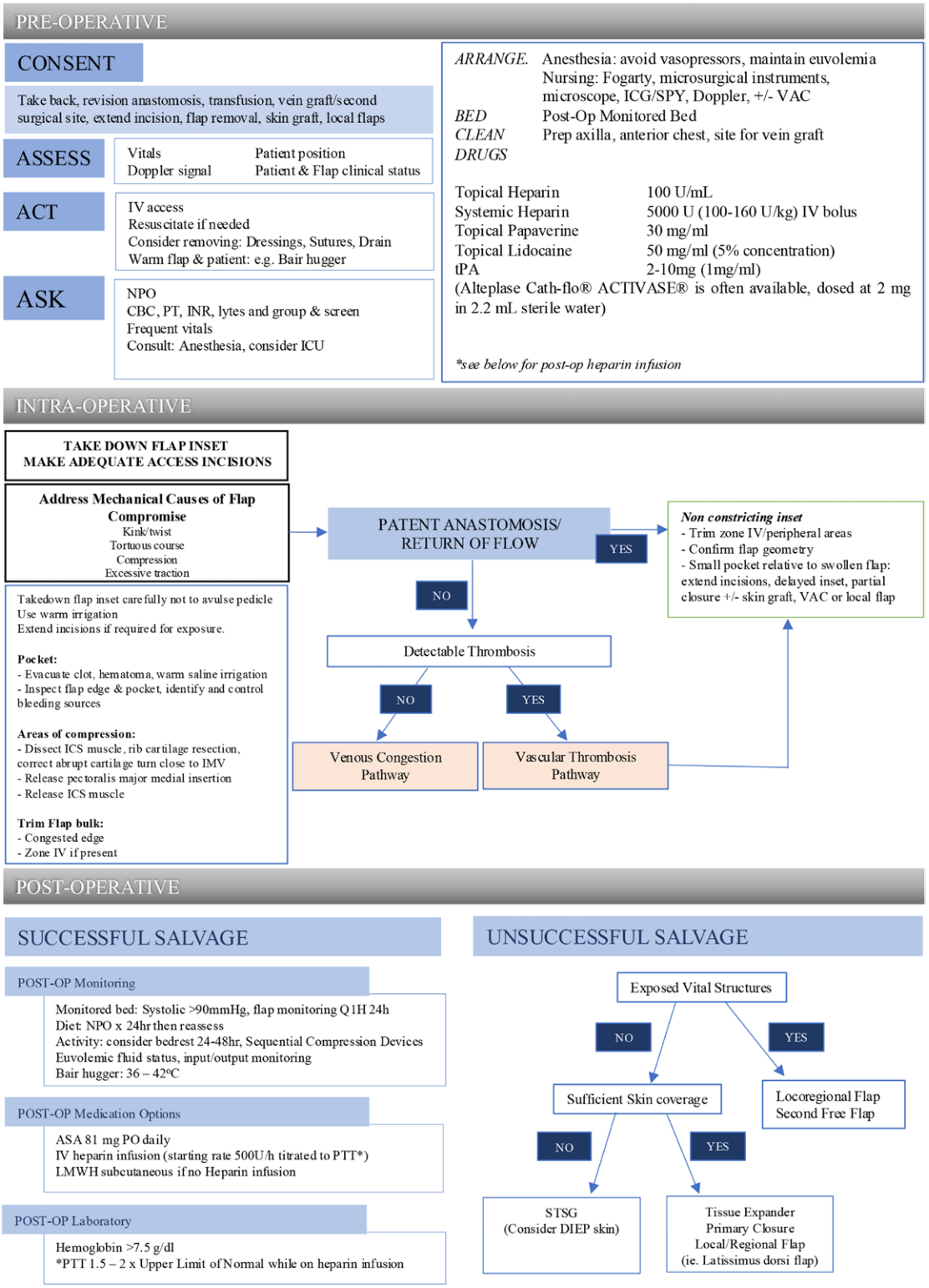

Fig. 2. Perioperative management strategies to DIEP free flap compromise in breast reconstruction.

discoloration, swollen appearance), steps to address venous insufficiency must be initiated. Initial assessment should ascertain whether the superficial drainage system is dominant and, therefore, can be used to augment venous drainage.[29,34] Clinical findings of superficial inferior epigastric vein (SIEV) dominance include a visibly engorged SIEV stump, brisk SIEV bleeding, and resolution of congestion with superficial venous egress.[5,17,29,35–37]

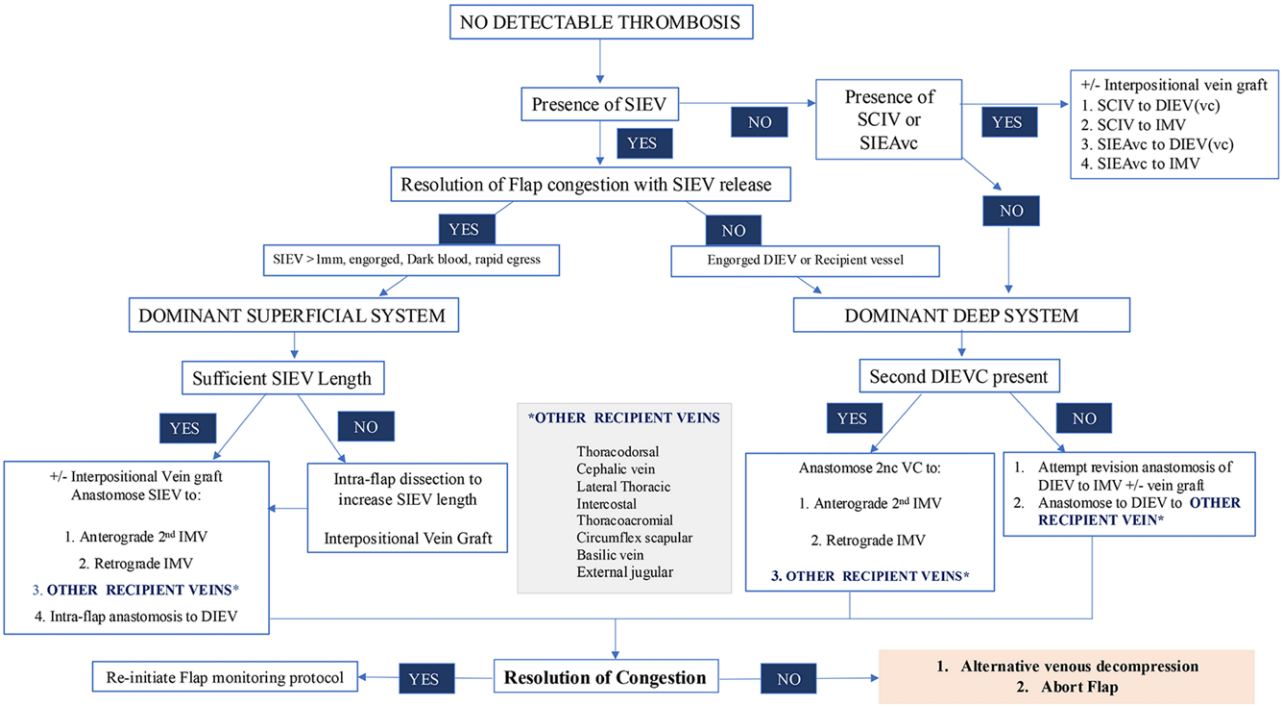

Fig. 3. Venous congestion.

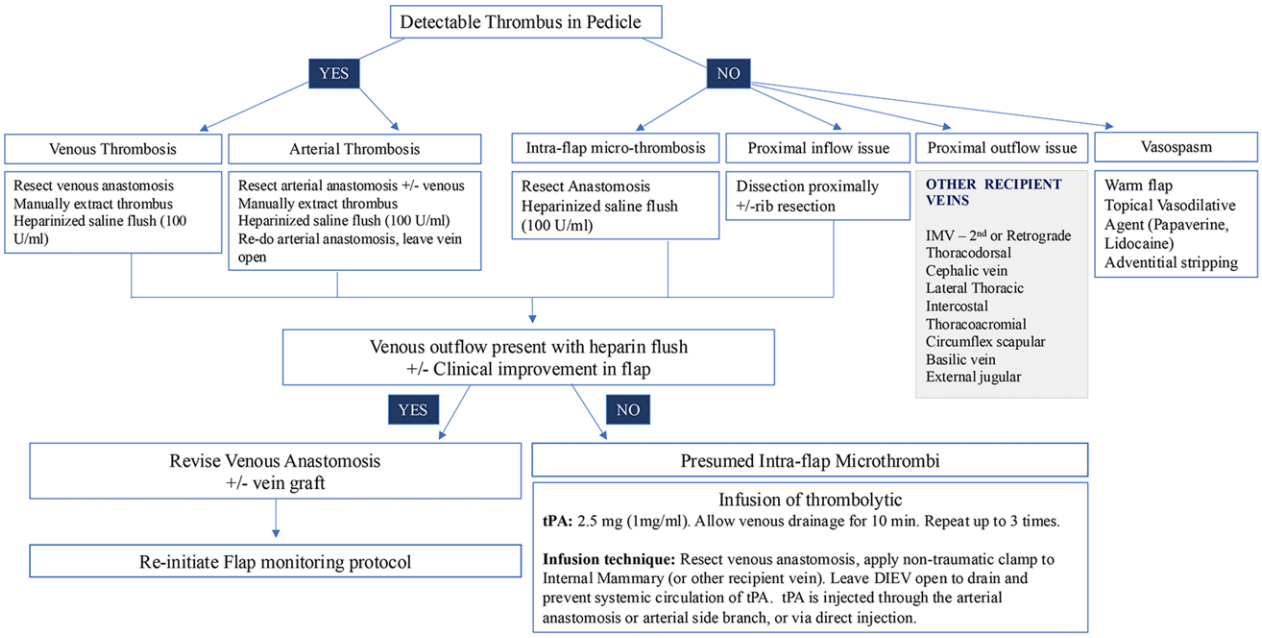

Fig. 4. Vascular compromise.

If clinical findings support a dominant superficial system, and there is an SIEV stump present, this may be released to decompress the congestion in the flap. The SIEV must then anastomosed to a recipient vein and may or may not require an interpositional vein graft depending on the length.[9,29,34,36–40] Intraflap dissection may also increase SIEV length. The SIEV (± vein graft) can be anastomosed, if available, to a second internal mammary vein (IMV) in an anterograde fashion.[8,17,18,29,34] If unavailable, retrograde anastomosis to the IMV is often possible.[5,17,41,42] Other recipient veins may be selected and include the thoracodorsal vein, cephalic vein, lateral thoracic, intercostal, thoracoacromial, external jugular, basilic, circumflex scapular, contralateral IMV, or IMV perforator veins.[5,8,17,19,20,35,36,43–48] Other studies have suggested intraflap anastomosis of the SIEV to the deep inferior

epigastric venae comitantes (DIEvc) (turbocharging) with or without vein graft, to achieve venous outflow through both systems without requiring an additional recipient vessel exposure[17,18,29,34,35,41,49] (Fig. 3).

If the superficial system does not appear to be contributing significantly to venous outflow, the deep system must be augmented.[8,17,34] Revision of the initial anastomosis may first be attempted and may require further dissection to increase IMV length. If a second DIEvc is available, this can be anastomosed anterograde to the lateral IMV (if present), or retrograde to the distal IMV.[17,37,41,50,51] Again, other recipient vessels can be used to anastomose the DIEvc; however, these often require a second surgical site and vein graft to achieve the length required.

Finally, if venous congestion is not resolved with these measures, postoperative salvage methods to address venous decompression have been reported. Venous cannulation of the superficial system, with regular aspiration over 3–5 days has been described.[17,52] Leech therapy has also been utilized as a final salvage attempt in flap reconstruction, although studies in breast reconstruction are limited.[53,54] Leech therapy in flap reconstruction has a high risk of associated morbidity, including infection and transfusion, and therefore, is not typically recommended.[53–57]

Vascular Thrombosis

In the presence of detectable thrombus, manual evacuation by direct thrombectomy or Fogarty catheter should be performed.[8–10,16,25,58] If a venous thrombus is visible, but arterial inflow appears patent, resection of the venous anastomosis and manual thrombectomy should be performed, followed by heparinized saline irrigation (100 U/mL).[9,10,25] If venous outflow from the open vein improves and the flap appears clinically perfused, the venous anastomosis should be performed again.[8,10,16] If thrombosis of the arterial anastomosis (or both venous and arterial) is suspected, both the arterial and venous anastomosis should be resected, and thrombus again manually extracted and the vessels flushed with heparinized saline.[8–10,16,40] The arterial anastomosis should then be reanastomosed, and the vein allowed to drain freely over a few minutes to ensure there are no microthrombi or need for intraflap thrombolytics.[7–9,59] If it flows well from the open vein, and the flap appears perfused, the venous anastomosis can be performed again.[7–10,16] (Fig. 4)

Intraoperatively, indocyanine green angiography may help to assess whether distal segment intrinsic thrombus or intraflap microthrombi are contributing to poor perfusion after reanastomosis.[8,9,60]

If there is not a detectable thrombus, other causes of flap compromise or hypoperfusion must be considered, including vasospasm or distal microthrombi. Systemic therapy for the patient, including warming and euvolemia, is important. Topical agents including papaverine (30 mg/mL), topical lidocaine, and topical calcium channel blockers have been described.[17,61] At a concentration of 5%, topical lidocaine is found to have the most potent vasodilatory effect, with the least amount of irreversible damage to the vessel.[62,63]

Thrombolytics

Three thrombolytic agents most often described in the literature in free flap salvage include streptokinase (SK), urokinase (UK), and recombinant tissue plasminogen activator (tPA). Lipton and Jupiter[64] and Schubert et al[65] published early case studies using SK in free flap salvage. The reported doses of SK for free flap salvage range from 50,000 to 250,000 U in normal saline at a concentration of 5000 U/mL.[10,25,26,64] SK is not used as commonly in microsurgery as compared with UK due to its antigenicity and longer half-life.[10,26,31,33] Several authors utilized UK in free flap salvage protocols, with doses ranging from 50,000 to 400,000 U (most commonly 100,000–250,000 U in 50–100 mL of normal saline for a dose of 5000 U/mL).[26,30,59,66,67]

Another commonly utilized agent for intraluminal injection in free flap salvage is recombinant tPA for lysis of microthrombi. Most authors recommend intra-arterial tPA at a dose of 2–10 mg diluted in saline at a concentration of 1 mg/mL, injected slowly over 1 minute.[8–10,15,18,25,33,59,66,68–72] A higher concentration may have added risk of hemorrhage, without evidence for increased efficacy.[33] It is commonly administered at a concentration of 2 mg/2.2 cm^3 due to its availability as Cathflo (Activase Genetech South, San Francisco, CA).[15]

For all agents described, the indications for thrombolytic use and methods of administration are similar. Indications for use of thrombolytic includes suspected intraflap microthrombi, typically presenting as poor venous outflow in the presence of good arterial inflow, or following mechanical thrombectomy.[10,26,70–72] Rooks et al[73] reported an advantage of intra-arterial over intravenous administration of thrombolytics.

The method of administration most often includes resection of the venous anastomosis and applying an atraumatic clamp to the recipient vein. The arterial anastomosis is either revised or left intact if there is flow across the anastomosis. With the artery in continuity, the thrombolytic agent is infused into an open branch of the arterial pedicle or directly into the lumen using a 25- to 30-gauge needle[9,31,67] or angiocatheter.[72] The open vein prevents systemic distribution of the thrombolytic agent, and also allows for direct visualization of the venous effluent to assess for improvement in venous outflow.[10,31,67] A repeat dose can be considered if flow has not been restored after waiting for at least one half-life of the drug (approximately 4 minutes for tPA, 14 minutes for UK)[30,31,33] and up to 3 doses total.[32,70]

Postoperative

Perioperative and postoperative monitoring protocols have been well studied and published for uncomplicated DIEP flap reconstruction.[74] In cases of flap compromise requiring return to the OR, the evidence is less consistent. Generally, reinitiation of postoperative monitoring and management protocols is recommended. This typically includes hourly monitoring for 24–48 hours to assess clinical features as well as external Doppler signal or other flap monitoring system, although there is some variation between institutions.[16,74,75]

Many studies reported the use of a systemic heparin infusion in the postoperative period following flap salvage.[7,8,15,29,31,71,72] A continuous infusion rate of 100–500 U/h, or tailored to achieve an activated partial thromboplastin time of 1.5–2× the upper limit of normal is commonly used.[7–10,15,31,71] The duration of heparin infusion is also variable, most often reported at 3–7 days.[8,15,29,71,72] Dextran is used in some protocols[71] but carries a risk of allergic reaction and pulmonary edema and not included in our algorithms.[76]

Postoperatively, it is important to have an ongoing management strategy to address factors that may have contributed to the initial cause of flap compromise. If the patient has recurrent thrombosis or a documented hypercoagulable state, anticoagulation, and antiplatelet protocols may be adjusted to address this.[71]

In the event of flap failure and total flap loss, available options will depend on patient preference and skin envelope. With sufficient skin redundancy, as is often the case following immediate reconstruction, it may be possible to remove the flap and proceed with primary closure of the residual defect. A tissue expander may be placed within the breast pocket as well. It is advisable to cover the recipient vessels with posterior perichondrium or pectoralis to prevent pressure from the TE on the vessels.

If there is insufficient skin for primary closure or closure over a device (tissue expander), then other options must be considered. These include placing an split thickness skin graft on the pectoralis or placement of a negative pressure dressing to the open wound. Postoperatively, a discussion with the patient regarding alternate reconstruction options, such as a pedicled latissimus dorsi flap (with or without TE) or alternate free flap reconstruction, could be approached[10] (Fig. 2).

DISCUSSION

We reviewed the literature to inform 3 comprehensive management algorithms aimed at improving outcomes and providing evidence-based guidance to free flap take-back in autologous breast reconstruction. Feedback from 6 expert surgeons was incorporated to enhance the content, structure, and accessibility of the data.

The first algorithm offers an overview of managing return to the OR, including initial steps to identify intrinsic or extrinsic concerns relating to flap compromise and postoperative considerations. The second algorithm provides a stepwise approach to address venous insufficiency, a common cause of flap take-back. The third algorithm outlines approaches for addressing venous or arterial thrombosis, including recommendations on the use of thrombolytics. The literature review that informed the creation of these pathways was detailed in the results sections. Many institutions have individual, effective strategies for flap monitoring and take-back protocols, which may vary from those presented. The present algorithms are meant to support surgeons requiring guidance in these difficult situations, especially in centers where these procedures are less common, or take-back events do not have set protocols. A key message throughout the literature is in regard to the timely recognition and intervention are crucial for successful free flap salvage.[15,59] Frequent clinical and device-assisted monitoring of tissue perfusion is critical; early recognition of vascular compromise and prompt surgical intervention correlate with flap salvage and improved outcomes. The change in trend of the arterial Doppler signal from a biphasic to monophasic (the "waterhammer" signal indicating impaired venous outflow) may indicate early, impending flap compromise.[15,25] Kroll et al[12] found that 80% of presentations of vascular thrombosis occurred within the first 48 hours postoperatively. Winterton et al[28] demonstrated improved salvage rates with re-exploration at 19 hours postoperatively compared to 56 hours. Vijan and Tran[15] recommended an optimal take-back time of less than 188 minutes after detection of flap compromise. "Vascular conversion" to an alternate venous recipient, rather than multiple revision attempts, has also been shown to increase flap salvage.[14,22]

Multidisciplinary teams are essential in healthcare delivery. Clear and timely communication between surgeons and house staff is vital.[15] Staff experience has also been correlated with successful flap salvage.[25]

Recombinant tPA for lysis of microthrombi is the most commonly used agent for intraluminal injection following manual thrombectomy.[33] Interestingly, Yii et al[66] found that thrombolytics did not increase flap salvage rates, and that salvage was more related to timing of return to OR. Chang et al[77] also found that thrombolytics did not significantly influence salvage rates; however, they may have a secondary effect of reducing rates of fat necrosis.[59]

Perioperative thrombolysis and anticoagulation protocols vary in the literature, and differ if administered for routine management as opposed to re-exploration. Conrad and Adams[7] provided guidelines for thrombolytics in microsurgery; they generally recommend IV heparin bolus following completion of anastomosis (80 U/kg); however, they recommend a higher dose (100–160 U/kg) during flap re-exploration. Kroll et al[78] found high-dose heparin bolus and infusion had significantly increased hematoma rates. Furthermore, there is no consensus on postsalvage heparin infusion duration, but neoendothelialization across a new anastomosis takes approximately 6 days.[79] As such, systemic heparin should continue into the postoperative period for that time frame.[8]

In summary, the algorithms presented offer a reference to organize the extensive information available in the literature for approaching free flap salvage in autologous breast reconstruction.

Limitations

Given their retrospective nature and lack of randomization, selection bias was present in these studies. We were also unable to do a formal meta-analysis of the quantitative data due to the heterogenous quality of the studies included. Some techniques described were derived from mixed populations of breast reconstruction patients, with

head and neck or extremity reconstruction, possibly limiting their applicability.

CONCLUSIONS

A coherent and stepwise approach to free flap compromise in breast reconstruction was developed. These expert-reviewed algorithms provide an approachable and evidence-based structure to support return to the OR in a concise and readily available format.

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DISCLOSURE

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

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