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# Flap Venous Congestion and Salvage Techniques: A Systematic Literature Review

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**Background:** Venous congestion is a frequent problem in flap surgery. Other than surgical revision, there are a multitude of procedures in the literature to tackle this problem, but their effectiveness is not clear. Through a systematic review, we aimed to identify and evaluate the different interventions available for managing flap venous congestion.

**Methods:** The MEDLINE, PubMed central, Embase, and Cochrane databases were searched. The study selection process was adapted from the PRISMA statement. All English and French original articles describing or comparing a method for managing flap venous congestion were included. For each article, a level of evidence was assigned, as defined by the Oxford Centre for Evidence-based Medicine. Lastly, we specifically analyzed the effectiveness of postoperative non-surgical methods. No formal analysis was performed.

**Results:** Through literature searches carried out in various databases, we identified 224 articles. Finally, 72 articles were included. The majority of these studies had a low-level evidence. A total of 17 different methods (7 pre- and intraoperative, and 10 postoperative) were found. Concerning non-surgical methods, the most represented were leeches, local subcutaneous injection of heparin with scarification, venocutaneous catheterization, negative pressure therapy, and hyperbaric oxygen therapy.

**Conclusions:** Risks of venous congestion of flaps must always be present in a surgeon's mind, at every stage of flap surgery. Apart from studies on the use of leeches, which have a significant follow-up and large enough patient numbers to support their efficacy, the low-level evidence associated with studies of other methods of venous congestion management does not allow us to draw a scientifically valid conclusion about their effectiveness. *(Plast Reconstr Surg Glob Open 2021;9:e3327; doi: 10.1097/GOX.0000000000003327; Published online 22 January 2021.)*

## INTRODUCTION

Regardless of whether it affects pedicled flaps or free flaps, venous congestion is often difficult to manage. Other than surgical revision, there are a multitude of procedures available to surgeons; however, their effectiveness is not clear.

A clinical diagnosis of venous insufficiency of a flap is made, which showed the following findings: purplish color, shortening refill time (<3 seconds), dark blood at pin prick, venous bleeding on the flap edges, and increased edema. This constitutes an emergency because severe microvascular lesions will develop that become irreversible within 6–8 hours. For this reason, monitoring under strict guidelines by a well-trained team is essential. We must distinguish between early venous insufficiency, which frequently concerns the entire flap (large vessel thrombosis), and late venous insufficiency, which often affects the flap only in its distal part (small vessel thrombosis) and rheological adaptation phenomena that are not real congestion (flows redistribution, new turbulence, choke vessels opening, modification of drainage direction involving hyperemia and diminution of the transient skin recoloration time). With the ever-increasing use of

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flaps, management of venous congestion is key to avoiding sequelae or loss of flap.

When a mechanical cause has been identified, surgical revision with exploration of the venous pedicle in the operating room is essential.[1–3] If necessary, the hematoma is drained, the pedicle is unkinked, the propeller flap is replaced to the original position by untwisting, venous anastomosis for a free flap is repaired, and a second drainage vein is added.

However, surgical revision is sometimes impossible, or the cause cannot be identified. It is precisely in these situations that medical therapies come into play.[4] For the most part, they consist of venous offloading techniques[1,2,5] to increase tissue perfusion and reduce congestion until venous neovascularization can occur (approximately between the fifth and seventh postoperative day).[2,6]

We analyzed all the data from the international literature dealing with the management of flaps with venous congestion to propose an inventory of the available procedures. We then evaluated the effectiveness of all the methods available to reduce venous congestion when surgical revision is impossible or does not seem justified.

## MATERIALS AND METHODS

This review was conducted according to the recommendations specified in the Cochrane Handbook for Systematic Reviews of Interventions (version 5.1.0), is AMSTAR compliant, and is reported in line with the PRISMA statement: Preferred Reporting Items for Systematic Reviews and Meta-Analysis. Searches were conducted in MEDLINE via PubMed, Cochrane Library, and Embase databases using the following keywords: "venous complication" OR "venous suffering" OR "venous thrombosis" OR "venous insufficiency" OR "venous suffering AND "flap management." The title, summary, and full text of the identified articles were examined.

All English and French original articles describing or comparing a method for managing venous congestion in flaps were included. Clinical cases, case series, observational studies (retrospective and prospective), controlled clinical trials, and randomized controlled trials were included. Items were excluded when found in duplicate or when they did not address the management of venous congestion. Detailed and critical reading of the entire texts of each article was carried out to collect data about authors, date of publication, place of study, type of study, and method used to manage venous congestion. For each article, a level of evidence was assigned, as defined by the Oxford Centre for Evidence-based Medicine. Lastly, we specifically analyzed the effectiveness of postoperative non-surgical methods. No formal analysis was performed.

## RESULTS

Searches carried out among the various databases identified 224 articles. After adding studies identified by reviewing the bibliographies and deleting duplicates, we obtained a total of 264 articles. After reviewing the titles, 96 articles were eligible. Of these, 10 were excluded after reading abstracts (they did not deal with venous congestion). Of the remaining 86 articles, 8 were excluded because they were written in a language other than English or French. Finally, 72 articles were included. The entire review process is illustrated as a flowchart (Fig. 1) (See also Table 1). Most of these studies had a low-level evidence (level 3 or 4).

A total of 17 different methods (7 pre- and intraoperative, and 10 postoperative) were found. The methods reported in the literature for managing primary and secondary prevention are classified in Table 2. However, Because our analysis focused on secondary prevention, the relevant methods were classified as surgical and non-surgical methods.

### Secondary Prevention of Venous Insufficiency by Surgical Procedures

The earlier that venous congestion is detected, the faster the management and the better the results in terms of flap survival.[7,8] Emergency return to the operating room aims to identify a compressive mechanical etiology and to treat it. Pedicled flaps can benefit from removing the pedicle compression or from venous supercharging, especially for retrograde flaps,[9] even if this procedure can be difficult in second-intention because a vein must be preserved during the first surgical procedure in anticipation of possible congestion (Fig. 2).

Propeller flaps have the option of being replaced to original position for 48 hours to promote venous return,[10] as shown in Figure 3. Moreover, pedicle release can be improved with or without repositioning of the latter. To avoid this revision, a 2-stage procedure (or "delayed procedure")[11] allows opening of the choke vessels and avalvular (oscillating) veins during a flap autonomization period.[12–15] Finally, we can also perform venous supercharging in propeller flaps.[16]

Regarding free flaps, the main cause of venous congestion is venous thrombosis.[7,17] The first step during surgical revision of a free flap is to look for thrombosis on the anastomosis. If venous flow is not restored despite correcting potential extrinsic compression and after performing thrombectomy, it means the thrombosis is in the flap microcirculation. This is a high-risk situation where administration of thrombolytic agents remains the ultimate solution. Recent studies have shown that thrombolytics are effective at rescuing flaps with clots in microvessels.[18–20] An intra-arterial injection (leaving the vein open to avoid any systemic diffusion) of 2 mg Actilyse diluted in 2 cc 0.9% NaCl is administered and repeated once after 10–15 minutes if ineffective thrombolysis occurs after the first dose.

### Secondary Prevention of Venous Insufficiency by Medical Procedures

When surgical revision is impossible, or the cause of venous congestion cannot be identified, medical therapies can be effective in improving or resolving venous congestion (Fig. 4). Before implementing them, simple measures can be used to remove extrinsic compression: redoing a dressing that is too tight,[21] removing a splint or

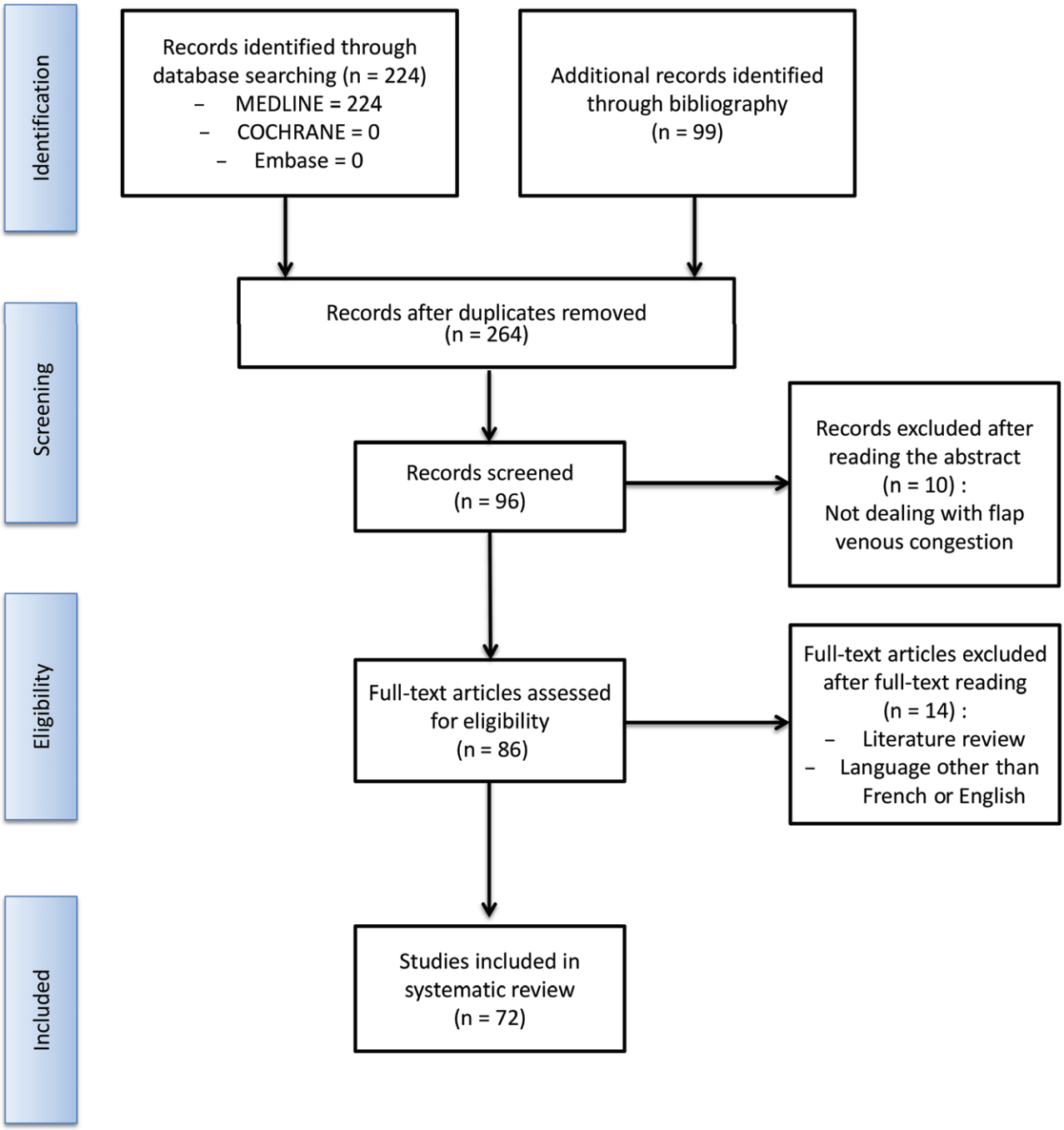


**Fig. 1.** Flowchart summarizing the search strategy and selection of included articles.

compressive garment, or removing sutures that contribute to a flap's tourniquet effect.[22]

**Leeches**

There are 27 articles in the literature on medicinal leeches. The effectiveness of hirudotherapy in relieving venous congestion is due to both mechanical and biological effects. Blood suction following a bite will temporarily improve tissue perfusion by actively draining blood from congested tissue (mechanism demonstrated by laser Doppler analysis by Knobloch et al).[23] About 5–15 ml of blood will be actively extracted. Once active suction is complete, passive blood loss will occur. Anticoagulants, inhibitors of platelet aggregation, and other vasodilators produced by leeches will allow blood flow at the bite site to continue even after the leech is detached. About 20–50 ml will then be extracted passively. Thanks to these 2 mechanisms, the venous flow and microcirculation in the flap will improve, and consequently the venous congestion will decrease (Fig. 5).

Several literature reviews have been conducted on this topic, with the most recent ones by Whitaker et al[24]

**Table 1. Presentation of the 72 Articles Included in the Review**

| Authors | Year | Method Used | Type of Study | Level of Evidence* | Country |
|---|---|---|---|---|---|
| Derganc and Zdravic | 1960 | Leech | Case series | 4 | Slovenia |
| Williams | 1973 | Delayed procedure | Case series | 4 | Ireland |
| Batchelor et al | 1984 | Leech | Case series | 4 | UK |
| Wieslander et al | 1986 | Systemic antithrombotic | Case-control study | 3 | Sweden |
| Hayden et al | 1988 | Leech | Case series | 4 | USA |
| Barnett et al | 1989 | "Chemical" leech | Case series | 4 | Australia |
| Smoot et al | 1990 | Leech | Case-control study | 3 | USA |
| Lee et al | 1992 | Leech | Comparative test | 4 | Canada |
| Dabb et al | 1992 | Leech | Case series | 4 | USA |
| Gross and Apesos | 1992 | Leech | Case series | 4 | USA |
| Rodgers et al | 1992 | Leech | Case series | 4 | USA |
| Miller et al | 1993 | Surgical revision | Retrospective study | 4 | USA |
| Soucacos et al | 1994 | Leech | Case-control study | 3 | Greece |
| Haycox et al | 1995 | Leech | Case series | 4 | USA |
| Smoot et al | 1995 | Leech | Case series | 4 | USA |
| Takamatsu et al | 1996 | Recipient vessels choice | Retrospective study | 4 | Japan |
| Wheatley and Meltzer | 1996 | Surgical revision | Case series | 4 | USA |
| Pantuck et al | 1996 | Leech | Case series | 4 | USA |
| Kamei et al | 1997 | Venocutaneous catheterization | Case series | 4 | Japan |
| Ritter et al | 1998 | Systemic antithrombotic | Case series | 4 | USA |
| Serletti et al | 1998 | Surgical revision | Retrospective study | 4 | USA |
| Mortenson et al | 1998 | Leech | Case series | 4 | USA |
| Utley et al | 1998 | Leech | Case series | 4 | USA |
| Robinson | 1998 | "Chemical" leech | Case series | 4 | USA |
| Iglesias and Butron | 1999 | "Chemical" leech | Case series | 4 | Mexico |
| Lozano et al | 1999 | Hyperbaric oxygen therapy | Case-control study | 3 | USA |
| Kirschner et al | 1999 | "Chemical" leech | Case-control study | 3 | USA |
| Davis et al | 1999 | Skin topicals | Case series | 4 | USA |
| Weinfeld et al | 2000 | Leech | Case series | 4 | USA |
| MacGill | 2000 | "Chemical" leech | Case series | 4 | USA |
| Yii et al | 2001 | Surgical revision | Retrospective study | 4 | USA |
| Chalian et al | 2001 | Recipient vessels choice | Retrospective study | 4 | USA |
| Ulkür et al | 2002 | Hyperbaric oxygen therapy | Case-control study | 3 | Turkey |
| Gampper et al | 2002 | Hyperbaric oxygen therapy | Case-control study | 3 | USA |
| Chepeha et al | 2002 | Leech | Case series | 4 | USA |
| Connor et al | 2002 | Leech | Case series | 4 | USA |
| Panchapakesan et al | 2003 | Surgical revision | Retrospective study | 4 | Canada |
| Namba et al | 2003 | Surgical revision | Case series | 4 | Japan |
| Eker et al | 2003 | Venocutaneous catheterization | Case series | 4 | Turkey |
| Gideroglu et al | 2003 | Leech | Retrospective study | 4 | Turkey |
| Tuncali et al | 2004 | Leech | Case series | 4 | Turkey |
| Ahmed et al | 2005 | Delayed procedure | Case series | 4 | Pakistan |
| Tan et al | 2005 | Venous supercharging | Case series | 4 | Turkey |
| Yazar | 2007 | Recipient vessels choice | Case series | 4 | Turkey |
| Chung et al | 2007 | Systemic antithrombotic | Randomized study | 2 | USA |
| Ogawa and Hyakusoku | 2008 | Super thin flaps | Case series | 4 | Japan |
| Gürsoy et al | 2008 | Venocutaneous catheterization | Case series | 4 | Turkey |
| Uygur et al | 2008 | NPT | Case series | 4 | Turkey |
| Chen et al | 2008 | Systemic antithrombotic | Comparative test | 2 | USA |
| Draenert et al | 2010 | Surgical revision | Case series | 4 | Germany |
| Ali et al | 2010 | Double venous anastomosis | Retrospective study | 4 | UK |
| Enajat et al | 2010 | Double venous anastomosis | Retrospective study | 4 | Sweden |
| Mozafari et al | 2011 | Venocutaneous catheterization | Randomized study | 2 | Iran |
| Whitaker et al | 2011 | Leech | Retrospective study | 4 | UK |
| Lorenzo et al | 2011 | Recipient vessels choice | Retrospective study | 4 | Taiwan |
| Jones et al | 2011 | Venocutaneous catheterization | Case series | 4 | USA |
| Reiter et al | 2012 | Systemic antithrombotic | Retrospective study | 4 | Germany |
| Ono et al | 2012 | Venous supercharging | Case series | 4 | Japan |
| Whitaker et al | 2012 | Leech | Retrospective study | 4 | UK |
| Koch et al | 2012 | Leech | Retrospective study | 4 | USA |
| Nguyen et al | 2012 | Leech | Case series | 4 | USA |
| Han et al | 2013 | Double venous anastomosis | Retrospective study | 4 | China |
| Vaienti et al | 2013 | NPT | Case series | 4 | Italy |
| Kashiwagi et al | 2013 | Leech | Case series | 4 | Japan |
| Damen et al | 2013 | Double venous anastomosis | Cohort study | 2 | Netherlands |
| Pérez et al | 2014 | "Chemical" leech | Retrospective study | 4 | Spain |
| Pannucci et al | 2014 | Leech | Cohort study | 2 | USA |
| Lee et Mun | 2015 | Systemic antithrombotic | Case-control study | 3 | South Korea |
| Jose et al | 2015 | Leech | Case series | 4 | India |
| Herlin et al | 2016 | Leech | Case series | 3 | France |
| Qui et al | 2016 | NPT | Case series | 4 | Taiwan |
| Chaput et al | 2017 | Delayed procedure | Case series | 4 | France |

*Oxford Center for Evidence-Based Medicine 2011 levels of evidence.

**Table 2. Articles on Primary Prevention and Secondary Prevention**

| Methods | No. Articles | Level of Evidence |
|---|---|---|
| Primary prevention | | |
| Delayed procedure | 3 | 4 |
| Venous supercharging | 2 | 4 |
| Super thin flaps | 1 | 4 |
| Double venous anastomosis | 4 | 2 to 4 |
| Systemic antithrombotic | 6 | 2 to 4 |
| Recipient vessels choice | 4 | 4 |
| Total | 20 | |
| Secondary prevention | | |
| Leeches | 27 | 4 |
| Surgical revision (repair of anastomoses, pedicle thrombectomy, venous bypass, pedicle thrombolysis) | 7 | 4 |
| Local injection of LMWH + scarification | 6 | 3 to 4 |
| Venocutaneous catheterization | 5 | 2 to 4 |
| Hyperbaric oxygen therapy | 3 | 3 |
| NPT | 3 | 4 |
| Skin topicals | 1 | 4 |
| Total | 52 | |

in 2012 and Herlin et al[25] in 2016. The overall success rate was 77.98% according to Whitaker, and between 65% and 80% according to Herlin. In general, the success rate in the included studies was close to 70%.[24–28] One of the limitations of leech therapy seems to be the flap volume. The success rate falls to around 30% for high-volume flaps such as TRAM or DIEP.[28,29]

Studies on hirudotherapy have a relatively low-level evidence, but they are numerous, with a large series of patients and a significant effect. For this reason, it is currently the only validated treatment for managing acute venous insufficiency of pedicled or free flaps when surgical revision is not appropriate. Hirudo medicinalis was approved by the FDA as a medical device in 2004.[30]

#### Local Subcutaneous Injection of Heparin with Scarification: Chemical Leeches

There are 6 articles in the literature on this topic. This procedure was first described by Barnett et al in 1989[31] as a treatment for venous congestion in the context of digital reimplantation. It is also called "chemical leeching."[6,31–33] It was proposed as an alternative to hirudotherapy, when leeches were not available.[6,31–34] Unfractionated heparins were used initially, but were gradually replaced by low-molecular-weight heparins given their superior pharmacokinetics.

Articles on the use of low-molecular-weight heparins for managing venous congestion of flaps are still quite rare. The largest study on low-molecular-weight heparins is that of Pérez et al,[35] with 15 flaps supported by this method. Success rates presented in the literature are high but based on small cohorts.[6,31,32,35]

Various usage patterns have been described, including the protocol of Pérez et al, which is fairly reproducible[35] (Table 3). Concomitant use of systemic anticoagulants such as intravenous heparin, dextran, or aspirin has not been shown to be effective and may even be harmful to patients with a higher risk of bleeding.[31] Treatment is initiated for a minimum of 5–7 days and continued depending on whether signs of venous congestion persist.

Various complications have been reported, but the major complication is blood loss and need for transfusion. According to various authors, chemical leeching will achieve identical results with fewer associated complications, particularly in terms of infection. This technique requires nursing care, but it is available immediately and easy to implement in case of venous congestion of a flap. It seems practical in a case where treatment could be delayed due to leech constraints, to begin with a local injection of LMWH and then to set up the leeches secondarily. Depending on the center, control and delivery of leeches can delay treatment for several hours,[36] which is critical in a situation where earlier treatment improves the chances of survival.[8]

#### Venocutaneous Catheterization

There are 5 articles in the literature on this topic. This technique involves introduction of a catheter into the lumen of a superficial vein in the flap and externalizing it so that venous offloading can be performed on demand by opening a valve[37] (Fig. 6).

There are few studies on the use of venocutaneous catheterization and only a small number of patients have been treated.[33,38–40] The largest study describes 28 neurocutaneous sural flaps.[41] The overall success rate is close to 100% in each of the available studies. Only Mozafari's team[41] has reported 1 case of partial necrosis


**Fig. 2.** A 40-year-old man presented with chronic osteitis following a tibial fracture. A venous-supercharged PTAP flap was planned with a racquet-shaped design. A, The skin paddle was centered on the great saphenous vein, which was detected using Doppler ultrasound. B, The great saphenous vein was transected and harvested with the flap. A 90 degree rotation was performed. After debridement, the defect was covered by the flap and a distal venous anastomosis was performed using magnification. C, Neither congestion nor flap necrosis occurred, and the wound healed after 3 weeks.

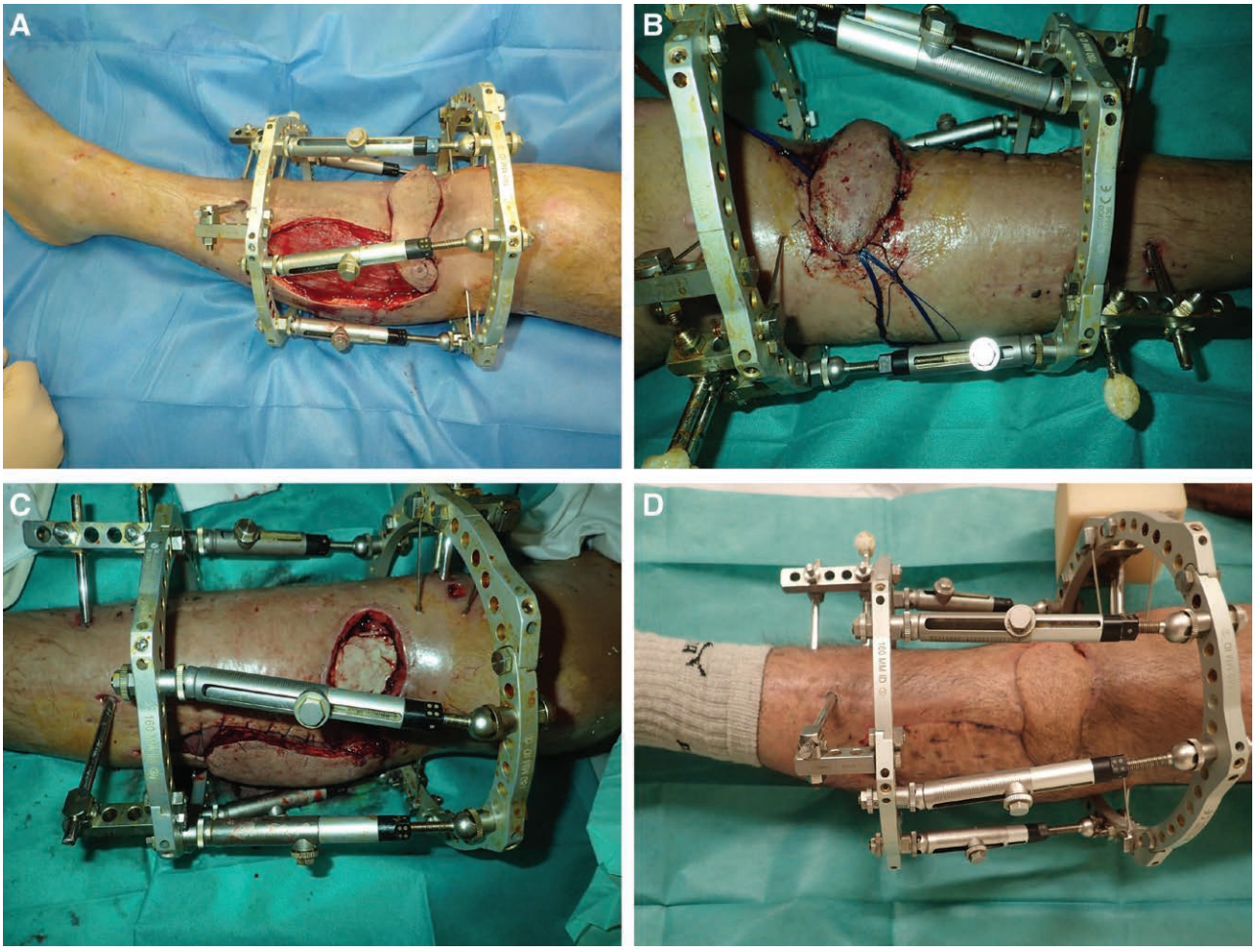


**Fig. 3.** Anterior tibial artery perforator flap (ATAP) for bone coverage. A, B, Rapid venous congestion, 3 hours after flap. C, The flap was urgently replaced to original position and left for 48 hours before replicating the rotation. D, At 1.5 months, the flap was completely healed and did not have necrosis because the untwisting was performed within 6 hours.


**Fig. 4.** Example of venous thrombosis of a DIEP flap. Revision surgery was performed but venous congestion persisted; therefore, hirudotherapy was undertaken (A, B). This provided effective decongestion, but after the treatment was discontinued on D5, the flap became completely necrotic in 48 hours (C).


**Fig. 5.** Example of postoperative congestion of a distally-based medial plantar flap in a 44-year-old man. A, Immediate postoperative. B, Introduction of leeches over 5 days. C, Complete flap salvage.

**Table 3. Dosing Protocol for Enoxaparin Sodium (Lovenox) according to Pérez et al[35]**

| Days | Congestive Area < 75 cm² | Congestive Area > 75 cm² |
|---|---|---|
| 1–3 | 20 mg/4–6 h | 40 mg / 4–6 h |
| 4–6 | 10 mg/8 h | 20 mg / 8 h |
| 7–9 | 10 mg/12 h | 20 mg / 12 h |
| 10–14 | 10 mg/24 h | 20 mg / 24 h |

of a neurocutaneous sural flap out of 28 flaps treated (3.6%). All protocols mention that the heparinized serum catheter must be rinsed; lumen obstruction by a venous thrombus remains the main problem. The second complication highlighted is the need for blood transfusion. The volume of drained blood is nevertheless much lower than with leech treatment.

According to Mozafari et al,[41] the use of a venous catheter is associated with significantly lower blood loss, lower local infection rate, and higher nurse and patient satisfaction than leech therapy. Also, the cost of treatment is much lower than medicinal leech therapy. The first drawback is that it can only be implanted in an operating room; therefore, it must be planned during initial surgery. In addition, a vein of good caliber could be used more judiciously by performing an additional venous anastomosis to obtain a supercharged flap.[9] However, if no recipient vein is present or if this vein is thrombosed, this technique seems to be an interesting alternative. Manual drainage by opening the catheter should be done every hour during the first few days; the soiled dressing will need to be drained several times a day.

### Negative Pressure Therapy

There are 3 articles in the literature on negative pressure therapy (NPT). NPT acts on venous congestion through 3 different mechanisms: increased local blood flow and therefore venous drainage; acceleration of neovascularization; reduction of interstitial pressure by drainage of exudates and edema. NPT is relevant in situations where the area to be covered is prone to significant edema, especially in trauma patients with a contused limb that can be site of lymphatic stasis.[42,43] Use of NPT for managing venous congestion in flaps is still rare in the literature. Between June 1997 (first description of NPT) and February 2017, only 3 studies were found[42,44,45] for a total of 17 treated flaps with venous congestion. The flap survival rate was 100% in each of the 3 included studies. Goldstein et al[43] used NPT as a preventive measure to reduce edema and prevent appearance of venous congestion in 17 local flaps for defect coverage in the ankles.

According to Morgan et al,[46] the depression induced by NPT may create compression of the pedicle and cause arterial insufficiency of flap. In addition to inducing depression, NPT also induces a compressive effect. Consequently, it seems advisable to use the discontinuous suction mode to avoid any worsening of flap congestion or ischemia. The other complication is blood loss secondary to aspiration, which can sometimes be significant and require a transfusion. However, the transfusion rates are much lower than when using leeches. The difficulty of viewing the skin paddle once the dressing has been applied must also be mentioned.

### Hyperbaric Oxygen Therapy

There are 3 articles in the literature on Hyperbaric Oxygen Therapy (HBOT). However, there is little data available because studies are almost exclusively animal studies,[47–52] the results are contradictory, and no protocol has been defined for managing venous congestion. In addition, the studies do not focus on pure venous congestion but rather on mixed ischemia. No benefit could be demonstrated when HBOT was applied in humans: in a prospective randomized study[53] on the use of HBOT in free flap surgery, no difference between the 2 groups were found in the venous congestion rate but also survival rate, edema, and duration of healing. HBOT does not appear to be suitable for managing venous congestion of a flap. It even seems to be ineffective when used alone. In addition, access to this therapy is very difficult, given the low availability of hyperbaric chambers and its expense.

### Topical Agents

There is 1 article in the literature that deals with the role of topical agents on venous congestion of flaps. Tested substances include sympatholytics, inhibitors of uric acid synthesis, prostaglandin inhibitors, and nitroglycerin. Long studied in animals, topical agents were then studied in humans, but none have been shown to be effective for venous congestion.[5,54,55] In contrast, transdermal nitroglycerin at a dose of 10 mg/24 hours appears to improve overall flap survival.[56] After reading the literature and in association with our practice, we propose in Figure 7 a decisional algorithm concerning flap venous congestion.


**Fig. 6.** Sural neurocutaneous flap to cover a calcaneal fracture. A, Flap design. B, Immediate postoperative. C, Venocutaneous catheterization was set up in anticipation of possible congestion. The valve was opened 3 times over the next 24 hours to decongest the flap and then the patient ripped out the catheter.

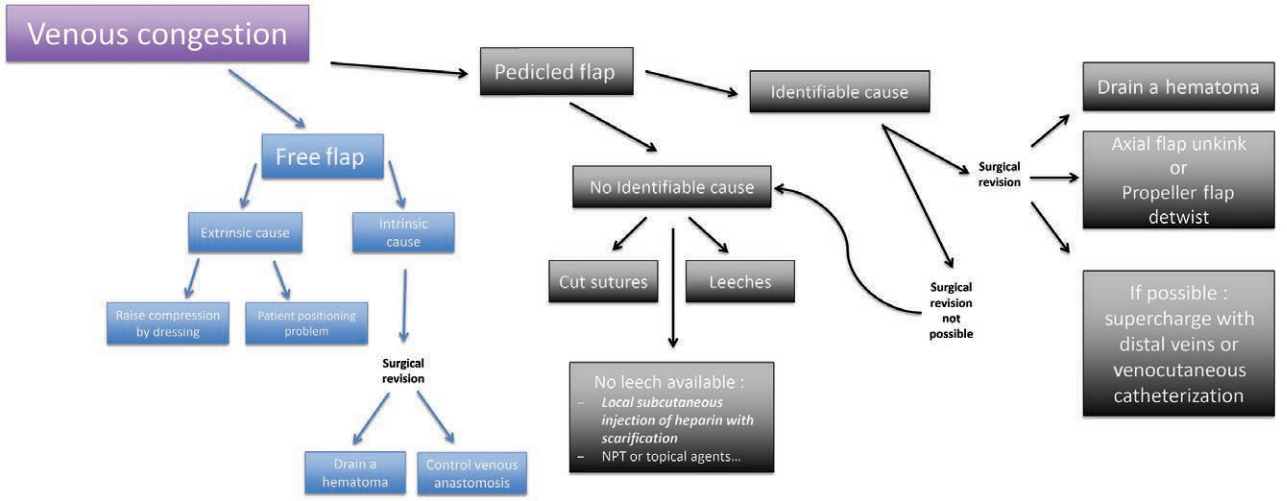


**Fig. 7.** Decisional algorithm concerning flap venous congestion.

## DISCUSSION

Altogether there are 2 broad causes of venous congestion of flaps: extrinsic (mechanical) and intrinsic (microcirculatory). It is common for surgeons to feel powerless when faced with venous congestion that cannot be explained by an extrinsic cause. The flap may deteriorate progressively in front of our eyes without having a valid solution.

When the situation suggests a mechanical cause, it is essential to return to the operating room to identify this cause and treat it electively. If no mechanical cause is found, and depending on operative context, we can consider performing a venous anastomosis with a superficial vein (venous supercharging) if one vein was preserved during flap harvesting. We can also try to rotate propeller perforator flaps in the opposite direction or replace a local flap at the donor site.

Regarding free flaps, any venous congestion requires an emergency return to the operating room. If a thrombus is found, thrombectomy is performed using Dumont forceps or a Fogarty venous thrombectomy catheter, depending on its accessibility. If venous flow does not return despite this thrombectomy, the thrombosis has affected the microcirculation of the skin paddle. Thrombolysis is the last resort. It is also essential to test the permeability of recipient vessels and, if necessary, to change them. Venous bridging may be necessary.

If these techniques are not feasible or if venous congestion persists after performing them, supplementary medical treatment is necessary. It should be pointed out that medical treatments are less effective in free flaps—fasciocutaneous flaps will benefit the most. Indeed, the techniques based on venous offloading are not sufficient to drain all the excess venous blood in large-volume flaps such as muscular or adipose flaps.

Leeches are the only medical treatment for managing venous congestion with a satisfactory level of evidence. It can be said that hirudotherapy remains the gold standard, with success rates of more than 70%. The effectiveness of "chemical" leeching reported in the literature is high, with a priori fewer problems than hirudotherapy. However, the lack of scientific evidence pushes us to use this method in addition to animal leeches or if they are not available.

NPT may be relevant in situations where the area to be covered is edematous, especially in traumatology. Although it has a 100% success rate in the literature, deficiencies in study methodology and sample size make it impossible to conclude whether this method is truly effective. We also advise using discontinuous suction mode (3 minutes of suction for 1 minute without aspiration).

Venocutaneous catheterization allows better control over drained blood volume but the rate of catheter thrombosis is high, and the level of evidence is low, which does not allow us to propose this technique as a first-line treatment. For experienced surgeons, using the same vein for supercharging is also a good alternative although it adds to the microsurgical time. Hyperbaric oxygen therapy has shown no benefit in the literature on venous congestion of flaps. Finally, no study has specifically analyzed the action of nitroglycerin or any other topical skin agents on isolated venous congestion of flaps.

At this point, it is clear that there is still room for research on mechanical procedures or on local or systemic drug therapies that would allow us to get out of these difficult situations with our reconstructions.

Our review has several limitations. First, as a systematic review, we were limited by the available published studies that summarize various surgical techniques (performed by different surgeons), which are highly variable and are not standardized. Second, there were missing data for comorbidity, localization, size of the flap, and etiology. Third, published studies do not have a homogenous consecutive series of patients. Finally, it was not possible to extract data to perform a meta-analysis.

## CONCLUSIONS

Risks of venous congestion of flaps must always be present in a surgeon's mind, at every stage of flap surgery.

Many methods can be used to avoid this major complication. Nevertheless, our analysis of the literature shows that it is difficult to draw a scientifically valid conclusion about their effectiveness. In the end, apart from studies on the use of leeches, which have a significant follow-up and large enough patient numbers to support their efficacy, the low-level evidence associated with studies of other methods of venous congestion management does not allow us to draw any real conclusions.

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## REFERENCES

1. Kubo T, Yano K, Hosokawa K. Management of flaps with compromised venous outflow in head and neck microsurgical reconstruction. *Microsurgery.* 2002;22:391–395.
2. Akan IM, Yildirim S, Gideroğlu K. Salvage of flaps with venous congestion. *Ann Plast Surg.* 2001;46:456.
3. Porshinsky BS, Saha S, Grossman MD, et al. Clinical uses of the medicinal leech: A practical review. *J Postgrad Med.* 2011;57:65–71.
4. Elyassi AR, Terres J, Rowshan HH. Medicinal leech therapy on head and neck patients: A review of literature and proposed protocol. *Oral Surg Oral Med Oral Pathol Oral Radiol.* 2013;116:e167–e172.
5. Jones NF, Lin MP, Dickinson BP, et al. Successful salvage of venous thrombosis of a free flap by creation of a venocutaneous fistula. *J Reconstr Microsurg.* 2011;27:243–250.
6. Iglesias M, Butrón P. Local subcutaneous heparin as treatment for venous insufficiency in replanted digits. *Plast Reconstr Surg.* 1999;103:1719–1724.
7. Riot S, Herlin C, Mojallal A, et al. A systematic review and meta-analysis of double venous anastomosis in free flaps. *Plast Reconstr Surg.* 2015;136:1299–1311.
8. Selber JC, Angel Soto-Miranda M, Liu J, et al. The survival curve: Factors impacting the outcome of free flap take-backs. *Plast Reconstr Surg.* 2012;130:105–113.
9. Tan O, Atik B, Bekerecioglu M. Supercharged reverse-flow sural flap: A new modification increasing the reliability of the flap. *Microsurgery.* 2005;25:36–43.
10. Demir A, Acar M, Yldz L, et al. The effect of twisting on perforator flap viability: An experimental study in rats. *Ann Plast Surg.* 2006;56:186–189.
11. Williams CW. Delaying of flaps. A useful adjunct. *Br J Plast Surg.* 1973;26:61–65.
12. Ahmed SK, Hashmi PM. Delayed supramalleolar flap–an innovative technique for enhanced viability. *J Ayub Med Coll Abbottabad.* 2005;17:76–79.
13. Tosun Z, Ozkan A, Karaçor Z, et al. Delaying the reverse sural flap provides predictable results for complicated wounds in diabetic foot. *Ann Plast Surg.* 2005;55:169–173.
14. Codner MA, Bostwick J III, Nahai F, et al. TRAM flap vascular delay for high-risk breast reconstruction. *Plast Reconstr Surg.* 1995;96:1615–1622.
15. Lambert DM, Rigano WC. Delaying the skin for TRAM flaps. *Curr Surg.* 2000;57:480–483.
16. Ono S, Ogawa R, Eura S, et al. Perforator-supercharged perforator-based propeller flaps. *Plast Reconstr Surg.* 2012;129:875e–877e.
17. Chaput B, Vergez S, Somda S, et al. Comparison of single and double venous anastomoses in head and neck oncologic reconstruction using free flaps: A meta-analysis. *Plast Reconstr Surg.* 2016;137:1583–1594.
18. Rinker BD, Stewart DH, Pu LL, et al. Role of recombinant tissue plasminogen activator in free flap salvage. *J Reconstr Microsurg.* 2007;23:69–73.
19. Casey WJ III, Craft RO, Rebecca AM, et al. Intra-arterial tissue plasminogen activator: An effective adjunct following microsurgical venous thrombosis. *Ann Plast Surg.* 2007;59:520–525.
20. Chang EI, Mehrara BJ, Festekjian JH, et al. Vascular complications and microvascular free flap salvage: The role of thrombolytic agents. *Microsurgery.* 2011;31:505–509.
21. Greene AK, Austen WG, May JW. Flap ischemia after pedicled tissue transfer to a lateral thigh wound: An example of complication assessment using the end result system of E. A. Codman. *Plast Reconstr Surg.* 2007;119:1599–1603; discussion 1604-5.
22. Chaput B, Herlin C, Grolleau JL, et al. Reply: The stitches could be the main risk for failure in perforator-pedicled flaps. *Plast Reconstr Surg.* 2016;138:383e–5e.
23. Knobloch K, Gohritz A, Busch K, et al. [Hirudo medicinalis-leech applications in plastic and reconstructive microsurgery–a literature review]. *Handchir Mikrochir Plast Chir.* 2007;39:103–107.
24. Whitaker IS, Oboumarzouk O, Rozen WM, et al. The efficacy of medicinal leeches in plastic and reconstructive surgery: A systematic review of 277 reported clinical cases. *Microsurgery.* 2012;32:240–250.
25. Herlin C, Bertheuil N, Bekara F, et al. Leech therapy in flap salvage: Systematic review and practical recommendations. *Ann Chir Plast Esthet.* 2017;62:e1–e13.
26. Soucacos PN, Beris AE, Malizos KN, et al. Successful treatment of venous congestion in free skin flaps using medical leeches. *Microsurgery.* 1994;15:496–501.
27. Chepeha DB, Nussenbaum B, Bradford CR, et al. Leech therapy for patients with surgically unsalvageable venous obstruction after revascularized free tissue transfer. *Arch Otolaryngol Head Neck Surg.* 2002;128:960–965.
28. Whitaker IS, Josty IC, Hawkins S, et al. Medicinal leeches and the microsurgeon: A four-year study, clinical series and risk benefit review. *Microsurgery.* 2011;31:281–287.
29. Nguyen MQ, Crosby MA, Skoracki RJ, et al. Outcomes of flap salvage with medicinal leech therapy. *Microsurgery.* 2012;32:351–357.
30. FDA. 2004. Available at: https://www.accessdata.fda.gov/cdrh_docs/pdf4/k040187.pdf.
31. Barnett GR, Taylor GI, Mutimer KL. The "chemical leech": Intra-replant subcutaneous heparin as an alternative to venous anastomosis. Report of three cases. *Br J Plast Surg.* 1989;42:556–558.
32. Robinson C. Artificial leech technique. *Plast Reconstr Surg.* 1998;102:1787–1788.
33. Eskitascioglu T, Coruh A, Ozyazgan I, et al. Salvage of venous congested flaps by simple methods. *Plast Reconstr Surg.* 2006;117:344–346.
34. MacGill KA. The "chemical leech" revisited. *Plast Reconstr Surg.* 2000;105:2272–2273.
35. Pérez M, Sancho J, Ferrer C, et al. Management of flap venous congestion: The role of heparin local subcutaneous injection. *J Plast Reconstr Aesthet Surg.* 2014;67:48–55.
36. Azzopardi EA, Whitaker IS, Rozen WM, et al. Chemical and mechanical alternatives to leech therapy: A systematic review and critical appraisal. *J Reconstr Microsurg.* 2011;27:481–486.
37. Fahmy HW, Moneim MS. The effect of prolonged blood stasis on a microarterial repair. *J Reconstr Microsurg.* 1988;4:139–143.
38. Caplin DA, Nathan CR, Couper SG. Salvage of TRAM flaps with compromised venous outflow. *Plast Reconstr Surg.* 2000;106:400–401.
39. Eker G, Akan IM, Aydoğdu E, et al. Salvage of neurocutaneous flaps with venous congestion using intravenous cannula. *Plast Reconstr Surg.* 2003;112:1191–1192.

40. Gürsoy K, Kankaya Y, Uysal A, et al. Dealing with the venous congestion of free flaps: Venous catheterization. *J Craniofac Surg.* 2008;19:1645–1647.
41. Mozafari N, Ghazisaidi MR, Hosseini SN, et al. Comparisons of medicinal leech therapy with venous catheterization in the treatment of venous congestion of the sural flap. *Microsurgery.* 2011;31:36–40.
42. Vaienti L, Gazzola R, Benanti E, et al. Failure by congestion of pedicled and free flaps for reconstruction of lower limbs after trauma: The role of negative-pressure wound therapy. *J Orthop Traumatol.* 2013;14:213–217.
43. Goldstein JA, Iorio ML, Brown B, et al. The use of negative pressure wound therapy for random local flaps at the ankle region. *J Foot Ankle Surg.* 2010;49:513–516.
44. Qiu SS, Hsu CC, Hanna SA, et al. Negative pressure wound therapy for the management of flaps with venous congestion. *Microsurgery.* 2016;36:467–473.
45. Uygur F, Duman H, Ulkür E, et al. The role of the vacuum-assisted closure therapy in the salvage of venous congestion of the free flap: Case report. *Int Wound J.* 2008;5:50–53.
46. Morgan K, Brantigan CO, Field CJ, et al. Reverse sural artery flap for the reconstruction of chronic lower extremity wounds in high-risk patients. *J Foot Ankle Surg.* 2006;45:417–423.
47. Gampper TJ, Zhang F, Mofakhami NF, et al. Beneficial effect of hyperbaric oxygen on island flaps subjected to secondary venous ischemia. *Microsurgery.* 2002;22:49–52.
48. Lozano DD, Stephenson LL, Zamboni WA. Effect of hyperbaric oxygen and medicinal leeching on survival of axial skin flaps subjected to total venous occlusion. *Plast Reconstr Surg.* 1999;104:1029–1032.
49. Nemiroff PM, Merwin GE, Brant T, et al. Effects of hyperbaric oxygen and irradiation on experimental skin flaps in rats. *Otolaryngol Head Neck Surg.* 1985;93:485–491.
50. Tan CM, Im MJ, Myers RA, et al. Effects of hyperbaric oxygen and hyperbaric air on the survival of island skin flaps. *Plast Reconstr Surg.* 1984;73:27–30.
51. Kaelin CM, Im MJ, Myers RA, et al. The effects of hyperbaric oxygen on free flaps in rats. *Arch Surg.* 1990;125:607–609.
52. Zamboni WA, Roth AC, Russell RC, et al. The effect of acute hyperbaric oxygen therapy on axial pattern skin flap survival when administered during and after total ischemia. *J Reconstr Microsurg.* 1989;5:343–7; discussion 349.
53. Vishwanath G. Hyperbaric oxygen therapy in free flap surgery: Is it meaningful? *Med J Armed Forces India.* 2011;67:253–256.
54. Kerrigan CL, Daniel RK. Pharmacologic treatment of the failing skin flap. *Plast Reconstr Surg.* 1982;70:541–549.
55. Nichter LS, Sobieski MW, Edgerton MT. Augmentation of critical skin flap survival following ibuprofen therapy. *Ann Plast Surg.* 1986;16:305–312.
56. Hwang K. Effects of nitroglycerin ointment on mastectomy flap necrosis in immediate breast reconstruction: A randomized controlled trial. *Plast Reconstr Surg.* 2016;137:747e–748e.