

The Reverse Sural Fasciocutaneous Flap in Lower Extremity Reconstruction: A Critical Review of Indications, Technical Modifications, And Clinical Outcomes

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ABSTRACT

Background: Reconstruction of soft-tissue defects in the distal third of the leg, ankle, and foot represents one of the most complex scenarios in reconstructive surgery due to the scarcity of local tissue and frequent exposure of noble structures. The reverse sural fasciocutaneous flap (RSFCF) has emerged as a robust local alternative to microsurgical free flaps.

Objective: To critically evaluate the clinical efficacy, anatomical basis, applications in special populations (trauma, diabetic foot ulcers, oncology), and the impact of surgical modifications on the survival rate of this flap through a synthesis of contemporary literature.

Materials and Methods: A systematic analysis of scientific evidence provided by recent meta-analyses, institutional comparative studies, and clinical case series evaluating the success and complication rates of classical and modified reverse sural flaps was conducted.

Results: The overall flap survival rate is approximately 95.2%, with a major complication incidence of 14.8% in its classical form, venous congestion being the primary adverse event (75.3% of complications). The implementation of technical refinements such as venous supercharging and the adipofascial variant significantly reduces overall failure rates to less than 1% and complications to 1.5% and 11%, respectively. In chronic diabetic foot ulcers, the flap achieves a weighted healing rate of 93.3%, demonstrating that factors such as active smoking and venous insufficiency are more predictive of failure than diabetes *per se*.

KEYWORDS: Reverse Sural Flap, Lower Extremity, Diabetic Foot, Venous Congestion, Surgical Modifications, Limb Salvage.

ARTICLE DETAILS

Published On:
30 May 2026

Available on:
<https://ijmscrs.com>

I. INTRODUCTION

Reconstruction of soft tissue defects in the distal third of the leg, perimalleolar region, and hindfoot historically represents one of the greatest challenges for the plastic surgeon [1,3].

The close adherence of the skin to the bony plane, along with the scarcity of underlying transposable muscle mass in this anatomical region, severely limits the options for simple randomized local or conventional rotational muscle flaps

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(such as the soleus or gastrocnemio), which remain restricted to the proximal and middle thirds of the extremity [3,6].

For decades, the gold standard for distal third defects has been microsurgical free tissue transfer. However, free flaps entail prolonged operative times, require advanced technological infrastructure (surgical microscope and specialized instrumentation), highly trained personnel, and represent a considerable metabolic burden for critical, elderly, or severely co-morbid cardiovascular patients [1,5]. In this context, the reverse-flow sural fasciocutaneous flap (RSFCF), initially described by Donski and Fogdestam in 1983 and clinically standardized by Masquelet in 1992, revolutionized the reconstructive algorithm [1,9].

This local pedicled flap offers unparalleled advantages: it does not sacrifice any of the main arteries of the limb (anterior tibial, posterior tibial, or peroneal arteries), possesses a wide arc of rotation capable of reaching the midfoot and the sole, and preserves surrounding protective tactile sensation [3,9]. Despite its popularity and the fact that its learning curve is appreciably shorter than that of a free flap, the classical reverse sural flap has historically been associated with a non-negligible incidence of venous congestion and distal partial necrosis [1,4]. The purpose of this review article is to systematically break down the essential anatomical foundations, perform a critical analysis of technical variations designed to counteract its hemodynamic failures, and evaluate its clinical efficacy in high-demand scenarios such as complex trauma, oncological resections, and diabetic foot ulcers.

II. ANATOMICAL BASES AND STANDARD SURGICAL TECHNIQUE

A. Arterial Vascularization and Retrograde Venous Return

The viability of the reverse sural flap rests upon a well-defined vascular network contained within the deep fascia of the posterior compartment of the leg [9]. The nourishing arterial supply originates from the median superficial sural artery, which runs in close association with the sural nerve and the lesser saphenous vein (LSV)



Figure 1.- Anatomic dissection of sural nerve.

[6,9]. When designing the flap with reverse or retrograde flow, the anterograde arterial flow is interrupted proximally. Perfusion of the cutaneous island becomes exclusively dependent on the anastomoses that the median superficial sural artery establishes with the branches arising from the

peroneal (fibular) artery [1,9]. These perforators emerge primarily through the posterior lateral intermuscular septum.

The anatomical literature agrees that the most distal perforator of the peroneal artery is located at an average distance of 5 to 6 cm above the apex of the lateral malleolus [1,3,9]. Consequently, this point is formally established as the indispensable **pivot point or axis of rotation** during preoperative planning. Designing the pivot point below this limit risks omitting the essential perforator, while placing it excessively proximal limits the flap's arc of rotation [9].

The true "Achilles' heel" of the flap lies in its venous drainage. Under physiological conditions, the valves of the lesser saphenous vein prevent retrograde flow (towards the foot). When inverting the flap, venous blood must overcome the resistance of these valves [1,4]. This occurs thanks to communicating collateral veins and valvular satellite veins that dilate under pressure, allowing the bypass of competent valves. If the pressure gradient is insufficient or if extrinsic mechanical compression exists, severe venous stasis ensues, triggering venous congestion, tissue hypertension, and ultimately secondary ischemic necrosis [4,8].

[Peroneal Artery] —> [Septocutaneous Perforators (5-6 cm proximal to malleolus)]

↓
▼ (Retrograde Flow)

[Median Superficial Sural Artery] —> [Fasciocutaneous Plexus of the Skin Island]

↓
▼ (Challenging Drainage)

[Lesser Saphenous Vein] —> [Overcoming Venous Valves]
—> [Potential Congestion]

B. Details of the Classical Surgical Technique

1. **Positioning and Marking:** The patient is placed preferably in the prone or lateral decubitus position.



Figure 2.- Reverse sural flap marking

A midline is drawn on the posterior aspect of the calf connecting the intercondylar space with the midpoint between the lateral malleolus and the Achilles tendon, marking the course of the sural neurovascular axis [9]. The pivot point is marked 5-6 cm proximal to the lateral malleolus.

2. **Skin Island Design:** The dimensions of the receptor defect are replicated in the middle or proximal third

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of the leg along the traced axis. The skin island can be designed with elliptical or fusiform shapes.

3. Approach and Incision:

It begins with the incision of the superior border of the skin island. Progression continues

meticulously through the subcutaneous cellular tissue until the deep fascia is identified. This is firmly incised and secured to the dermis of the skin island with absorbable



Figure 3.- Reverse sural flap dissection

sutures to prevent shearing forces from destroying the delicate fasciocutaneous perforating vessels [3,9].

4. **Pedicle Dissection:** The sural nerve and the lesser saphenous vein are identified and ligated at the proximal end of the flap [9]. Dissection progresses in a cephalocaudal direction (proximal to distal) in the subfascial plane, harvesting the fascia, fat, vein, nerve, and sural artery together. The optimal width of the fasciocutaneous pedicle must be maintained between 3.5 and 4 cm to ensure the inclusion of peripatetic vascular plexuses [3].

5. **Transposition and Inset:** Once the pivot point is reached, tissue viability is evaluated via capillary refill of the island. The flap is rotated toward the defect. The pedicle can be tunneled subcutaneously or, preferably, left exposed if the intermediate skin generates compression, being covered with a split-thickness skin graft (interpolated technique) [4].

III. CRITICAL ANALYSIS OF TECHNICAL MODIFICATIONS

To mitigate flap failure due to intrinsic hemodynamic vulnerability, modern reconstructive plastic surgery has developed well-documented technical variants. A massive meta-analysis conducted by Schmidt et al. [1], which evaluated global series totaling thousands of flaps, provided conclusive data on how surgical refinements modify the morbidity and mortality profile of the RSFCF. While the classical unmodified flap presents an overall failure rate of 5.1% and complications in 14.8% of cases, technical variants reduce the overall risk of loss to 3.2% and complications to 9.1% [1].

a) A. Adipofascial Variant



Figure 4.- Reverse sural flap inset.

The adipofascial reverse sural flap completely dispenses with the overlying skin paddle. Only the deep fascia is elevated along with a controlled layer of subcutaneous adipose tissue that protects the sural plexus [1]. The receptor bed is covered with this tissue and supplemented immediately or in a staged manner using a split-thickness skin graft (STSG) [1,9].

- **Mechanism of improvement:** By removing the rigid cutaneous component, the total volume of tissue demanding perfusion decreases drastically. Likewise, the absence of dermis reduces the intrinsic resistance to flow and allows a therapeutic venous "sweating" through the raw surface of the flap during the first 72 postoperative hours, alleviating microvascular tension.

- **Statistical results:** It registers the lowest rate of total tissue loss reported in the literature (0.7%) and a reduction of overall complications to 11.0% [1]. Additionally, it decreases the aesthetic morbidity of the donor site, allowing direct primary closure of the calf without the need for visible grafts in that area.

b) B. Venous Supercharging

This technique consists of performing a direct microsurgical anastomosis between the proximal end (now free in rotation) of the lesser saphenous vein of the flap and a patent receptor vein adjacent to the defect (for example, a collateral vein of the posterior tibial or a vein from the deep venous system of the foot) [1,4].

- **Mechanism of improvement:** It is the most pathophysiologically rational modification. By connecting the proximal end of the LSV to a low-pressure receptor system, venous flow within the flap regains its physiological anterograde direction. Drainage no longer requires overcoming venous valves retrogradely, immediately abolishing tissue congestion.

- **Statistical results:** Although it increases operative time and requires microsurgical skill, the clinical impact is radical: it lowers the complication rate to a historical minimum of 1.5%, maintaining total flap loss at a marginal 0.8% [1]. It is the strategy of choice in patients with demonstrated chronic venous insufficiency or large defects.

c) C. Surgical Delay (Sural Flap Delay) and Muscle Cuff

- **Sural Flap Delay:** Performed in two surgical stages. In the first stage (10 to 14 days prior to transfer), the cutaneous margins of the island are incised and the

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proximal sural vessels are ligated, maintaining the flap in its donor site [4,9]. This stimulates angiogenesis, dilates the vascular plexus through the distal pivot point, and conditions the tissue to relative hypoxia. It manages to reduce total failure to **3.6%**, but maintains a complication rate of **13.4%** due to the delayed management of the wounds [1].

- **Muscle Cuff:** Consists of harvesting a small portion of the gastrocnemius muscle (Al-Qattan's cuff) surrounding the perforating vessels at the origin of the pedicle to protect them against twisting or kinking [1,3]. It reduces failure to **2.6%** and complications to **5.2%** [1].

IV. CLINICAL APPLICATIONS IN COMPLEX SCENARIOS

Clinical Feature / Outcome	Traumatic Population (Clivatti et al. [3])	Diabetic Population (Yammine et al. [2])
Primary Indication	Defects due to traffic accidents, electrical trauma, acute bony/tendinous exposure.	Chronic neuropathic and neuroischemic ulcers, mal perforant, post-debridement exposure.
Success / Healing Rate	High viability (0% total loss in selected series, successful outpatient management).	93.3% definitive ulcer healing rate after transposition.
Distal Partial Necrosis	Frequent at distal ends of the skin island; resolved with conservative management.	12.0% of cases (strongly associated with systemic comorbidities).
Total Flap Necrosis	Low incidence (associated with extensive vascular trauma zones undetected).	6.6% (linked to active smoking and venous insufficiency, not isolated HbA1c).
Critical Comorbidity	Smoking, crushing of soft tissues adjacent to the pedicle.	Chronic smoking, peripheral arterial disease, advanced age (>60 years).

d) A. High-Energy Post-Traumatic Reconstruction

Trauma represents the classical indication for the RSFCF, encompassing more than 60% of clinical scenarios in hospital trauma centers [3]. Defects resulting from motorcycle collisions, pedestrian accidents, or electrical burns commonly involve open fractures (Gustilo-Anderson IIIB) with loss of periosteum or denudation of the Achilles tendon [3,5].

Institutional studies such as that by Clivatti et al. [3] demonstrate the viability of the flap in young patients with acute trauma or chronic post-traumatic sequelae. The flap provides a malleable subcutaneous cellular tissue and a cutaneous coverage resistant to shoe friction [3,6]. In these contexts, the main care lies in ensuring that the trauma zone does not extend to the posterior region of the calf, which would compromise the bed of the sural pedicle or inactivate the critical peroneal perforators [3,9].

e) B. The Paradigm Shift in the Diabetic Foot

Traditionally, the presence of diabetes mellitus was considered a relative or absolute contraindication for the use of local pedicled flaps in the lower limb due to underlying microangiopathy and the risk of peripheral arterial disease (PAD). However, contemporary meta-analysis by Yammine et al. [2] has revolutionized this concept by providing convincing empirical evidence:

1. **Effective Salvage Rate:** The RSFCF achieves a weighted healing rate of **93.3%** in the coverage of complex chronic diabetic foot ulcers (including those with mild-to-moderate bone or tendon involvement) [2].
2. **Risk Factor Analysis:** The isolated presence of diabetes does not statistically increase flap loss. Multivariate analysis demonstrates that the true increase in total (**6.6%**) and partial (**12.0%**) necrosis rates is heavily conditioned by three factors: **active smoking, pre-existing deep venous disease, and advanced age (>60 years)** [2,5].
3. **Reconstructive Advantage:** Compared to simple randomized local flaps, the reverse sural flap provides a thicker adipose cushion, essential for resisting hydrodynamic loading forces on the sole of the foot and calcaneus, drastically decreasing ulcer recurrence rates [2].

f) C. Reconstruction of Oncological Defects

In the field of cutaneous oncological surgery, the resection of aggressive malignant tumors (mainly malignant melanoma and squamous cell carcinoma) on the sole of the foot, heel, and malleolar region demands wide three-dimensional surgical margins [7]. This generates extensive defects that expose underlying bony structures.

Talukdar and colleagues [7] documented an important retrospective series of reconstructions with RSFCF following oncological resections, where **61.5%** of cases corresponded to melanomas located primarily on the heel (42.3%) and the plantar region (26.9%). The sural flap proved to be a highly viable and oncologically safe alternative, avoiding major amputations (infrapatellar) and allowing patients to resume ambulation and weight-bearing quickly, which is critical to avoid delaying adjuvant therapies such as systemic chemotherapy or immunotherapy [7].

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V. DISCUSSION AND COMPLICATION MANAGEMENT.

Success in executing the reverse sural flap depends both on technical skill in subfascial dissection and immediate postoperative vigilance. It must be understood that venous congestion represents 75.3% of all complications recorded in the literature [1,4].



Figure 5.- Peripheral necrosis of reverse sural flap

II. A.

Clinical Diagnosis of Venous Congestion vs. Arterial Ischemia

- **Venous Congestion:** The flap becomes edematous, purplish, or frankly cyanotic. Capillary refill becomes hyperdynamic (less than 1 second), and bleeding upon fine-needle puncture is dark/venous immediately.
- **Arterial Ischemia:** The flap appears pale, cold to the touch, with sluggish or absent capillary refill (greater than 3 seconds) and an absence of bleeding upon puncture.

III. B. Postoperative Prevention and Management Algorithm

1. **Positioning:** The patient must be maintained in the prone or supine position with the affected limb elevated between 15 and 30 degrees, ensuring there is no direct pressure on the posterior aspect of the ankle (pedicle rotation site).
2. **Open Track Design:** Avoid blind subcutaneous tunneling at all costs if the patient's skin is rigid or the cellular tissue is dense. It is preferable to open the intermediate skin bridge or utilize the interpolated flap technique [4,9].
3. **Leech Therapy (Hirudotherapy) / Scarification:** In case of established venous congestion in the first 48 hours, chemical scarification or selective suture removal in the distal zone decreases mechanical tension.
4. **Ex Tempore Microsurgical Rescue:** If the flap presents massive refractory congestion in the first few hours, the patient must be re-explored in the operating room to perform emergency venous supercharging of the lesser saphenous vein [1,4].

CONCLUSIONS

The reverse-flow sural fasciocutaneous flap is consolidated as a highly reliable, reproducible, and essential technique in the training of the plastic surgery resident. With an overall survival rate exceeding 95%, its capacity to provide stable coverage in the distal third of the leg and foot without

sacrificing main arterial axes places it as an irreplaceable step prior to the need for free flaps.

The technical modifications analyzed critically—particularly the adipofascial flap and venous supercharging—elegantly resolve the flap's biological propensity for venous congestion, lowering morbidity rates to minimal ranges. Finally, the robust 93.3% healing rate demonstrated in diabetic foot ulcers overturns old medical dogmas, confirming that, under proper vascular evaluation, the reverse sural flap is a first-line tool for limb salvage in chronic patients.

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