Technique Report

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Simplified soft tissue coverage of the distal lower extremity: The reverse sural flap

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Summary:
Soft tissue defects involving the distal lower extremity present challenging problems for orthopaedic surgeons to manage. Historically, wounds not amenable to primary closure have necessitated assistance from multidisciplinary teams using plastic surgeons to obtain adequate soft tissue coverage through rotational flap or free tissue transfer procedures. Techniques related to soft tissue rearrangement and local rotational flap coverage have advanced over the years with a growing knowledge of local anatomy and vasculature. The reverse sural flap may be performed to cover soft tissue defects within 10 cm of the foot or ankle region, negating the need for microvascular intervention. The simplistic nature of the reverse sural flap is appealing to orthopaedic surgeons as a means to provide timely patient care without additional support because it does not require microvasculature work or the need for intraoperative microscopes and has been popularized among orthopaedic trauma surgeons as a necessary tool to possess. Here, we discuss the reverse sural flap to include history, relevant anatomy, clinical indications, and a description of the technique for application.

Key Words: rotational, flap, reverse, sural, soft, tissue, coverage

1. Introduction

The need for soft tissue coverage within the realm of orthopaedics is broad and may be required when treating a variety of diagnoses to include open fractures, degloving injuries, and musculoskeletal infection/tumors. Orthopaedic surgeons are not traditionally trained in advanced soft tissue coverage using rotational flaps and may enlist the assistance of plastic surgeons when indicated. Delays in flap coverage of greater than 7 days have shown significant increase in complication rates leading to deep infection, osteomyelitis, and infection.[1] Aggressive collaborative approaches between orthopaedic and plastic surgeons to provide rapid coverage completed in a single stage at the time of fixation have shown reassuring outcomes, minimizing complications when performed within 72 hours of injury.[2] It is well-established that reduced time to surgery helps reduce complication rates; however, immediate collaboration between surgical services may not always be feasible secondary to factors such as operating room capacity and surgeon availability.[1] Issues such as these can lead to a delay in flap coverage, often at the expense of patient care.

Orthopaedic surgeon acquisition of further skill in soft tissue coverage may negate issues associated with collaborative efforts and lead to decreased time to flap coverage. When treating wounds of the distal leg, the reverse sural flap (RSF) has gained popularity among orthopaedic surgeons as the technique negates the use of microsurgery or microscopes and may be completed under 2 hours.[3,4] The RSF can reliably be applied by nonplastic surgeons with outcomes similar to standards reported in the literature.[5] Surgeons who have learned and applied the RSF have reported ease of technique acquisition and commented on the usefulness of the RSF when plastic surgeons are not available.[5]

2. History

Free flaps were previously the preferred management choice for distal leg soft tissue reconstruction throughout the 1980s, although their usage has been challenged and trending downward largely in part due to the introduction and increasing popularity of the RSF.[6] Based along a distal donor site, commonly used free flaps for the distal lower leg include gracilis, latissimus dorsi, and anterolateral flaps.[7,8] The use of free flaps may create a bulky appearance about the application site that is not esthetically appealing to patients. Unlike free flaps, local flaps such as the RSF do not require the presence or assistance of a microsurgeon and generally require a shorter operative duration.[9] Both local rotational flaps (RSF) and free flaps share a similar complication profile to include marginal necrosis, venous congestion, arterial occlusion, infection, donor site morbidity, and, most devastatingly, flap loss. However, studies have shown the degree of complication severity to be decreased when performing a RSF relative to those encountered with free tissue transfer.[6,10–12] Free flaps are noted to have a higher degree of donor site morbidity, and the literature suggests that flap necrosis occurs more often in free flaps than local flaps.[6,9] While necrosis

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of any flap is undesirable, necrosis of a RSF limits donor site morbidity as the flap does not involve the underlying muscle tissue.

The basis of a local flap relies on the movement of tissue around a pivot point and requires an intact blood supply that is preserved in the setting of injury. Local flaps can be divided into subcategories based on their blood supply. The random pattern cutaneous flaps lack a specified vessel and rather rely on many smaller unnamed vessels. These flaps are limited by their arc of rotation, decreased bacterial resistance, and their nonadherence to the 2:1 ratio rule, which suggests that a flap should be designed with a 2:1 length: width ratio on the trunk and extremities.[13,14] The axial flap has a named vessel and allows a longer flap reach, often incorporating muscle tissue into the flap.[13] Muscle rotational flaps are difficult in the distal leg because of the limited thickness and availability of muscle tissue in this region and subsequent lack of coverage offered by the flap.[15]

The RSF is a neurofasciocutaenous flap that has proven useful in the coverage of soft tissue defects in the distal 1/3rd of the lower leg, including the ankle and posterior heel.[16] The fasciocutaneous flap technique was introduced in 1981 for lower leg tissue reconstruction, and the technique was expanded on in 1992 with the inclusion of the sural nerve.[15,17] A rotational component was then added in 2004, allowing for easy 180-degree rotation.[18] Being a perforator flap, the RSF relies on blood supply stemming from the deep vasculature.[19] Thus, one huge benefit offered by the RSF is a constant blood supply that does not sacrifice a major artery of the lower limb.[20]

3. Anatomy

The prominent neurovascular structures included within the RSF are the sural nerve, superficial sural artery, and lesser saphenous vein.[21] The sural nerve is a cutaneous nerve that is typically formed from the merging of the medial sural cutaneous nerve and the lateral sural cutaneous nerve, which arises from the tibial nerve and common peroneal nerve, respectively.[22] The sural nerve can be found running between the 2 heads of the gastrocnemius muscle and descending into the deep fascia of the middle third of the leg.[17] The vascular supply to the RSF is primarily from distal septocutaneous perforators that arise laterally from the peroneal artery and the middle sural artery with the most distal perforator reliably found 5 cm proximal to the tip of the distal fibula.[4,23] The venous drainage of the RSF is accomplished through the lesser saphenous vein.[24]

4. Clinical Indications

The RSF is useful in reconstruction of the lower third leg, heel, malleoli, and hind foot defects.[3] Traumatic wounds are consistently the most common reason for using the RSF, followed by burns, scarring, and ulcers.[25] In addition, the RSF has been used to cover wounds originating from pathologies including oncologic, pressure sores, diabetic foot, infection, and peripheral vascular disease (PVD).[25] Higher risk populations include patients with diabetes mellitus, PVD, venous insufficiency, and the elderly.[10,26] Comorbidities must be considered when selecting patients for RSF coverage because those with diabetes mellitus, PVD, or venous insufficiency have been reported to experience complication rates as high as 30%.[26] In addition, a large meta-analysis showed that patients with venous insufficiency could have up to nine times the risk of developing a complication as compared with those without venous insufficiency.[10] These patients are particularly high risk given increased venous congestion, which is often followed by complete or partial flap loss.[26] Although complications are more common in these populations, the long-term outcomes of the flap are not always affected because the flap may remain salvageable when complications are detected early.[27] Doppler ultrasound or angiography can be used before surgery to assess the patency of the vessels to aid in determining the degree of risk.[28]

A clear assessment of a wound after a thorough debridement and irrigation should be completed to determine the appropriate mode of coverage. The degree of soft tissue damage (size, depth, and location), available vasculature to the area, and esthetic outcome should all be considered.[29,30] Smaller wounds may be amenable to primary closure or healing by secondary intention.[29] Split thickness skin grafts (STSGs) may be used in the setting of larger defects that do not include exposure of underlying tendon or bone.[29,31] It is important to note that a STSG does not provide additional blood supply to the wound bed and should generally not be used to cover poorly perfused wounds.[29] Soft tissue flaps are indicated for deep wounds in which there is underlying tendon, bone, joint, prosthesis, or other implants exposed.[30] The RSF has been widely used for the treatment of soft tissue defects within 10 cm of the foot and ankle region. The RSF may be used to cover large surface area with published flap dimensions averaging 8.8 cm × 5.6 cm, although the authors have reported successful application of flaps up to 12 cm × 18 cm in size.[9,27]

5. Technique

The patient is placed in the prone position on a regular operating room bed. As an alternative, the patient may be placed in the lateral decubitus position and access to the medial side can be obtained through external rotation of the hip. The thigh should be prepped into the surgical field for skin grafting near the conclusion of the procedure. After the surgeon's preferred prep and drape, exsanguination and a sterile tourniquet may be used for improved visualization. The wound bed is debrided of any fibrinous exudate, and the wound is measured at both its widest and longest dimensions to determine the size of the flap required (Fig. 1). The entry point for the flap in the wound bed is chosen. The ideal entry point is typically located so that the flap rotates medially into the wound, at a point where the elliptical shape of the flap can be rotated into the wound bed and best match the wound dimensions. Once the entry point is known, the tip of the lateral malleolus is identified and marked. A transverse line 5 cm proximal to the tip of the lateral malleolus is drawn on the skin. This line represents the point with which no further distal dissection should occur as it marks the most distal extent of the peroneal perforators and marks the pivot point of the pedicle and flap.

Next, the pedicle length is determined. The ideal pedicle length is such that there is sufficient excursion for rotation of the flap into the wound bed to avoid tension on the blood supply, but not excessive length as to avoid redundancy, which may be symptomatic. To determine an appropriate length of the pedicle, the distance from the entry point at the wound bed to the midline of the leg is determined with a ruler. Add 1 cm to this length to determine the length of the pedicle that is required for flap rotation. The addition of 1 cm to the measurement allows for decreased tension on the pedicle during flap rotation. If the flap is required to rotate 180 degrees to inset into the wound, additional length will be required and 1.5 cm is added to the measured length instead. Intraoperatively, the flap shape and pedicle length can be traced onto sterile glove paper or other sterile packaging, and rotation can be practiced before making incisions to ensure the pedicle length is accurate (Fig. 2A).

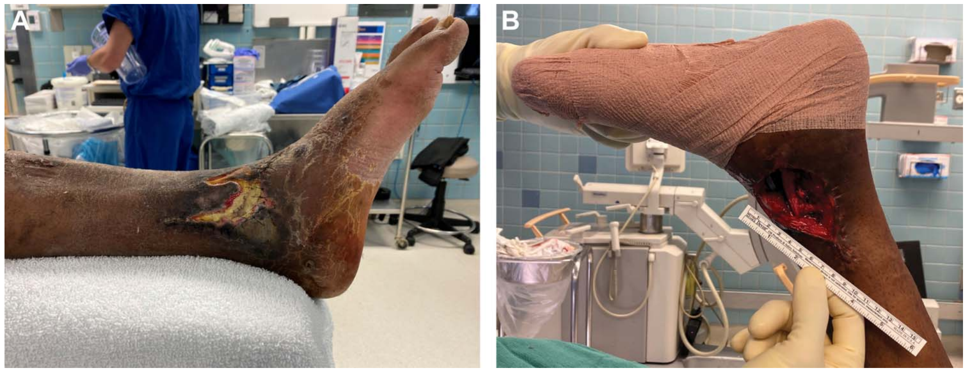

FIGURE 1. A 31-year-old man undergoing limb salvage through plate-assisted bone segment transport to an ankle arthrodesis after sustaining a left type IIIB open pilon fracture with significant bone and articular cartilage loss. A, Anteromedial ankle wound with skin necrosis at the traumatic wound site. Patient positioning: Supine. B, Wound appearance after debridement and irrigation. No signs of infection were encountered, and the wound was deemed appropriate for coverage. The patient was indicated for reverse sural flap given exposed tendon and bone. Patient positioning: Prone.

Now that the required pedicle length is known, the complete flap can be drawn onto the skin (Fig. 2B). The midline of the leg is identified and marked with a dashed line to maintain orientation throughout the procedure. Using the pedicle length as determined previously, the inferior boundary of the flap is noted and marked. As an example, if the measurement from the midline to the entry point of the flap was noted to be 4 cm, after adding 1 cm for flap rotation, a point 5 cm above the pivot point would mark the inferior boundary of the flap. Next, the previous wound bed measurements are used to create the skin paddle, which will be the source of soft tissue coverage for this technique. The flap is designed and marked on the skin so that the longest measurement is located along the vertical axis of the limb and the widest measurement is in the horizontal axis of the limb, forming an elliptical shape along the long axis of the limb. Finally, the skin flaps over the pedicle are created by drawing a line from the most inferior edge of the flap to the pivot point. The pedicle width is 2 cm on either side of midline, which will be marked with a solid line.

A pedicle width of 4 cm is preferable to avoid iatrogenic injury to vessels, leaving 2 cm on each side of midline. A midline incision is made from the most inferior aspect of the flap to the pivot point of the flap, which was determined in previous steps. Keep in mind that the pivot point needs to be no lower than 5 cm above the tip of the lateral malleolus to ensure there are peroneal perforators supplying reversed inflow to the flap. This incision is made through the epidermal and dermal layers only, ensuring that subcutaneous fat remains with the pedicle. The skin flaps are developed 2 cm from midline both medially and laterally along

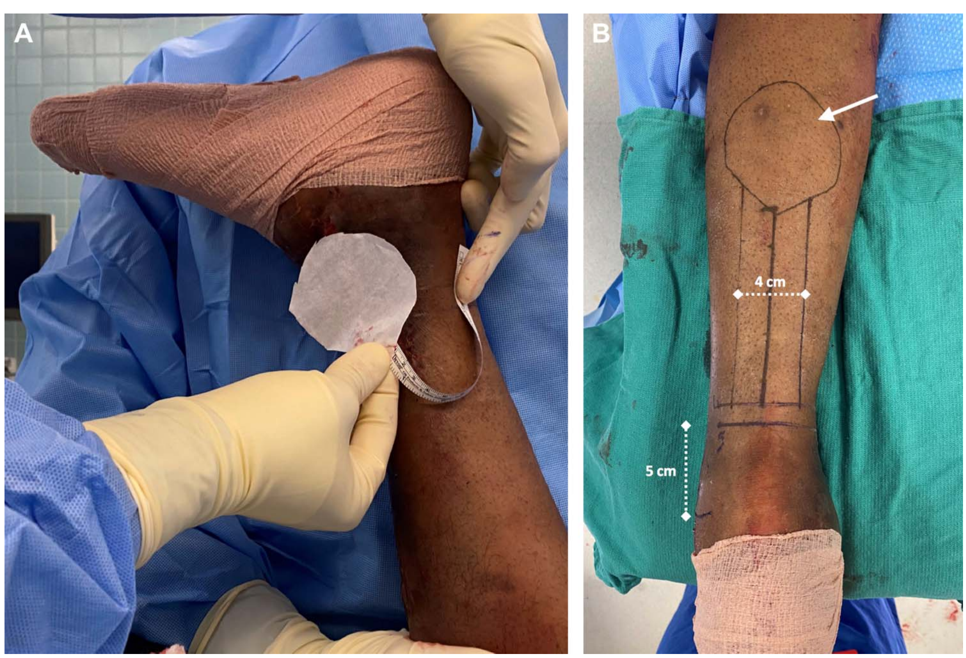

FIGURE 2. Determination of pedicle length. A, A sterile flexible ruler is used to template the necessary pedicle length for rotation of the desired flap. Appropriate slack must remain in the pedicle to negate kinking of the vascular supply originating from the lateral ankle. B, Donor site planning. Pedicle dissection should begin at a minimum of 5 cm above the tip of the fibula to avoid injury to the lateral perforators. Pedicle width is drawn to 4 cm and marked proximally to the previously determined length. Flap paddle (arrow) dimensions are traced using the paper template at the proximal extent of the pedicle.

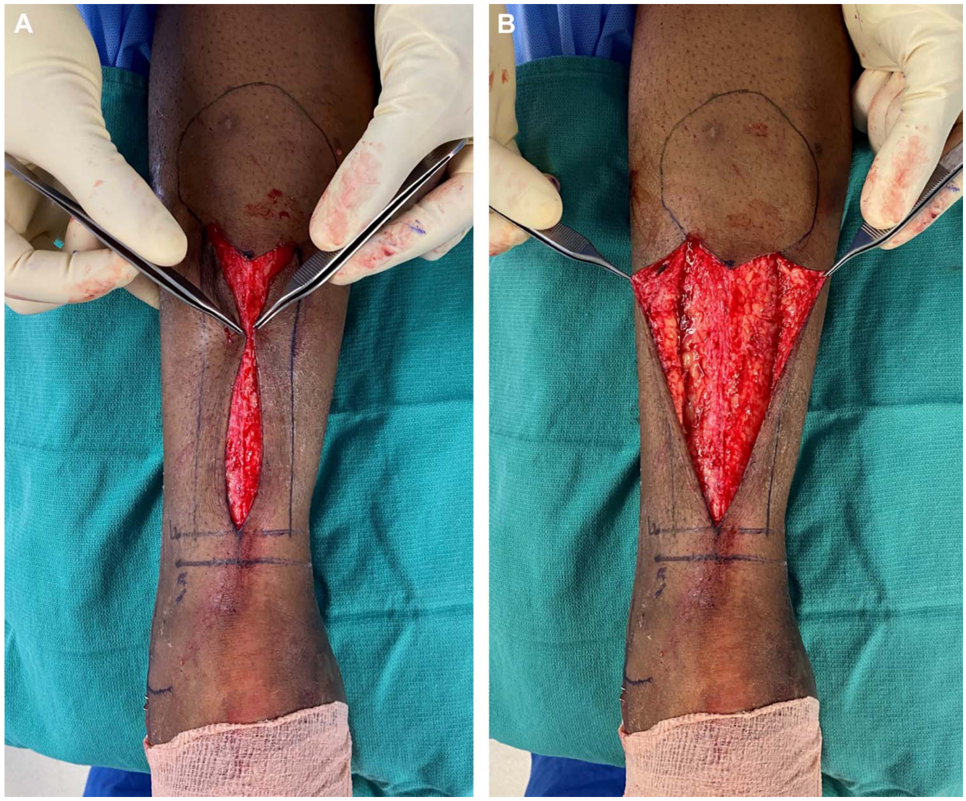

FIGURE 3. Skin is incised (A) longitudinally along the central aspect of the pedicle with (B) subsequent elevation of subdermal skin flaps using a knife.

the length of the pedicle (Fig. 3). It is preferable to have several new scalpel blades available and change frequently to assist with dissection. If the surgeon notes adherent subcutaneous fat with the skin layer, this is indicative of a dissection that has been carried too deeply and correction must be performed to continue in more superficial layers. Conversely, if dissection is performed too superficially, this will result in buttonholing of the skin.

The flap is then raised by incising the marked edges, taking care to note the sural artery and vein will be located at the superior margin of the flap in the midline (Fig. 4A–B). Once dissected bluntly with Metzenbaum scissors, the artery and vein may be clipped or tied per the surgeon's preference. The nerve should be sharply divided through traction neurolysis. When dissecting the flap distally, care must be taken to avoid truncating the flap from the pedicle, which will be found at the inferior margin of the flap. During dissection of the flap, the surgeon must ensure that the skin, subcutaneous tissue, and fascia are incised without beveling the margins. The flap must be handled gently with the surgeon's fingers, with no retractors used. The flap is then elevated with blunt dissection, using the surgeon's fingers and a lap sponge to separate the fascia from the underlying adventitial layer. The paratenon over the gastrocnemius is left intact. The skin, subcutaneous tissue, and fascia will then be elevated bluntly as a unit. If there is preoperative concern regarding blood supply to the flap or in the event the patient has previous lateral incisions or lateral ankle exposures, the flap can be drawn out, raised, and then simply sutured back down and the operation completed. If the blood supply to the flap remained adequate after the flap was viable after 10–14 days, the surgeon can then proceed with continuing the flap rotation as a second stage procedure.

The next step is to dissect the pedicle from adjacent tissue along its length (Fig. 4C–D). This can be performed with Bovie electrocautery or Metzenbaum scissors. If scissors are selected, care should be taken to cauterize bridging vessels as dissection is performed. The pedicle is dissected from its origin at the flap beginning proximally, down to the pivot point, again ensuring to remain at least 5 cm proximal to the tip of the lateral malleolus. The skin over the pedicle origin will be primarily closed with staples or simple interrupted sutures at the end of the procedure.

Now that the flap and pedicle are both dissected, the flap may be rotated into position (Fig. 5). The flap may either be tunneled under the skin into position or an incision is made so that there is no tension over the pedicle. If tunneling is performed, care must be taken to ensure there are no areas of constriction of the pedicle. Once the flap is rotated into position, the periphery of the flap is sutured into place with 2-0 nylon suture spaced 1–1.5 cm apart (Fig. 6A). If the donor site is small enough (as is the case with a small-sized flap), primary repair of the donor site may be performed. Owing to the elliptical shape of the flap, dog ear correction will be required. In cases of a larger flap, the donor site may be covered with STSG (Fig. 6B). In either case, a STSG is required over the exposed pedicle. The skin graft may be obtained from the lateral thigh and stapled into place, ensuring the staples do not pierce the pedicle itself when securing the skin graft.

Postoperative dressings are then placed. The flap can then either be covered with a bolster dressing or a vacuum-assisted closure device. A bulky splint may be applied, with care taken to make sure that there are no areas of constriction over the flap or pedicle. Alternatively, an ankle-spanning external fixator with heel "kickstand" may be placed to ensure no pressure is placed

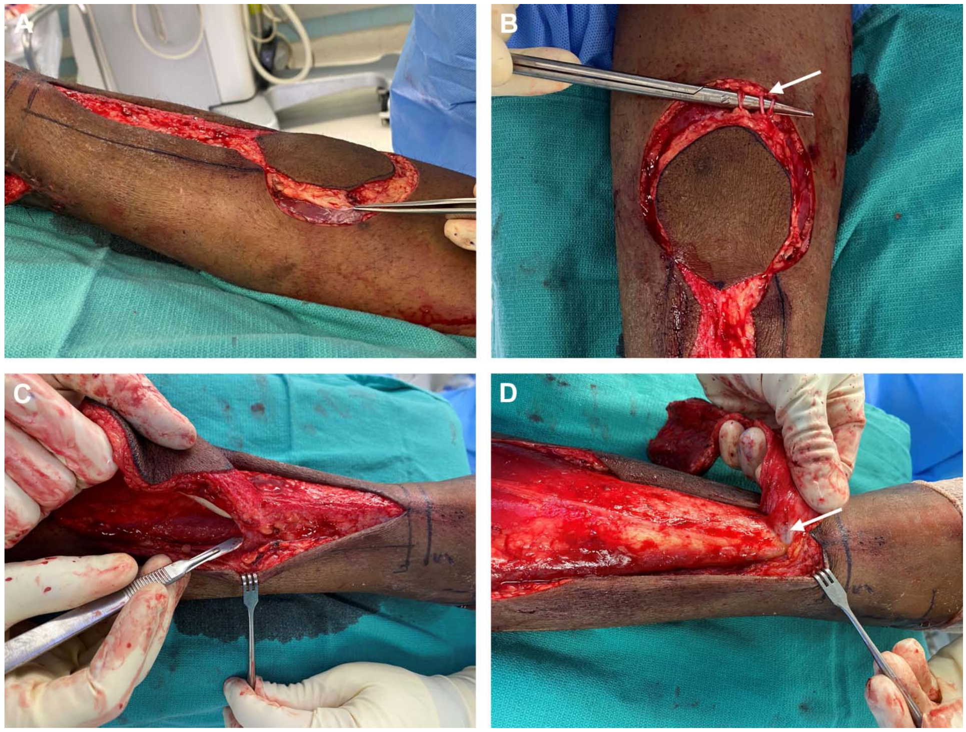

FIGURE 4. Flap dissection. A, The flap paddle is elevated subfascially taking care to remain within the fascial plane. B, The proximal sural neurovascular bundle (arrow) enters along the superomedial aspect of the flap paddle and is transected. C, Subfascial dissection is continued distally along the pedicle, maintaining a 4-cm pedicle width. D, Vascular branch of the peroneal perforator (arrow) visualized laterally at the distal extent of the pedicle.

over the flap and pedicle. If negative pressure wound therapy is used for the STSG, it should be removed in 4–7 days. The patient then returns to clinic for a wound check in 2 weeks. At that time, the splint and dressings are removed. Nonstick dressings may be applied, and the flap redressed. The sutures around the flap itself remain for an additional 2 weeks to ensure ingrowth into the flap from the periphery. Weight bearing status is determined by the location of the flap and the surgeon's preference or any underlying fracture fixation.

6. Discussion

Distal lower leg reconstruction continues to pose a challenge to orthopaedic surgeons because of the weight-bearing requirement, lack of musculature in the region, and limited skin mobility.[18] The extremity must remain functional, and although esthetic appearance is not the main priority, it is important that the foot at least remains able to fit in a shoe.[8] When soft tissue wounds are not appropriate for primary closure or STSG, the RSF provides a reliable option for reconstruction of the lower extremity with flap

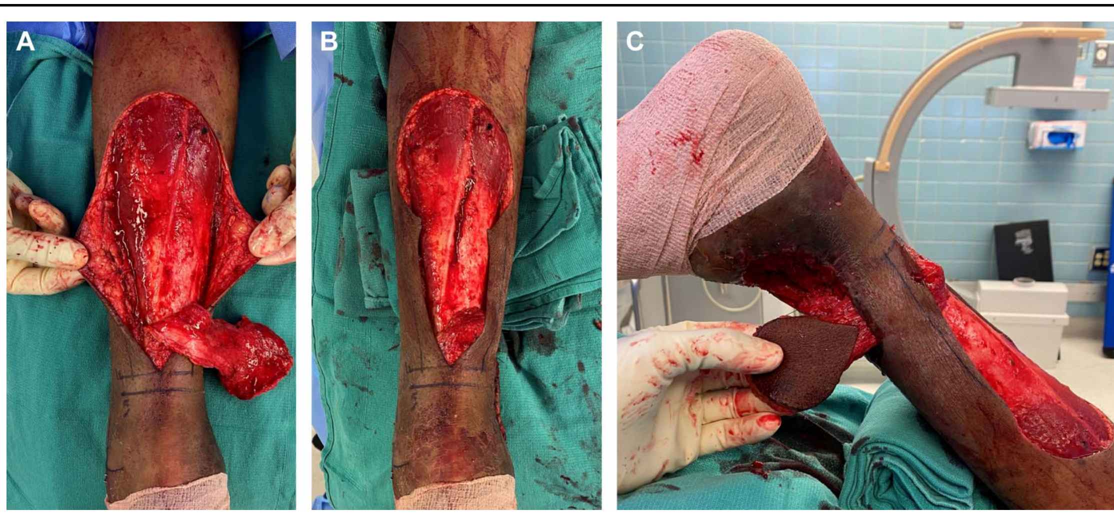

FIGURE 5. Rotation of reverse sural flap after completed dissection. (A) Appearance of donor site and flap after completed dissection. (B–C) The flap paddle and pedicle are tunneled medially under a skin bridge and placed over the wound bed. Tunneling should be avoided in the event undue tension is placed across the pedicle, in which case the skin should be incised to preserve the vascular supply.

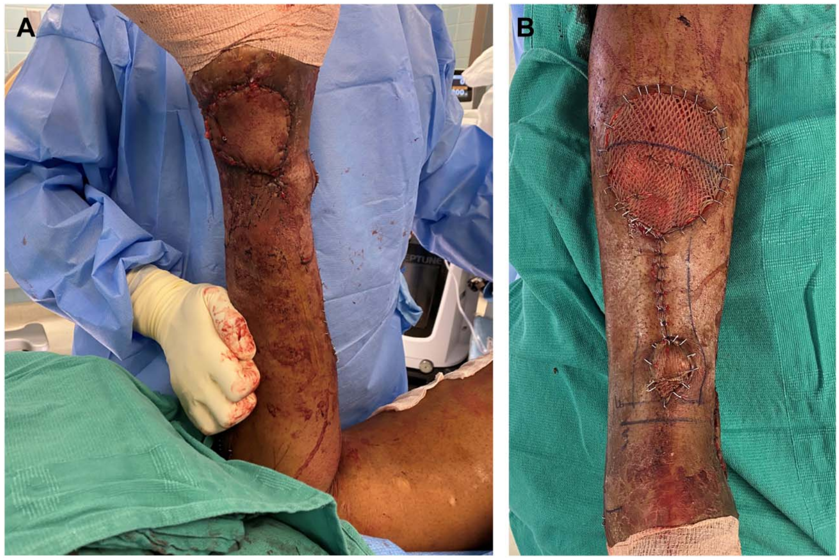

FIGURE 6. Final appearance of wound after reverse sural flap placement. A, The flap paddle is secured in place over the wound bed using a combination of 3-0 nylon and 3-0 chromic suture. B, Skin amenable to primary closure is closed using suture. Split thickness skin graft is harvested to provide coverage over the flap paddle donor site and distal pedicle. A wound vacuum dressing is applied over the flap and donor site.

survival rates reported at 95.2%.[9] A 2022 international meta-analysis reviewing 2592 RSF applications revealed an overall all type complication rate of 25.19%, although total flap necrosis, the most devastating complication, was only observed in 2.51% of patients.[25] These values are consistent with a separate systematic review and pooled analysis completed in 2014, showing an overall RSF complication rate of 26% and 3.2% incidence of total flap necrosis.[10] The most commonly encountered complication of RSF has been reported to be partial flap loss (7.87%), followed by venous congestion (3.05%). In the presence of complications, early detection is crucial in permitting surgeons to salvage the flap and preserve end outcomes.[25]

Several recent modifications to the RSF technique, such as supercharging, flap delay, wide pedicle harvest, and adipofascial flap, have aimed to increase the reliability of the RSF by improving venous flow, thus aiding in prevention of venous congestion.[9,32–34] The literature has shown decreased complication rates with incorporation of the supercharging technique (1.5%) relative to the unmodified RSF (14%), supporting the use of supercharging when managing high-risk patients.[9] In addition, although complication rates are equivalent when applying the adipofascial flap, some data suggest that it is an easier, faster, more aesthetically appealing option when compared with the classic RSF technique.[33] Overall, the RSF shows promise as a highly resourceful technique to orthopaedic surgeons that is simplistic in nature, avoids the use of microsurgery, and allows for timely wound coverage application geared toward improving patient outcomes.

7. Conclusions

The RSF is a relatively simple technique the can be used by orthopaedic surgeons to assume full patient care without the need for microvascular techniques when managing patients with soft tissue defects about the lower leg.

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