OPEN

ORIGINAL ARTICLE

Reconstructive

The Reverse Superficial Sural Artery Flap Revisited for Complex Lower Extremity and Foot Reconstruction

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Background: Soft-tissue defects of the distal lower extremity and foot present significant challenges to the reconstructive surgeon. The reverse superficial sural artery flap (RSSAF) is a popular option for many of these difficult wounds. Our initial experience with this flap at multiple institutions resulted in a 50% failure rate, mostly because of critical venous congestion. To overcome this, we have modified our operative technique, which has produced a more reliable flap.
Methods: All patients reconstructed with an RSSAF between May 2002 and September 2013 were retrospectively reviewed. In response to a high rate of venous congestion in an early group of patients, we adopted a uniform change in operative technique for a late group of patients. A key modification was an increase in pedicle width to at least 4 cm. Outcomes of interest included postoperative complications and limb salvage rate.
Results: Twenty-seven patients were reconstructed with an RSSAF (n = 12 for early group, n = 15 for late group). Salvage rate in the early group was 50% compared with 93% in the late group ($P = 0.02$). Postoperative complications (75% vs. 67%, $P = 0.70$) were similar between groups. Venous congestion that required leech therapy was 42% in the early group (n = 5) and 0% in the late group ($P = 0.01$).
Conclusions: Venous congestion greatly impairs the survival of the RSSAF. A pedicle width of at least 4 cm is recommended to maintain venous drainage and preserve flap viability. *(Plast Reconstr Surg Glob Open 2015;3:e519; doi: 10.1097/GOX.0000000000000500; Published online 22 September 2015.)*

The distal lower extremity and foot have long been recognized as problematic areas for reconstruction. Unreliable blood supply and paucity of local donor tissue often preclude the use of local and regional flaps. As a result, free tissue transfer has become the mainstay of treatment for the traumatized lower limb over the past few decades.[1,2] Goals of reconstruction are to provide stable soft-tissue coverage, preserve plantar sensation, and allow for bipedal ambulation with normal weight bearing. Although free tissue transfer permits the movement of composite tissue to meet the specific needs of the defect, drawbacks to this procedure include longer operative times, potential donor site morbidity, and the requisite for qualified surgeons with microsurgical experience.[3] Reliable alternatives are beneficial to shorten operative times and to accommodate those cases in which

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Received for publication November 22, 2015; accepted July 27, 2015.

DOI: 10.1097/GOX.0000000000000500

Disclosure: *The authors have no financial interest to declare in relation to the content of this article. The Article Processing Charge was paid for by the authors.*

either the patient is not an appropriate surgical candidate or free tissue transfer cannot be performed.

The reverse superficial sural artery flap (RSSAF) is a distally based fasciocutaneous or adipofascial flap that is increasingly being used for coverage of defects that involve the distal third of the leg, ankle, and foot. First described by Donski and Fogdestam[4] and later championed by Masquelet et al,[5] the RSSAF has become a popular option for many of these difficult wounds. A significant advantage of this flap is a constant blood supply that does not require sacrifice or manipulation of a major artery to the lower limb.[6] Touted for its reliability and ease of dissection, the RSSAF is often reputed to have a favorable complication profile as evidenced by a recent meta-analysis that found 82% of flaps heal without any flap-related complications.[7] However, the RSSAF is often at risk for venous congestion, as it relies on communication between the venae comitantes of the sural nerve and the lesser saphenous vein, thus circumventing the valves of the deep venous system.[8] A growing consensus among reconstructive surgeons is that impaired venous drainage of the RSSAF is one of the preeminent factors that contribute to flap necrosis in the early postoperative period.[7,9] It has been shown that flap survival was improved by various modifications to the operative technique that enhanced venous outflow of the RSSAF, and that these changes reduced the use of leech therapy.[7,10–16]

A number of studies have established the utility of the RSSAF in lower extremity and foot reconstruction over the past 30 years.[9,17–23] Despite promising results from these early reports, our initial outcomes with the RSSAF, as performed by 6 fellowship-trained microvascular surgeons, were discouraging. We observed a high rate of venous congestion in an early group of patients, who did not respond to traditional rescue therapies of leg elevation and leech application (Fig. 1).

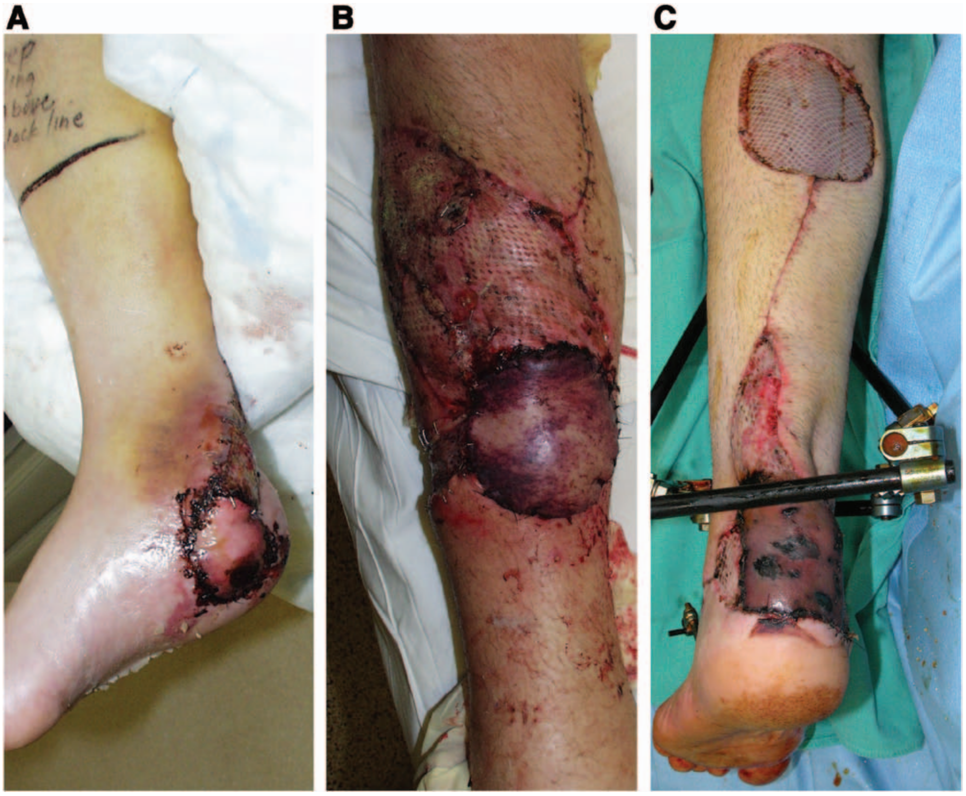

Fig. 1. Representative flaps requiring leech therapy for critical venous congestion. (A) Partial flap loss because of venous congestion of an island-type reverse superficial sural artery flap (RSSAF) to the heel in a patient with an open calcaneal fracture. After leech therapy and partial debridement, wound closure was achieved with negative pressure therapy. (B) An anterior leg defect overlying a grade IIIB tibial fracture was reconstructed with an island-type RSSAF after a previous soleus muscle flap had failed. Venous congestion plagued this reconstruction. (C) An island-type RSSAF was used for coverage of a posterior heel defect in a patient with a soft-tissue degloving injury. Leech therapy instituted in the early postoperative period for venous congestion was unsuccessful. Eighty percent of the flap was debrided, and the wound was closed with a split-thickness skin graft.

Before abandoning use of the flap, we discussed this common issue among several surgeons from different institutions, and a few modifications were made to our operative technique. We hypothesized that increasing pedicle width would enhance venous drainage and improve flap survival. Herein, we describe our early experience with the RSSAF that resulted in a significant number of flap failures and the subsequent changes we made that led to better outcomes.

METHODS

Study Design

Following institutional review board approval, a database search was completed to identify all patients who underwent reconstruction of distal lower extremity and foot defects with an RSSAF between May 2002 and September 2013. Six fellowship-trained microvascular surgeons at 2 separate institutions performed all the reconstructions. Patients who required multiple flaps or patients who had a prior surgical delay procedure were excluded from the analysis. After the collective realization that 50% of the initial flaps failed, primarily because of venous congestion, the surgeons adopted a uniform change in RSSAF design and dissection. A key modification to the flap was an increase in pedicle width to at least 4 cm (Fig. 2). In addition, a majority of the surgeons eliminated the island-type design in favor of either a full fasciocutaneous or adipofascial flap design. Differences in outcomes between the early and late groups of patients were compared to determine if these modifications resulted in improved flap survival. Patient demographics, mechanism of injury, defect size, operative time, and postoperative complications were extracted from the clinical record. Postoperative complications were defined as any untoward event that occurred within 30 days of the procedure and required either medical or surgical intervention. Venous congestion was only considered a complication if leeches were required. Failure of the RSSAF was determined by the use of additional procedures to assist in closure of the defect such as another flap, skin graft, or use of a vacuum-assisted closure device or if amputation was performed.

Operative Technique

The patient was placed in the prone or lateral decubitus position. Perforating vessels from the peroneal artery were then identified by Doppler ultrasonography along the posterolateral intermuscular septum of the lower leg. Typically 2–5 perforators were found at an average distance of 5–7 cm proximal to the lateral malleolus. A line was drawn from the popliteal fossa to the lateral malleolus to approximate the vascular axis of the flap. A template of the defect was used to position the flap along this axis, such that the distance from the chosen pivot point to the end of the flap was just greater than the distance from the pivot point to the farthest edge of the defect.

The pedicle of the RSSAF contains the sural nerve, median superficial sural artery, and lesser saphenous vein. The sural nerve transmits sensory information from the posterolateral aspect of the lower leg and lateral foot and is formed by the confluence of the

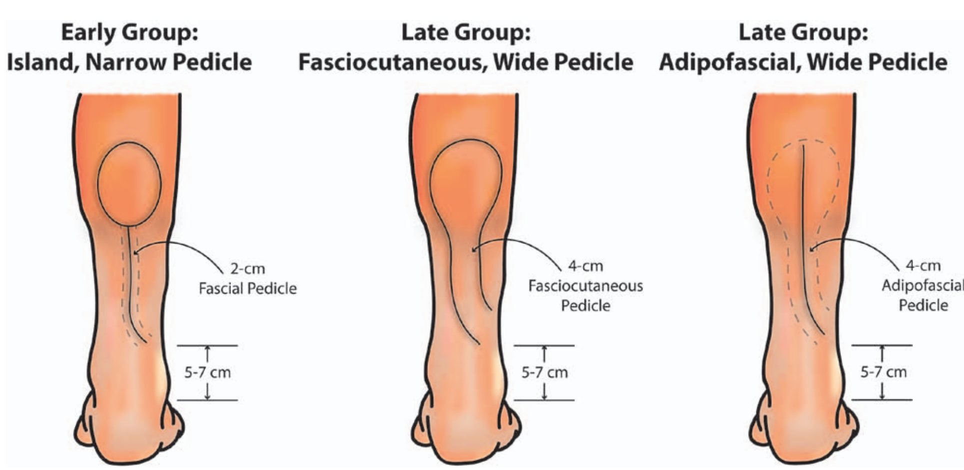

Fig. 2. Changes in flap design between the early and late groups of patients. Before July 2004, the reverse superficial sural artery flap (RSSAF) was raised as an island flap with a 2-cm fascial pedicle. After July 2004, a 4-cm pedicle was used for all flaps. The majority of flaps in the late group of patients incorporated either a fasciocutaneous pedicle overlying the nerve and vessels or the flap was raised entirely as an adipofascial flap. The pivot point for all flaps was positioned 5–7 cm above the lateral malleolus. Solid black lines indicate placement of the incisions, whereas dashed gray lines demonstrate the extent of flap or pedicle dissection.

medial and lateral sural cutaneous branches of the tibial and common fibular nerves, respectively.[24] The RSSAF receives retrograde arterial flow through septocutaneous perforators that originate from the peroneal artery and directly anastomose with the median superficial sural artery.[7,25] The median superficial sural artery arises proximally from the popliteal artery and is the largest of the 3 superficial sural arteries that together form a dense arterial network known as the sural angiosome.[26,27] The lesser saphenous vein transports retrograde venous flow from the flap and bypasses the valves of the deep venous system through anastomotic connections with the venae comitantes of the sural nerve.[8]

In the early group, the authors' preferred approach to the RSSAF was the design of a skin island with a narrow fascial pedicle around the neurovascular bundle, similar to that described by Hasegawa et al (Fig. 3).[21–23] The skin island was incised down to the level of the fascia. The sural nerve, median superficial sural artery, and lesser saphenous vein were ligated as part of the proximal dissection. The pedicle was then exposed distally, and the skin between the skin island and the chosen pivot point was either divided or undermined in the subcutaneous plane along the entire length of the pedicle. The fascial pedicle was dissected at a width of 2 cm. Next, both the skin island and pedicle were elevated from proximal to distal in the subfascial plane to the level of the chosen pivot point. The skin island was then either passed through a wide subcutaneous tunnel into the defect without kinking or twisting, or a portion of the intervening skin bridge was excised to allow for transposition of the pedicle, and the flap was inset. Finally, the skin at the donor site was closed primarily to the greatest extent possible. The exposed fascial pedicle and any remaining open wound at the donor site were covered with split-thickness skin grafts. All patients were placed in a custom posterior leg splint to relieve any external pressure on the flap and pedicle and to facilitate flap monitoring.

In the late group, the operative technique was amended by a few notable changes (Figs. 4, 5). First, the pedicle width was increased to at least 4 cm in an effort to capture more collateral veins and improve venous drainage. Second, flaps were raised with either a complete skin bridge overlying the pedicle, or the entire flap was raised as an adipofascial flap and covered with a split-thickness skin graft. Additional benefits cited were elimination of the skin graft required for the pedicle with use of a full fasciocutaneous flap and improved donor site cosmesis and improved ability to obliterate dead space with use of the adipofascial flap.

Statistical Analysis

A commercially available statistical software package (GraphPad Prism 6; San Diego, Calif.) was used to analyze the data. The relationship between categorical variables was determined by a two-tailed Fisher's exact test. An unpaired t test was used to compare continuous variables. Pearson's correlation coefficient was used to determine the relationship between surgeon experience and the incidence of failed reconstructions. Our null hypothesis states that no difference exists in the rate of venous congestion between the early and late groups of patients. A P value less than 0.05 was considered statistically significant.

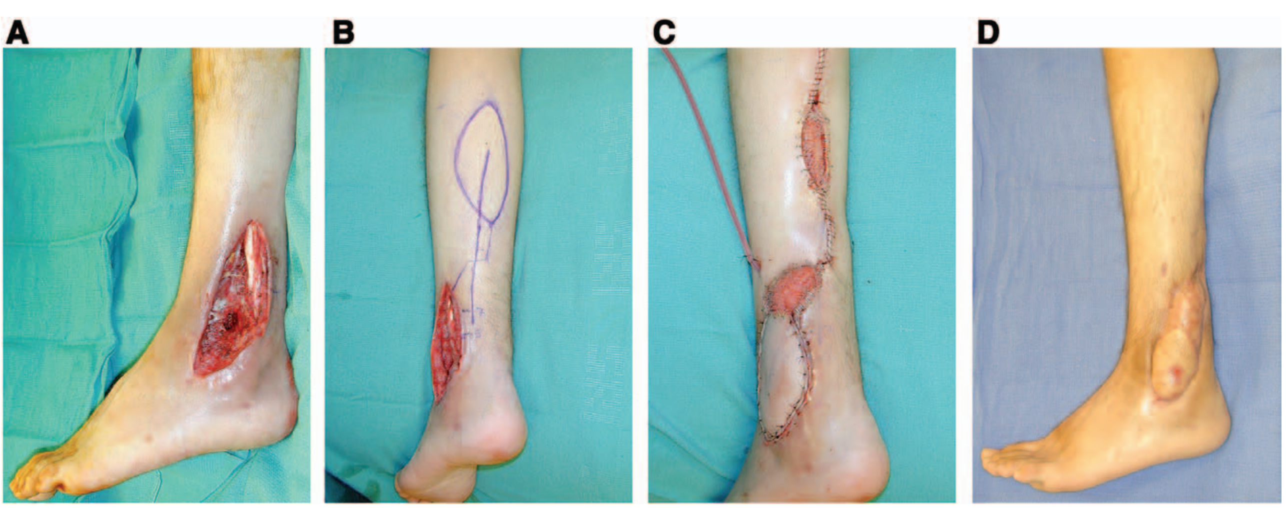

Fig. 3. A successful island-type flap design, in the early group. A 20-year-old man with a lateral malleolar defect and fibular fracture from a motocross accident. An island-type reverse superficial sural artery flap (RSSAF) was used for coverage of the wound. (A) The lateral malleolar defect after debridement, showing exposed tendon and fibula defect. (B) Outline of the flap. (C) Final wound closure, including skin graft coverage of the donor site and flap pedicle. (D) Healed wound at 4 months.

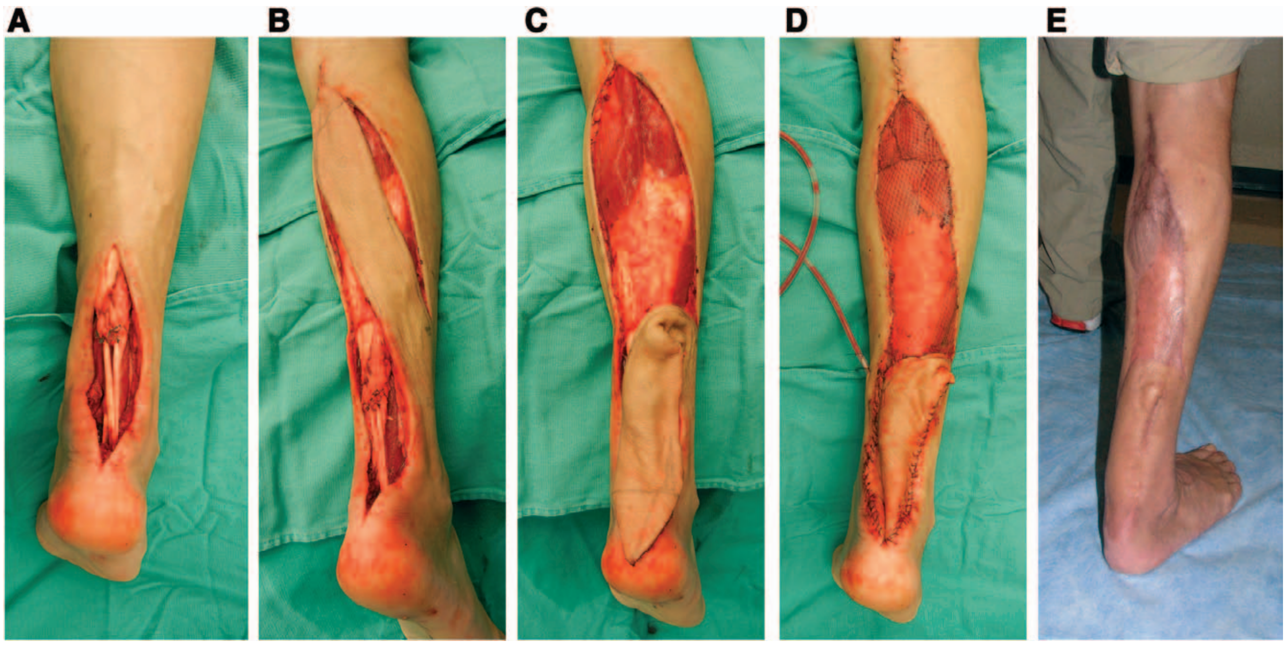

Fig. 4. Fasciocutaneous flap with wide pedicle in the late group. A 57-year-old man with a posterior leg defect after Achilles tendon rupture. A reverse superficial sural artery flap (RSSAF) raised as a full fasciocutaneous flap was used for coverage of the wound. (A) The posterior leg defect after debridement and Achilles tendon repair. (B) Flap elevation. (C) Flap transposition. (D) Skin graft coverage of donor site. (E) Healed wound at 4 months.

RESULTS

Thirty-two patients were reconstructed with an RSSAF between May 2002 and September 2013. Five patients were excluded from the analysis because of either a prior surgical delay procedure (n = 4) or multiple flaps performed at the time of the RSSAF reconstruction (n = 1). From the remaining 27 patients, 12 patients were reconstructed before July 2004, and 15 patients were reconstructed after July 2004. All patients from the "early" group were reconstructed with an island flap, whereas patients from the "late" group were reconstructed with an island flap (n = 1), a fasciocutaneous flap (n = 8), or an adipofascial flap (n = 6). Minimum postoperative follow-up for all patients was at least 6 months.

Patient demographics are listed in Table 1. The age (P = 0.62) and sex (P = 0.24) of patients were similar between groups. Three patients in the early group (25%) and 2 patients in the late group (13%) were current smokers (P = 0.63). No difference in the rates of diabetes mellitus (P = 0.29), peripheral arterial disease (P = 0.19), or chronic venous insufficiency (P = 1.00) was observed between groups.

Table 1. Patient Demographics

Variable	Early Group	Late Group	P*
Age (yr)			
Mean(range)	46 (19–91)	42 (12–72)	0.62
Sex			
Male	10	9	0.24
Female	2	6	
Smoking	3 (25%)	2 (13%)	0.63
Diabetes mellitus	3 (25%)	1 (7%)	0.29
Peripheral arterial disease	2 (17%)	0	0.19
Chronic venous insufficiency	0	0	1.00

*P < 0.05.

Wound characteristics are outlined in Table 2. Etiologies of the wounds were similar between the groups. For the trauma cases, the presence of fracture was the same in both groups (P = 1.00). No differences in defect size (58 vs. 47 cm^2, P = 0.50) or operative time (136 vs. 160 minutes, P = 0.23) were found between the early and late groups, respectively.

Postoperative complications are listed in Table 3. Nine patients in the early group (75%) and 10 patients in the late group (67%) had at least 1 complication (P = 0.70), whereas several patients (n = 5 for early group, n = 1 for late group) experienced multiple complications (P = 0.06). No difference in the rates of partial necrosis (P = 0.14) or complete necrosis (P = 0.57) was observed between groups. Three patients reconstructed with an adipofascial flap lost part of their skin graft and were treated with local wound care (n = 2) or repeated skin grafting (n = 1). The incidence of venous congestion that required leech therapy was 42% in the early group (n = 5) and 0% in the late group (P = 0.01; Fig. 5). Two of the congested flaps were salvaged by leech

Table 2. Wound Characteristics

Variable	Early Group	Late Group
Location		
Calcaneus	6 (50%)	4 (27%)
Posterior heel	1 (8%)	3 (20%)
Lateral malleolus	1 (8%)	2 (13%)
Medial malleolus	1 (8%)	2 (13%)
Anterior leg	3 (25%)	2 (13%)
Dorsal foot	0	2 (13%)
Etiology		
Trauma	8 (67%)	11 (73%)
Pressure sore	3 (25%)	2 (13%)
Osteomyelitis	1 (8%)	1 (7%)
Burn	0	1 (7%)
Defect size (cm^2)		
Mean (range)	58 (4.5–150)	47 (9–140)
Presence of fracture	6/8 (75%)	8/11 (73%)
Mean operative time (min)	136	160

therapy, 1 patient developed a chronic wound, and 2 patients underwent amputation for either a failed flap (n = 1) or an infected nonunion (n = 1).

The limb salvage rate of the reconstruction was significantly greater in the late group than in the early group (93% vs. 50%, $P = 0.02$; Fig. 6). Among the limbs that were not salvaged in the early group, 3 flaps did not survive because of critical venous congestion, 2 flaps failed as a result of poor arterial inflow, and 1 flap that dehisced required a keystone perforator island flap to close the initial defect. In the late group, 1 adipofascial flap developed pressure necrosis from an ill-fitting splint and that patient eventually underwent amputation. Finally, we examined whether poor outcomes were more likely to be associated with surgeons who performed a fewer number of flaps and found a very weak correlation between surgeon experience and the incidence of failed reconstructions ($r = 0.06$).

DISCUSSION

Soft-tissue defects of the distal lower extremity and foot have a reputation as challenging reconstructive cases. The overarching goal of reconstruction in these patients is to recreate a functional lower limb.[28] Because local donor tissue is often insufficient or is located within the zone of injury, microsurgical reconstruction remains the standard for the management of these complicated wounds.[2,3,28] However, even with its many advantages, free tissue transfer is encumbered by donor site morbidity, longer operative times, bulky contours, recipient vessel trauma, and the requirement for advanced surgical expertise and expensive equipment.[28] Moreover, not every patient is a good candidate for prolonged general anesthesia. These issues highlight the need for locally based tissue reconstructive alternatives that are shorter in duration, easy to perform, and reliable. The RSSAF has been touted to be the ideal solution. Advantages of the RSSAF over more complex options include ease of dissection, high reliability, low profile and bulk, and preservation of the major lower extremity arteries.[7,19,21] Compared with other local and regional flaps, the RSSAF has a larger arc of rotation than the extensor digitorum brevis and peroneus brevis muscle flaps,[29–31] long periods of immobilization and difficult positioning are avoided unlike the cross-leg flap,[32–34] and the RSSAF has been shown to be significantly more reliable than the lateral supramalleolar flap.[20] Several revisions to the operative technique have been proposed since its original description almost 30 years ago,[10–18,21,35] and the RSSAF is now considered an accepted and popular method for coverage of soft-tissue loss in the distal third of the leg, ankle, and foot from a number of etiologies.[7,9,17–23,36–42]

Table 3. Postoperative Complications

Complications	Early Group	Late Group	P*
Venous congestion	5 (42%)	0	0.01
Infection	1 (8%)	4 (27%)	0.34
Hematoma	1 (8%)	1 (7%)	1.00
Dehiscence	2 (17%)	1 (7%)	0.57
Partial necrosis	4 (33%)	1 (7%)	0.14
Complete necrosis	2 (17%)	1 (7%)	0.57
Partial loss of skin graft (adipofascial flap)	N/A	3 (20%)	N/A

*$P < 0.05$.

Upon initial adoption of this procedure according to published reports, the qualified surgeons in this study shared their frustrations in experiencing higher than acceptable complication rates. As a group, they used the same techniques and identified that venous congestion was a common occurrence plaguing their outcomes. Together, they modified their operative technique in an attempt to solve this issue. To this end, the purpose of this study is to share some of the lessons learned in creating a more reliable solution to local flap coverage of the lower leg and foot.

We suspected that impaired venous outflow was because of insufficient pedicle size compared with the volume of tissue it supplied. One method to improve this was to increase the pedicle width to a minimum of 4 cm and to leave the skin intact over the pedicle between the flap and its chosen pivot point. Another alternative was to remove the overlying skin and superficial subcutaneous tissue from the entire flap, creating an adipofascial flap (to be covered with a skin graft). The theoretical advantage to this modification was decreased venous return by decreased flap volume overall. These simple changes to the RSSAF technique reduced our rate of venous congestion requiring leech therapy from 42% to 0%. A few flaps

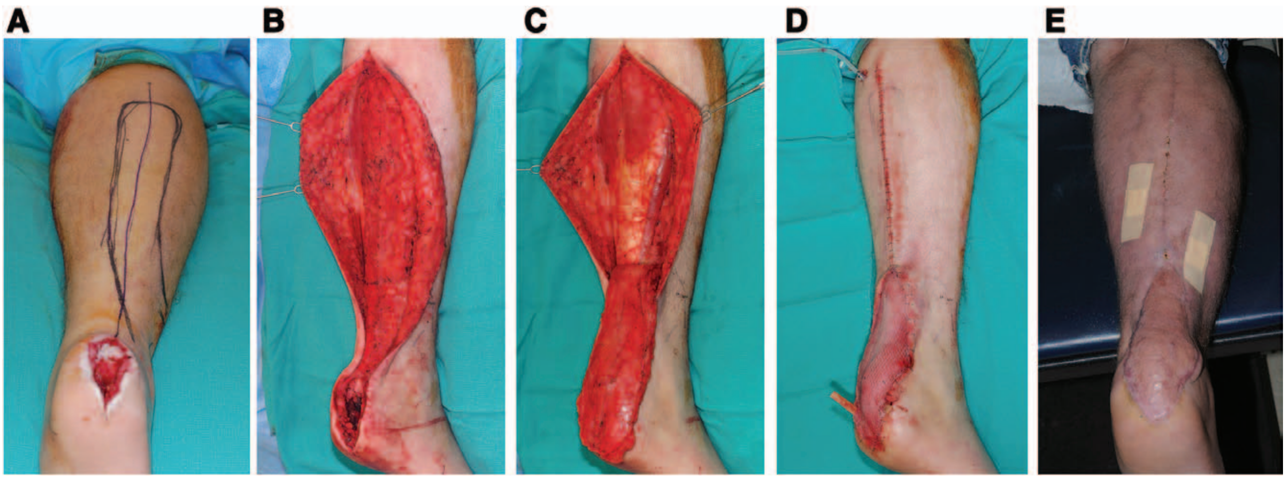

Fig. 5. Adipofascial flap with wide pedicle in the late group. A 47-year-old man with a calcaneal defect from chronic osteomyelitis. A reverse superficial sural artery flap (RSSAF) raised as an adipofascial flap was used for coverage of the wound. (A) Outline of the flap and the calcaneal defect before debridement. (B) Flap elevation and calcaneal defect after debridement. (C) Flap transposition. (D) Primary donor site closure and skin graft coverage of the flap and pedicle. (E) Healed wound at 4 months.

in the late group experienced mild congestion but were able to be successfully managed with leg elevation alone. Although no flaps were supercharged in this study, coaptation of the lesser saphenous vein to either the greater saphenous system or to a dorsal vein on the foot has also been reported with some success in the literature.[13] However, this technique requires the use of microsurgery, and we typically reserve supercharging for flaps that appear congested at the time of inset without an identifiable source for that congestion. Perforator flaps are another option for reconstruction of foot and ankle defects, but the longer operative times and meticulous microvascular dissection associated with these flaps still favor the use of local flaps in certain clinical situations.

Venous congestion is a well-known complication of the RSSAF because of the presence of valves in the deep venous system that prevent uninterrupted retrograde venous flow.[7–9] The true incidence of congestion is difficult to interpret from the literature as most data are derived from small case series and not every reconstructive surgeon performs the same technique. Proposed explanations for the wide variation in outcomes include differences in patient comorbidities, pedicle widths, whether the pedicle is tunneled or exteriorized, or if the flap is supercharged.[7,9–17] Almeida et al[40] described venous congestion as one of the main causes of necrosis in their series of 71 patients, with 25% of flaps demonstrating partial or complete necrosis. It is unclear that how many of these flaps displayed signs of venous congestion, but it was inferred that the larger flaps were more commonly affected. Yilmaz et al[21] observed venous congestion in only 2 of 17 flaps, despite tunneling their pedicles under intact skin bridges. Only 1 of our flaps from the early group was tunneled, and this patient did not experience venous congestion. In a comprehensive retrospective analysis of 70 consecutive flaps by Baumeister et al,[9] 2 patients with tunneled flaps developed venous congestion in the early postoperative period and were

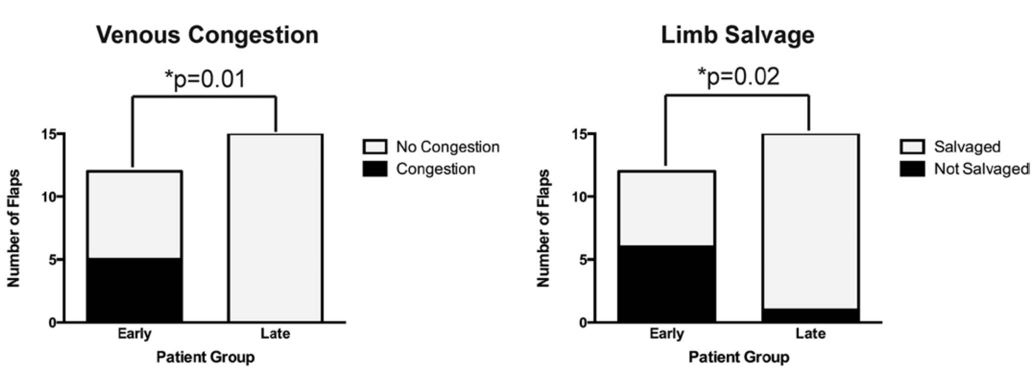

Fig. 6. Comparison of venous congestion and limb salvage rates between the early and late groups of patients. The incidence of venous congestion was significantly greater in the early group, whereas the limb salvage rate was significantly greater in the late group. *$P < 0.05$.

treated by exteriorization of the pedicle, whereas flap necrosis occurred in 2 other patients as a result of venous thrombosis. The combined rate of partial and complete necrosis in this series was 36%, and almost two thirds of the flaps had at least 1 complication (41 of 70 flaps). Our data are fairly consistent with these results, in that our combined rate of partial and complete necrosis for all flaps was 30% with an overall complication rate of 70% (19 of 27 flaps).

There are many limitations inherent to this study. As a retrospective review, an element of selection bias exists in that patients were not randomized into treatment groups. The additional microsurgical training of each surgeon also needs to be considered, but the overall complication rate for this study was still 70%, which along with the data presented by Baumeister et al[9] represents a more realistic view of the complication rate that should be anticipated with use of this flap. Lastly, there is a learning curve to master any operation, and it can be argued that the surgeons in this study became more proficient at the RSSAF procedure over time, and this may have contributed to the reduced incidence of venous congestion in the late group of patients. Although this is certainly possible, the complication rate between the groups was not significantly different, which supports the notion that the increase in pedicle width improved flap survival by enhancing venous drainage of the flap.

CONCLUSIONS

The RSSAF has burgeoned as a local tissue alternative to microsurgical reconstruction of complex wounds of the lower leg and foot. In this study, we observed a high rate of venous congestion in an early group of patients that prompted a uniform change in operative technique. An increase in pedicle width enhanced venous drainage and improved flap survival. Even with a higher overall complication rate than previously reported in the literature, we recommend use of the RSSAF especially in situations where shorter operative times are desirable or microsurgical resources are limited.

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ACKNOWLEDGMENTS

The authors sincerely thank Drs. Kevin Chung, William Kuzon, and Edwin Wilkins for their contributions of patient data and photographs.

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