Original Article

Evaluation of the versatility of increasing proximal limit of distally based reversed sural fasciocutaneous flap for soft tissue coverage of foot and ankle area

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ABSTRACT

Background: Addressing soft-tissue injuries in the distal parts of the foot and ankle continues to be a complex issue for reconstructive and trauma surgeons. Management strategies encompass local fasciocutaneous flaps, pedicled muscle flaps, and microsurgical free-flap. The distal pivot of the sural fasciocutaneous flap was crafted at the most inferior septocutaneous perforator, originating from the peroneal artery in the posterolateral septum. This point typically sits 5cm (range, 4–7cm) above the tip of the lateral malleolus. In this research, we aim to evaluate the reverse sural flap versatility when we raise it to 5cm above the line of junction between the upper third and the lower two thirds of the leg.

Patients and Methods: This is a prospective randomized study. The study was approved by the local ethics committee. This study included 20 patients with complicated wounds over the heel and the foot treated by a distally based reversed sural fasciocutaneous flap with increasing its proximal limits.

Results: G The mean age among the study group was 42±10.4 years and ranged between 25 and 60 years, with 85% being males versus 15% being females. The mean patient satisfaction score was 8.5±0.95. There was a statistically significantly higher level of distal congestion, necrosis, and viable necrosis flap among cases with proximal extension 5cm and with a *P value* of 0.02. There was a statistically significant sensitivity to proximal extension in the diagnosis of distal necrosis of 71.4% and a specificity of 85.6% at the cutoff value 3.5 with a *P value* of 0.008.

Conclusion: We could conclude that increasing the proximal limits up to 2cm above the middle one-third of the calf is very safe, while increasing the proximal limits more than 2cm may have risks regarding distal flap necrosis and congestion.

Key Words: Ankle area, increasing proximal limits, reversed sural flap.

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INTRODUCTION

Coverage of soft tissue defects in the lower leg and foot continues to be a difficult but common reconstructive challenge due to the region's unique structural features, the comparatively low cutaneous circulation, and the deficiency of locally accessible tissues for transposition[1].

Soft-tissue defects of the lower leg and ankle have been recorded in numerous reconstructive procedures, including skin grafts, distant flaps, local flaps, and free flaps. The cost, difficulty, and outcomes of these procedures vary[2].

Local flaps, encompassing advancement and transposition flaps, can only be employed under specific conditions due to the restricted amount of tissue that can be transported from areas surrounding the defect and the limited amount of flap mobilization[3].

Although free flaps have been utilized successfully to address soft tissue deficiencies, their greater complexity requires the presence of particularly experienced surgeons, who are not always available in hospitals, and they have a higher complication rate than loco-regional flaps. Fasciocutaneous flaps were tested for defects in the lower third of the leg based on the axis of the main vessels. Nevertheless, it was later revealed that there was a vascular axis along the path of the body's cutaneous nerves[4].

Defects around the foot, ankle, and distal tibia can be treated with a distally based reverse sural fasciocutaneous flap. It is dependent on the sural artery's retrograde flow, which runs parallel to the sural nerve and the lesser saphenous vein. The most distal segmental perforator, which joins this tiny artery with the peroneal artery, is placed about 5 cm away from the tip of the lateral malleolus. Over the decades that followed the first explanation, the description of the approach was revised and improved multiple times. Since that time, surgeons have introduced methods to enhance its effectiveness, including retaining 2–3cm of perivascular tissue and delaying flapping[5].

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In recent decades, researchers have documented several alterations to the sural flap, along with a variety of often confusing designations. Based on different classification criteria, but mostly suggested by the surgical method for harvesting and employing this flap in reconstruction of different defects, the sural flap has been addressed as delayed sural flap, reverse sural artery flap, sural fasciomusculocutaneous flap, supercharged reverse sural flap, cross-leg distally based sural flap, distally based sural flap, distally based sural neuro-fasciomyocutaneous flap, distally based sural neurocutaneous flap, nerve-sparing distally based sural fasciocutaneous flap, and distally based sural neuro-lesser saphenous veno-fasciocutaneous compound flap[6].

According to some authors, typical flaps taken from the middle third of the leg mostly relied on the median sural artery, which only provided direct cutaneous branches in the distal two-thirds of the leg. As a result, it has been suggested that the proximal extension of the flap is a random form of the flap[7].

To increase flap reach, the proximal third of the leg should be extended with the flap, and it is important to harvest the flap along with the mesentery-like structure connected to the deep fascia and the small blood vessels located in the delicate fibro-adipo-areolar tissue between the two heads of the gastrocnemius muscle[7].

The flap's arterial supply and venous drainage will be enhanced by including the small saphenous vein. Extended sural flap surgery proved to be a safe, effective, and successful method for treating deficiencies in the distal portion of the leg. With more adaptability and better recipient reach, it may be utilized to address patients with large and distant wounds, from the distal leg to the foot and sole. It may be utilized as an alternative to free tissue transfers when reconstructing a foot with a significant defect[8].

In our study, we aim to evaluate the impact of the versatility of increasing proximal limits of a distally based reversed sural fasciocutaneous flap on soft tissue coverage of the ankle and foot area.

PATIENTS AND METHODS:

Prospective research of the increasing proximal limits of a distally based reversed sural fasciocutaneous flap for soft tissue coverage of the foot and ankle area was carried out in 20 patients, 17 men and three women, from December 2021 to June 2024 at Fayoum University Hospital. The postoperative follow-up period was between 6 months and 1 year.

All participants provided informed consent, and the local ethics committee approved the study.

Exclusion criteria

(1) Patients with compromised blood supply to the leg due to previous trauma or fractured tibia or fibula.

(2) Patients should not do any orthopedic intervention around the ankle area in order not to compromise the distal perforators supplying the flap.

(3) Patients with chronic diseases affecting the blood supply of the distal leg (autoimmune disease, vasculitis).

Preoperative preparation

(1) History-taking: full history-taking, including previous operations, comorbidities, and the mood of the trauma.

(2) Clinical leg examination is performed to assess any scars on the posterior aspect of the leg, assess the pulsations, and conduct a clinical examination of the defect.

(3) Laboratories: full blood count, kidney function, and liver function.

(4) Imaging: arterial duplex of the affected lower limbs and radiograph of the tibia and ankle region.

Preoperative marking of the flap

The initial step is to divide the leg into thirds. We identify the midpoint of the knee joint line and mark another point midway between the lateral malleolus and the Achilles tendon's highest point. These points are then connected to form the flap's axis. This line is then measured and split into thirds, with the standard flap extending to the proximal portion of the middle third.

Using a Doppler device, the perforator along the flap's axis is located surrounding the ankle joint. Generally, perforators are located along this axis at a distance ranging from 4 to 7cm from the lateral malleolus. For more distal defects, a perforator located further away can be selected, designating this as the flap's pivot point. Reverse planning involved sketching a template and positioning it over the defect. This template is then linked to the pivot point with a piece of gauze. The complete mock flap is then moved to the back leg, and the outline of the flap is indicated.

Operative steps

The patient was positioned either ventrally or laterally, under general or spinal anesthesia. Initially, the wound was surgically cleaned and debrided, after which the defect was assessed and the flap was outlined. Typically, the cutaneous perforators that supply the flap are located along the posterolateral edge of the lower leg's distal area.

To ensure a higher number of preserved perforators, the rotation point was indicated at a position about 6cm from the lateral malleolus. In all cases, the skin island was extending proximally beyond the line of junction between the upper one-third and middle one-third (from 2 to 5cm proximal extension), ensuring coverage of the complete defect without putting undue tension on the pedicle.

The dissection commenced with an incision along the flap's proximal edge, continuing until the deep fascia was reached. The neurovascular bundle and small saphenous vein were then located and ligated at the flap's center.

The flap was elevated, and the pedicle remained clearly visible and intact while being dissected up to the rotation point. Subsequently, the flap was rotated to cover the imperfection and secured in place to shield the underlying structures, which typically included tendons, bones, or joints.

Finally, the donor site was primarily closed with an autologous skin graft in all instances, with follow-up at least 6 months postoperative.

The leg is fully wrapped up, and a specialized splint is used to ensure that no pressure is applied to the flap's base.

Postoperative care

The patients were placed laterally with the outer side of the leg facing upward. The position of prone might also be used if the patient tolerated. Follow-up of the flap vascularity was done every 4h to detect any congestion. Removal of the tie-over was done after 1 week.

Postoperative monitoring and follow-up

The patient was discharged after 1 week, and follow-up was done in the outpatient clinic with a1-week visit, at least for 6 months and up to 1 year.

Postoperative assessment and evaluation

The sheet of data was created to document the postoperative complications. Complications evaluation involved early complications during their stay in the hospital and postponed problems on their weekly outpatient clinic visits, including wound dehiscence, infection, flap congestion, and partial or entire flap failures.

RESULTS:

The mean age of the participants in the study group was 42±10.4 years, with ages spanning from 25 to 60 years. The group comprised 85% males and 15% females.

Fifteen percent of cases complain of hypertension, and the same for diabetes mellitus, with no cases complaining of renal, cardiac, or autoimmune disease. For the smoking habit, 45% were smokers.

The mean defect length was 7.2±1.2cm, and defect width was 7.2±1.5cm, and the mean surface area of the defect was 52.8±17.2. Sixty-five percent of cases had defects on the posterior ankle and 20% had defects on the posterior ankle and heel. All cases develop defects because of trauma (Table 1).

The mean operation duration was 206.5±25.4min, and the mean blood loss during operation was 20 530.7ml, and the mean proximal extension was 3.25±1.02cm.

Thirteen (65%) patients developed no congestion and only seven (35%) patients developed only distal necrosis, and no one developed total flap congestion.

Thirteen (65%) patients developed no flap necrosis and seven (35%) patients developed only distal flap necrosis, with a mean distal necrosis length was 1.75±0.78cm.

The flaps were totally viable in 13 (65%) patients and were viable with only distal necrosis in seven (35%) patients (Table 2).

In case of proximal extension up to 2cm (five patients) (25%) no flap congestion, no distal flap necrosis, and the flaps were totally viable.

In case of proximal extension up to 3 cm (eight patients) (40%) (Figs 1-3), there was distal flap congestion with distal flap necrosis in two (25%) patients. In case of proximal extension up to 4cm (four patients) (20%), there was distal flap congestion with distal flap necrosis in two (50%) patients. In the case of proximal extension up to 5cm (three patients) (15%) (Figs 4-6), there was distal flap congestion with distal flap necrosis in all three patients ranging from 1 to 3cm (100%) (Table 3).

The mean patient satisfaction score was 8.5±0.95, ranging between 7 and 10 and all cases had intact postoperative sensation.

There was a statistically significantly higher level of distal congestion, necrosis, and viable necrosis flab among cases with proximal extension 5cm and with *P value* 0.02.

There was a statistically significant younger age and higher measures of length, width, surface area, in addition to a higher volume of blood loss, with a *P value* less than 0.05 among cases with distal necrosis. Conversely, there was no statistically significant difference with a *P value* more than 0.05 concerning operation duration (Table 4).

There was a statistically significant negative correlation with a *P value* of 0.03 between proximal extension and patient satisfaction score, which indicated an increase in proximal extension is associated with a decrease in patient satisfaction score. Conversely, there was no statistically significant correlation with a *P value* more than 0.05 between proximal extension and area of distal necrosis.

There was a statistically significant sensitivity to proximal extension in diagnosis of distal necrosis of 71.4% and a specificity of 85.6% at cut-off value 3.5 with a *P value* of 0.008.

Table 1: Description of lesion data between the study groups

	Frequency	
Variables (*N*=35)	Mean±SD	Range
Length of defect (cm)	7.2±1.2	8 (5–9)
Width of defect (cm)	7.2±1.5	7 (5–10)
Surface area of defect (cm)	52.8±17.2	52.5 (30–90)
Defect site	*n* (%)	
Posterior ankle	13 (65)	
Posterior ankle and heel	4 (20)	
Heel	3 (15)	
Defect cause		
Trauma	20 (100)	

Table 2: Description of flap data between the study groups

	Frequency	
Variables (*N*=20)	Mean±SD	Range
Distal necrosis (cm)	1.57±0.78	1–3
Flab congestion	*n* (%)	
No congestion	13 (65)	
Distal congestion	7 (35)	
Total congestion	–	
Distal necrosis		
No	13 (65)	
Yes	7 (35)	
Flab survival		
Totally viable	13 (65)	
Viable with distal necrosis	7 (35)	
Nonviable	–	

Table 3: Comparison of proximal extension in different flap characters among study group

	Proximal extension				
Variables (*N*=20)	2 cm 5 pt.	3 cm 8 pt.	4 cm 4 pt.	5 cm 3 pt.	*P* value
Flab congestion					
No congestion	5 (100%)	6 (75%)	2 (50%)	0	0.02*
Distal congestion	0	2 (25%)	2 (50%)	3 (100%)	
Distal necrosis					
No	5 (100%)	6 (75%)	2 (50%)	0	0.02*
Yes	0	2 (25%)	2 (50%)	3 (100%)	
Flab survival					
Totally viable	5 (100%)	6 (75%)	2 (50%)	0	0.02*
Viable with distal necrosis	0	2 (25%)	2 (50%)	3 (100%)	

Table 4: Comparisons of different variables between cases with and without necrosis

	Distal necrosis				
	No (*N*=13)		Yes (*N*=7)		
Variables	Mean	SD	Mean	SD	*P* value
Age (year)	45.5	9.3	35.6	9.7	0.03*
Length of defect (cm)	6.7	1.2	8.1	0.38	0.006*
Width of defect (cm)	6.7	0.95	8.1	1.9	0.03*
Surface area of defect (cm)	45.4	12.5	66.6	16.9	0.005*
Operation duration (min)	203.9	28.1	211.4	20.4	0.53
Blood loss (ml)	193.9	29.8	225.7	20.7	0.02*

Fig. 1: Preoperative photo of left heel defect.

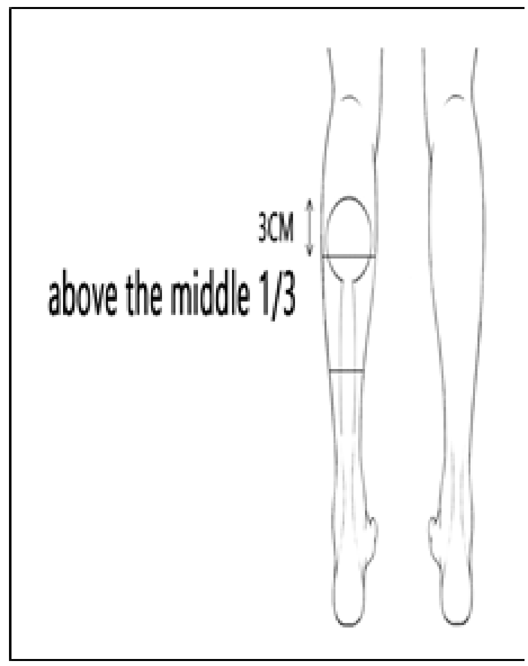

Fig. 2: Diagram showing marking of the flap extending 3cm above the junction between the middle third and upper third of the leg in the same patient.

Fig. 3: Postoperative photo after 2 months showing complete flap survival in the same patient.

Fig. 4: Preoperative photo of right heel defect.

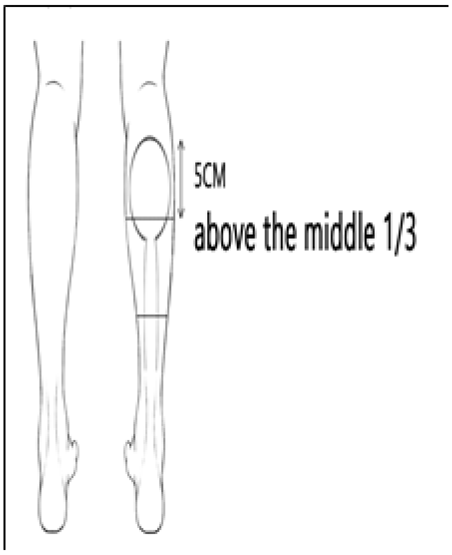

Fig. 5: Diagram showing marking of the flap extending 5cm above the junction between the middle third and upper third of the leg in the same patient.

Fig. 6: Postoperative photo after 6 months showing distal flap necrosis, which was treated with split-thickness graft in the same patient.

DISCUSSION

The main reason for soft tissue defects within the tendoachilles region, ankle, distal third leg, foot dorsum, and heel is road traffic accidents[9]. Reconstructing these defects safely without microsurgery tools is a tough and demanding plastic surgery process. Free-flap reconstruction is one of the potential options being presented. Nevertheless, there are time, expertise, and infrastructure requirements[10].

Masquelet *et al*.[11] described the reverse sural artery flap, which was used to generate the extended reverse sural artery flap. According to some writers, typical flaps obtained from the middle part of the leg relied mostly on the median sural artery, which only had direct cutaneous branches in the lower two-thirds of the leg. As reported by Hassanpour *et al*.[7], Masquelet and colleagues, proximal flap extension is a random type of flap with unexpected survival.

The proximal third of the leg should be extended with the flap in order to maximize flap reach[10–12]. Furthermore, the mesentery-like structure linked to the deep fascia, as well as the small blood vessels seen in the delicate fibro adipose-areolar tissue between the two gastrocnemius muscle heads, should be harvested and preserved. The flap will benefit from increased venous drainage and arterial supply due to the small saphenous vein. Delaying the flap is one of several other options[13].

Delays have been demonstrated to greatly improve blood circulation in the random pattern skin flap's distal region[14] and when the midline cuff of the gastrocnemius muscle is harvested with the flap[15]. In cases of venous supercharging and venous insufficiencies, a microsurgical method may be considered[16]. It has been shown in several studies[12–15] that there were arteries that accompanied the short saphenous vein, as well as long veins that ran alongside it.

Our study comprised 17 males and three females, with a mean age of 42. Only three of the included patients suffer from diabetes, and another three patients suffer from hypertension. Nine of the included patients are smokers. Most of the patients had ankle reconstruction (65%), 20% had heel reconstruction, and 15% had ankle and heel reconstruction.

Thirteen flaps of the included participants were totally viable, and seven flaps were viable with distal necrosis. There was a statistically significantly higher level of proximal extension with a *P value* of 0.006 among cases with distal congestion, necrosis, and viable flap with distal necrosis.

There was a statistically significant negative correlation with a *P value* of 0.03 between proximal extension and patient satisfaction score, which indicated a decrease in patient satisfaction score with an increase in proximal extension of the flap.

Ramesha and colleagues conducted a study that aimed to assess the success, safety, and effectiveness of a lengthened reverse sural artery flap that was extended to the leg's proximal third. Ramesha included 16 patients who underwent coverage of the lower limb defects. Four patients are females and 12 patients are males. Ramesha included two diabetic patients, and three of the included patients were smokers. Ramesha included two (12.5%) participants who had ankle reconstruction, three (19%) participants who had medial malleolus reconstruction, five (31%) participants who had lateral side of foot reconstructions, and three (19%) patients who had dorsum of foot reconstructions. Ramesha *et al*.[8] found that four patients had venous congestion, and in two (12.5%) patients, marginal necrosis occurred along with distal flap loss, necessitating debridement and the application of split-thickness skin grafts.

Yousaf and colleagues aimed to evaluate the results of an extended delayed reverse sural artery flap for the restoration of foot deformities close to the toes in terms of flap survival, complications, and extended area. They reported several complications, such as infection noted in three (9.37%) flaps, two (6.25%) flaps each underwent venous congestion and epidermolysis, and three (9.37%) flaps showed tip necrosis. Additionally, reduced complications have been reported as a result of the delayed flap. The most frequent complication was tip necrosis, which was decreased from 25 to 36% to 9.3%; epidermolysis was decreased from 11.2 to 6.2%; venous congestion was decreased from 11.2 to 6.2%; and total flap loss was decreased from 9.5 to 0%[17].

Hassanpour and colleagues utilized medium to very large flaps from the upper third of the calf in 28 patients to address defects in the sole, foot, heel, ankle, and distal tibia. Six of these flaps experienced venous congestion. Additionally, minor complications, including hypertrophic scarring at the donor site, suture ruptures, and superficial epidermolysis, were noted in seven other patients. Despite these issues, the complications did not affect the overall outcome for these 13 individuals[7].

Cheema and colleagues utilized this flap in 66 instances. The skin paddle was extended up to the level of the knee joint crease. Among the cases, 26 involved imperfections in the lower leg, 18 in the heel, and 15 required soft tissue coverage for the dorsum of the foot. The flap procedure was successful in 62 instances, while it was unsuccessful in four instances[18].

In our study, only three of the included patients suffer from diabetes, another three patients suffer from hypertension, and 45% of the included patients are smokers. In our study, most of the patients had ankle reconstruction (65%), 20% had ankle and heel reconstruction, and 15% had heel reconstruction. In our study, seven (35%) flaps developed venous congestion and distal flap necrosis. The necrosis affected a mean of 1.57±0.78cm of the flaps of the participants.

In our study, we found that crossing the proximal limits increases the risk of flap necrosis and flap congestion. In three cases, increasing the proximal limits up to 5cm above the junction between the upper one-third and middle one-third was associated with distal or partial flap necrosis.

While increasing the proximal limits up to 4cm in four patients was associated with distal flap necrosis in 50% of the cases. Increasing the proximal limits up to 3cm in eight patients showed distal flap necrosis in only two (25%) patients of the cases. In five patients, increasing the proximal limits up to 2cm showed no complications and presented with 100% total flap survival. In all patients, the functional outcome was excellent, although their visual appeal was deemed satisfactory; this was also true for female patients.

All of the defects were effectively repaired with no serious problems. In all cases, tip necrosis of the flap was managed by repeated dressing and left to heal by second intention, except in one patient, which required a split-thickness graft.

CONCLUSION

In our study, increasing the proximal limits up to 5cm above the junction between the upper one-third and middle one-third was associated with distal or partial flap necrosis. While increasing the proximal limits up to 4cm was associated with distal flap necrosis in 50% of the cases. Increasing the proximal limits up to 3cm showed distal flap necrosis in only 25% of the cases. Increasing the proximal limits up to 2cm showed no complications and presented with 100% total flap survival. In all patients, the functional outcome was good, while their esthetic appearance was acceptable.

So, we could conclude that increasing the proximal limits up to 2cm above the middle one-third of the leg is very safe, while increasing the proximal limits more than 2cm may have risks regarding distal flap necrosis and congestion.

The primary constraints of our research included a limited sample size and an insufficient number of prior published studies about this topic, which made it difficult to compare our results with those of other results.

CONFLICT OF INTEREST

There are no conflicts of interest.

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