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Comparison of Reverse Sural Artery Flap Healing for Traumatic Injuries Above and Below the Ankle Joint

Rajamani Perumal, MS[1], Kaushik Bhowmick, MS[1], Karuppusami Reka, MSc[2], Abel Livingston, MS[1], P.R.J.V.C Boopalan, MS[3], Thilak Samuel Jepegnanam, MS[3]

[1] *Assistant Professor, Department of Orthopaedics, Christian Medical College, Vellore, India*
[2] *Senior Demonstrator, Department of Biostatistics, Christian Medical College, Vellore, India*
[3] *Professor, Department of Orthopaedics, Christian Medical College, Vellore, India*

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ABSTRACT

The reverse sural artery (RSA) flap is popular among trauma surgeons to cover the distal third of the leg to the foot. However, flaps that inset in the foot seem to have a high necrosis rate. This study compared the healing of RSA flaps performed for defects proximal to the ankle versus defects distal to the ankle. Patient data were collected retrospectively between January 2005 and December 2009. Eighty-five patients with the lower leg, ankle, and traumatic foot injuries were divided into 2 groups. Group 1 (49 patients) had RSA flap cover for soft tissue and bony defect proximal and up to the ankle joint line, and group 2 (36 patients) had RSA flap cover distal to the ankle joint line. The time to healing and type of healing were compared between the groups. The demographics between the 2 groups were similar. The successful RSA flap healing rate was 65% in group 1 (32 of 49) and 42% in group 2 (15 of 36). The average time to flap healing between the groups was similar ($p = .16$). Group 1 had predominantly primary healing compared with group 2 ($p = .03$). Group 2 had a higher reoperation rate for wound necrosis, which was significant ($p = .001$). The success of the RSA flap is higher when used for proximal to ankle joint line defects. Surgeons should be aware of the chances of flap necrosis when undertaking RSA flap cover distal to the ankle joint line.

Foot and distal third tibial injuries are common in developing countries, resulting in soft tissue loss over this region. Other causes of lower limb soft tissue loss are chronic osteomyelitis, diabetes mellitus, and chronic ulcers caused by arterial and venous insufficiency. Because there is no muscle coverage over the distal third of the leg, open wounds require soft tissue coverage for both bone and soft tissue healing.

The options for soft tissue coverage for these defects include adipofascial turnover flaps, reverse sural artery (RSA) flaps, local perforator flaps, and microvascular free flaps. The RSA flap is commonly performed for coverage of the distal one third of the leg, ankle, and foot (1). It is popular among surgeons for its reliability, relative technical ease, lack of dependency on microsurgery, preservation of the major arterial supply to the lower limb, and relative economic liability to the patient and the health care infrastructure (2–7).

The RSA flap has a wide arc of rotation, which allows for coverage from the lower half of the leg up to the metatarsophalangeal joints on the dorsal aspect and base of the metatarsal bones on the plantar aspect of the foot (8–14). It can be used either proximally or distally (3,15). This flap can also cover a large area of defect (approximately 17×16 cm to 20×15 cm^2) (8,9). One of the main reasons for flap necrosis is venous congestion caused by a narrow flap pedicle and excessive rotation (16–18). Excessive rotation is required when the flap must cover very distal soft tissue defects, such as the dorsum of the foot. This study compares the healing of RSA flaps done for traumatic injuries proximal and distal to the level of the ankle joint.

Patients and Methods

This retrospective study was performed at a tertiary care teaching hospital. Eighty-five patients who consecutively underwent RSA flap for traumatic injuries of the lower limb between January 2005 and December 2009 were included in the study. Patients with vascular injury or diagnosed peripheral vascular disease were excluded from the study. Data were collected from the inpatient and outpatient records by 3 authors (R.P., K.B., A.L.). Informed consent was obtained from all patients. We arbitrarily divided these patients into 2 groups based on the level of flap inset. Patients who underwent RSA flap for traumatic bony and soft tissue injuries proximal and at the level of the ankle joint were classified as group 1 (49 flaps) and as group 2 (36 flaps) when RSA flap was done for injuries distal to the level of the ankle joint. Flap healing was considered as primary if it healed with the index surgery or secondary when it required a second procedure because of flap necrosis. Flap necrosis was further subdivided into 3 categories: (1) tip necrosis, (2) 10% to 50 % necrosis, and (3) >50% necrosis. All the flaps were operated on by 2 authors (P.R.J.V.C., T.S.J.).

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Address correspondence to: Kaushik Bhowmick, MS, Department of Orthopaedics, Unit 3, Paul Brand Building, Christian Medical College, Vellore, Tamilnadu, India, 632 004.
E-mail address: kaushikbhowmick97@yahoo.co.in (K. Bhowmick).

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Table 1
Patient demographic data

Serial No.	Age (years)	Sex	Debridement Prior to Flap Surgery	Preoperative Blood Tests	PA/DA	Diagnosis	Defect Area (cm^2)	Comorbidities	Follow-Up (months)
1	33	M	1	WNL	PA	Gustilo and Anderson type 3B fracture both bones lower third leg	3 × 2	NIL	8
2	20	M	1	WNL	DA	Gustilo and Anderson type 3B multiple metatarsal fracture foot	10 × 5	NIL	4
3	31	M	1	WNL	PA	Tibia chronic osteomyelitis secondary to trauma	2 × 2	NIL	6
4	20	M	NIL	WNL	PA	Gustilo and Anderson type 3B fracture both bones lower third leg	8 × 4	NIL	60
5	54	M	1	WNL	DA	Gustilo and Anderson type 3B multiple metatarsal fracture foot	15 × 4	NIL	12
6	35	M	2	WNL	PA	Gustilo and Anderson type 3B fracture both bones lower third leg	12 × 6	NIL	12
7	33	M	NIL	WNL	PA	Chronic infected tendo-Achilles rupture	3 × 3	NIL	3
8	21	F	1	WNL	PA	Gustilo and Anderson type 3B fracture dislocation ankle	8 × 3	NIL	24
9	23	M	1	WNL	PA	Gustilo and Anderson type 3B fracture dislocation ankle	20 × 10	Smoker	7
10	14	M	1	WNL	PA	Gustilo and Anderson type 3B fracture both bones lower third leg	10 × 5	NIL	60
11	46	M	1	WNL	DA	Gustilo and Anderson type multiple metatarsal fracture foot	6 × 8	NIL	9
12	46	F	1	WNL	PA	Gusilo and Anderson type 3B tibia fracture	10 × 8	NIL	6
13	44	M	1	WNL	DA	Gustilo and Anderson type 3B fracture calcaneum	10 × 5	NIL	6
14	40	F	2	WNL	PA	Gustilo and Anderson type 3B fracture both bones lower third leg	10 × 3	NIL	48
15	33	M	2	WNL	DA	Open soft tissue laceration dorsum of foot	16 × 4	NIL	6
16	17	F	1	ESR ↑	PA	Gustilo and Anderson type 3B fracture ankle	10 × 15	NIL	12
17	46	M	1	ESR, CRP↑	DA	Gustilo and Anderson type 3B fracture of calcaneum and talus	10 × 15	NIL	60
18	31	F	2	WNL	PA	Closed fracture both bones leg post fracture fixation	15 × 8	NIL	18
19	23	M	1	WNL	DA	Crush injury foot	15 × 10	NIL	18
20	56	F	1	ESR ↑	PA	Open infected tendo-Achilles repair	3 × 2	NIL	6
21	54	M	1	ESR, CRP↑	PA	Open infected tendo-Achilles repair	7 × 8	NIL	3
22	42	M	1	WNL	DA	Degloving soft tissue injury dorsomedial aspect of foot	8 × 5	NIL	14
23	27	M	1	WNL	PA	Degloving soft tissue injury dorsomedial aspect of foot	7 × 6	NIL	6
24	55	M	1	WNL	PA	Open tendo-Achilles laceration	5 × 3	NIL	3
25	46	M	NIL	WNL	PA	Open infected tendo-Achilles repair	5 × 3	Smoker	60
26	46	F	1	WNL	PA	Gustilo and Anderson type 3B fracture both bones lower third leg	15 × 6	NIL	72
27	22	M	1	WNL	DA	Degloving soft tissue injury dorsal aspect of foot	20 × 15	NIL	36
28	30	M	1	WNL	PA	Gustilo and Anderson type 3B fracture both bones lower third leg	8 × 6	NIL	60
29	53	M	1	WNL	DA	Crush injury foot	4 × 3	NIL	8
30	67	M	1	WNL	DA	Gustilo and Anderson type 3B calcaneum fracture	15 × 15	HT	36
31	26	F	1	WNL	PA	Gustilo and Anderson type 3B fracture both bones lower third leg	15 × 15	NIL	11
32	62	M	2	WNL	PA	Gustilo and Anderson type 3B fracture both bones lower third leg	10 × 15	Smoker	12
33	21	M	1	WNL	PA	Gustilo and Anderson type 3B ankle fracture dislocation	6 × 4	NIL	5
34	20	M	1	WNL	PA	Gustilo and Anderson type 3B fracture both bones lower third leg	3 × 2	NIL	6
35	56	F	1	WNL	PA	Open soft tissue injury lower leg	3 × 2	NIL	7
36	46	M	NIL	ESR ↑	DA	Gustilo and Anderson type 3B fracture calcaneum	15 × 15	NIL	6
37	28	M	2	CRP↑	DA	Gustilo and Anderson type 3B fracture dislocation first TMT joint	12 × 4	Smoker	96
38	22	M	NIL	WNL	PA	Nonhealing wound of tendo Achilles	8 × 5	NIL	3
39	19	M	1	WNL	DA	Degloving soft tissue injury dorsal aspect of foot	15 × 15	NIL	12
40	66	M	1	WNL	PA	Gustilo and Anderson type 3B fracture both bones lower third leg	5 × 5	NIL	4
41	28	M	1	WNL	PA	Open ankle dislocation with fracture of the talus	10 × 10	NIL	36
42	30	M	NIL	WNL	DA	Open dislocation of talonavicular joint	6 × 4	NIL	120
43	49	M	1	WNL	DA	Gustilo and Anderson type 3B fracture calcaneum	15 × 4	DM	36
44	16	M	1	WNL	DA	Gustilo and Anderson type 3B fracture calcaneum	10 × 10	NIL	60
45	40	M	2	WNL	DA	Gustilo and Anderson type 3B fracture calcaneum	10 × 3	NIL	60
46	21	M	2	WNL	DA	Gustilo and Anderson type 3B crush injury foot	12 × 10	NIL	72
47	19	M	NIL	WNL	DA	Degloving soft tissue injury	15 × 10	NIL	60
48	39	M	1	WNL	DA	Open degloving injury heel pad	5 × 2	NIL	24
49	64	M	1	WNL	PA	Chronic open infected tendo-Achilles rupture	8 × 2	DM	4
50	46	M	1	WNL	DA	Gustilo and Anderson type 3B fracture calcaneum	7 × 9	DM	3
51	45	M	NIL	WNL	DA	Crush injury foot	5 × 5	NIL	5
52	18	M	1	WNL	DA	Open degloving injury heel pad	20 × 10	NIL	72
53	36	F	2	CRP↑	PA	Chronic osteomyelitis right tibia secondary to trauma	7 × 8	NIL	24
54	29	M	1	WNL	PA	Gustilo and Anderson type 3B fracture ankle	8 × 4	NIL	24
55	41	M	1	WNL	PA	Chronic infected tendo-Achilles open injury	2 × 1	NIL	5
56	49	M	NIL	WNL	PA	Gustilo and Anderson type 3B fracture both bones lower third leg	12 × 8	DM	12
57	6	M	1	WNL	PA	Gustilo and Anderson type 3B fracture both bones lower third leg	5 × 7	NIL	120
58	13	F	1	WNL	PA	Gustilo and Anderson type 3B fracture both bones lower third leg	12 × 10	NIL	98
59	25	M	1	WNL	DA	Gustilo and Anderson type 3B fracture calcaneum	8 × 8	Smoker	120
60	26	M	1	WNL	PA	Gustilo and Anderson type 3B fracture both bones lower third leg	7 × 5	NIL	5
61	58	M	1	WNL	PA	Gustilo and Anderson type 3B fracture both bones lower third leg	15 × 8	NIL	5
62	17	M	NIL	WNL	DA	Open degloving injury heel pad	10 × 5	NIL	6
53	13	F	2	WNL	PA	Gustilo and Anderson type 3B fracture dislocation ankle	12 × 6	NIL	72
64	17	M	NIL	WNL	PA	Open partial rupture of tendo Achilles	8 × 4	NIL	3
65	22	M	1	WNL	DA	Open soft tissue laceration dorsum of foot	12 × 12	NIL	120
66	35	F	1	WNL	DA	Open degloving injury heel pad	10 × 10	DM, HT	4
67	25	F	1	ESR ↑	DA	Infected comminuted extra-articular fracture calcaneum	10 × 4	NIL	10
68	30	F	6	WNL	PA	Gustilo and Anderson type 3B fracture both bones lower third leg	8 × 6	NIL	48
69	58	M	1	WNL	PA	Gustilo and Anderson type 3B fracture both bones lower third leg	3 × 3	DM, HT	120

(*continued*)

Table 1. (*Continued*)

Serial No.	Age (years)	Sex	Debridement Prior to Flap Surgery	Preoperative Blood Tests	PA/DA	Diagnosis	Defect Area (cm^2)	Comorbidities	Follow-Up (months)
70	25	M	NIL	WNL	DA	Gustilo and Anderson type 3B fracture third and fourth metatarsal	10 × 10	NIL	48
71	50	M	NIL	WNL	DA	Bilateral heel pad avulsion injury	10 × 8	DM	120
72	30	M	NIL	WNL	DA	Degloving soft tissue injury dorsal aspect of foot	15 × 10	NIL	3
73	46	M	1	WNL	DA	Open crush injury foot	15 × 10	NIL	98
74	40	M	1	WNL	DA	Open degloving injury heel pad	15 × 10	NIL	3
75	59	M	1	WNL	PA	Gustilo and Anderson type 3B fracture both bones lower third leg	5 × 5	Smoker	4
76	53	M	1	WNL	PA	Chronic infected tendo-Achilles repair leg	10 × 5	NIL	3
77	25	F	NIL	WNL	DA	Gustilo and Anderson type 3B fracture calcaneum	5 × 4	NIL	24
78	16	M	2	WNL	PA	Gustilo and Anderson type 3B fracture dislocation ankle	15 × 15	NIL	15
79	46	M	1	WNL	DA	Gustilo and Anderson type 3B Lisfranc fracture dislocation	12 × 4	NIL	3
80	38	M	1	WNL	PA	Gustilo and Anderson type 3B fracture both bones lower third leg	10 × 5	NIL	15
81	9	F	1	WNL	DA	Open soft tissue injury dorsal aspect foot	25 × 7	NIL	3
82	52	M	NIL	WNL	PA	Gustilo and Anderson type 3B fracture ankle	10 × 6	Smoker	3
83	13	M	NIL	WNL	PA	Open laceration of tendo Achilles	12 × 5	NIL	3
84	20	M	1	WNL	PA	Gustilo and Anderson type 3B fracture ankle	10 × 5	NIL	10
85	38	M	NIL	WNL	PA	Extensive soft tissue degloving of lower third leg	8 × 4	NIL	3

Abbreviations: CRP, C-reactive protein; DA, distal to ankle (group 2); DM, diabetes mellitus; ESR, erythrocyte sedimentation rate; F, female; HT, hypertension; M, male; NIL, nothing; PA, proximal to ankle (group 1), WNL, within normal limits.

In this retrospective study, we evaluated the following factors. Did factors such as age, sex, presence or absence of comorbidities, and area of the defect influence the type of healing in group 1 versus group 2? Was there an association between the site of the flap (group 1/group 2) and the type of healing (primary /secondary)?

Statistical Analysis

All analyses were done by 1 author (R.K.) using the Statistical Package for Social Services software Version 21.0 (IBM Corp., Armonk, NY). Two-tailed p values $\leq .05$ were considered significant. Continuously distributed data were reported as mean ± standard deviation. Categorical data are reported in terms of the number of patients and percentage.

Categorical values between proximal ankle (group 1) and distal ankle (group 2) were compared by the Pearson χ^2 test. Normally distributed data and skewed data were compared between groups by the t test and nonparametric Mann-Whitney test.

Results

There were 49 (male = 36, female = 13) patients in group 1 and 36 (male = 32, female = 4) patients in group 2. These patients were followed for an average of 29 (range 3 to 120) months. Patient demographic data are shown in Table 1. Group 1 had flaps predominantly for bone coverage, whereas in group 2 the flap was done to cover combined bone, tendon, and soft tissue defects (Table 2). The demographic factors such as age, sex, and time to healing were similar between groups 1 and 2. The average time for flap healing was about 30 days in both groups. However, in both groups, injuries were present predominantly in males (Table 3).

When both groups were compared with regard to the type of healing, it was found that primary flap healing occurred in 65% (32 of 49 patients) of group 1 patients as compared with 42% (15 of 36 patients) of group 2 patients, which was statistically significant ($p = .03$) (Table 4). Factors such as the area of the defect, comorbidities, and age were compared for the type of healing (primary/secondary) between groups 1 and 2. We did not find a significant difference in the type of healing when age, comorbidities, and area of defect were compared (Tables 5 and 6). Photographs show healing of the defect in a group 1 patient (Figs. 1–3) and a group 2 patient (Figs. 4–6), both of whom were followed for 2 years.

Of the 38 patients who had healed secondarily (group 1 = 17, group 2 = 21), 5 had tip necrosis, 11 had < 50% necrosis, and 22 had > 50% necrosis. Group 1 patients predominantly had tip necrosis, whereas group 2 patients had > 10% to full necrosis. Tip necrosis was managed with dressings and secondary suturing in the outpatient department, whereas > 10% necrosis to full necrosis required secondary procedures in the operating theater. Group 2 required more operating theater procedures than did group 1 patients. There was a significant difference statistically between the 2 groups requiring secondary procedures in the operating theater ($p = .001$) (Table 7).

Table 2
Indications for reverse sural artery flap based on type of injury (N = 85)

Diagnosis	No. of Patients (%)
Proximal ankle	
1. Open both bone leg fracture	22 (26%)
2. Tibia chronic osteomyelitis secondary to trauma	2 (2.3%)
3. Open ankle fracture dislocation	10 (12%)
4. Soft tissue injury of leg	4 (5%)
5. Acute tendo-Achilles rupture	3 (3.5%)
6. Chronic infected tendo-Achilles rupture	8 (9.4%)
Distal ankle	
1. Open multiple metatarsal fractures	6 (7%)
2. Heel pad avulsion	6 (7%)
3. Open soft tissue foot injury	7 (8.2%)
4. Open calcaneal fractures	11(13%)
5. Crush injury foot	6 (7%)

Discussion

RSA flap was initially described in 1992 by Masquelet et al (19) as a sural neurocutaneous island flap. This term was later changed by Hasegawa et al (9) to *reverse sural artery flap*. Since the initial description, many technical modifications have been added in the form of foregoing the cutaneous tunnel and exteriorizing the pedicle, the addition of a T-shaped skin paddle to eliminate venous congestion, the addition of a gastrocnemius muscle cuff to improve flap survival, and lowering the pivot for rotation of the flap (20–22). Despite these technical modifications, the incidence of partial or total flap necrosis ranges from 25% to almost 36% (2,4,20).

This study evaluates the difference in flap healing in patients for injuries incurred proximal and distal to the ankle joint line. All 85 patients had sustained traumatic injuries with no vascular compromise. Even in the patients with comorbidities, there was no diagnosed or manifested peripheral vascular disease. All flaps were done in patients with good local skin condition and the presence of perforators, which was confirmed by handheld Doppler scanning before surgery. In our

Table 3
Comparison of patient demographic between groups

		Proximal Ankle (n = 49)	Distal Ankle (n = 36)	*p* Value ≤.05
Age, mean years ± SD		32.5 ± 14.9	35.5 ± 14.1	.36
Gender	Female, n (%)	13 (26.5)	4 (11.1)	.07
	Male, n (%)	36 (73.5)	32 (88.9)	
Area of defect, mean (range)		74 cm^2 (2 to 300)	80 cm^2 (15 to 200)	NA
Time to healing, mean days ± SD range = (minimum, maximum)		30.3 ± 16.4	36.8 ± 19.2	.14

Abbreviations: NA, not applicable; SD, standard deviation.

Table 4
Comparison of type of healing between groups

Type of Flap Healing	Proximal Ankle n (%)	Distal Ankle n (%)	*p* Value ≤.05
Primary	32 (65)	15 (42)	.030
Secondary	17 (35)	21 (58)	

Table 5
Comparison of patient demographics versus type of healing within groups

	Primary Healing n (%)	Secondary Healing n (%)	*p* Value ≤.05
Age			
≤40 years	33 (71%)	22 (58%)	.21
>40 years	14 (29%)	16 (42%)	
Comorbidities			
Yes	11 (23%)	5 (13%)	.24
No	36 (77%)	33 (87%)	
Area of defect			
Proximal ankle	65 cm^2	88 cm^2	.04
Distal ankle	75 cm^2	84 cm^2	

Table 6
Comparison of comorbidities between the groups

	Smoking [n (%)]	Diabetes Mellitus [n (%)]	Hypertension
Group 1 (PA) (N = 49)	6 (12.24%)	3 (6.1%)	1 (2%)
Group 2 (DA) (N = 36)	2 (5.5%)	4 (11%)	2 (5.5%)

Abbreviations: DA, distal to ankle (group 2); PA, proximal to ankle (group 1).

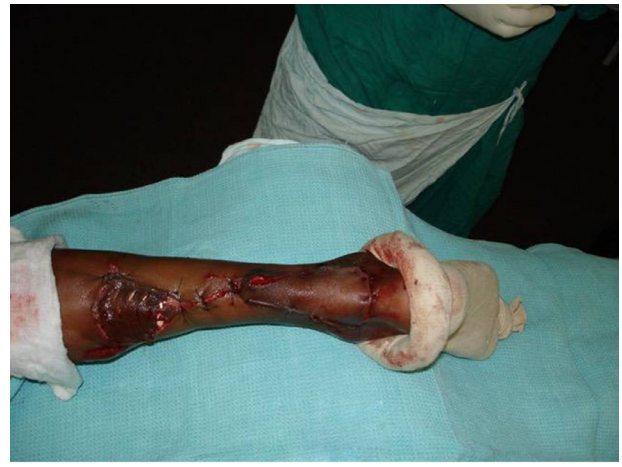

Fig. 2. Group 1 patient in the immediate postoperative period after undergoing reverse sural artery flap.

series, flap success (ie, primary flap healing) was 65% in patients with injuries at or proximal to the level of the ankle joint, compared with only 42% in patients with injuries distal to the level of the ankle joint. This was found to be statistically significant.

Studies in the literature have reported that flap necrosis results from excessive rotation of the narrow pedicle, venous congestion, high pivot point, and very proximal top edge, indirectly indicating a very distal injury (16,17,23–26). In our study, we made the ankle joint as the base around which we could categorically divide the injuries as “near” (group 1) or “far” (group 2). For some of the far injuries, the flaps had to have the top edge almost at the upper calf region, which resulted in

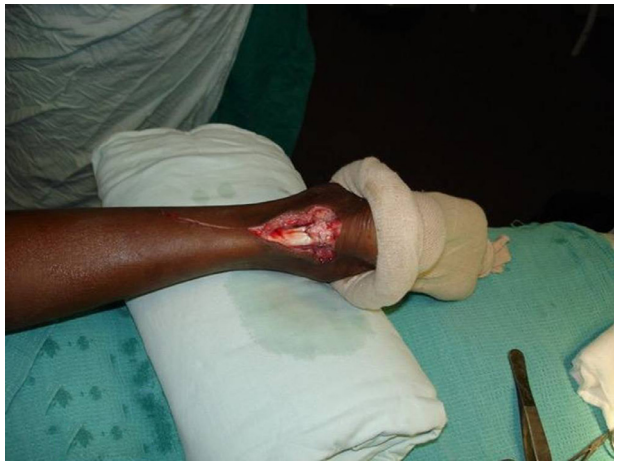

Fig. 1. Group 1 patient with open soft tissue injury exposing the tendo Achilles.

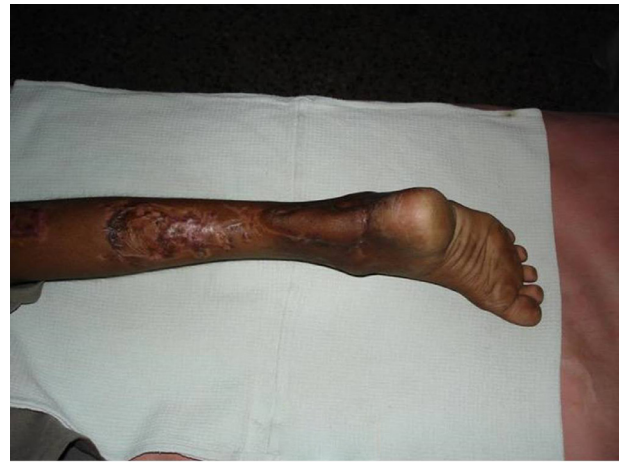

Fig. 3. Group 1 patient with exposed tendo Achilles, showing healing after 2 years.

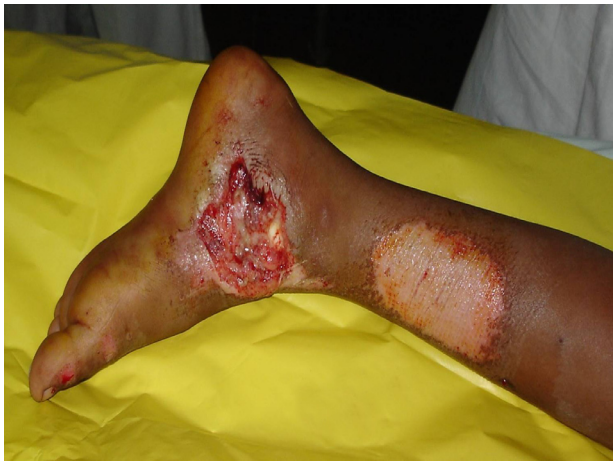

Fig. 4. Group 2 patient with extensive soft tissue injury over the dorsum of the foot exposing the ankle joint.

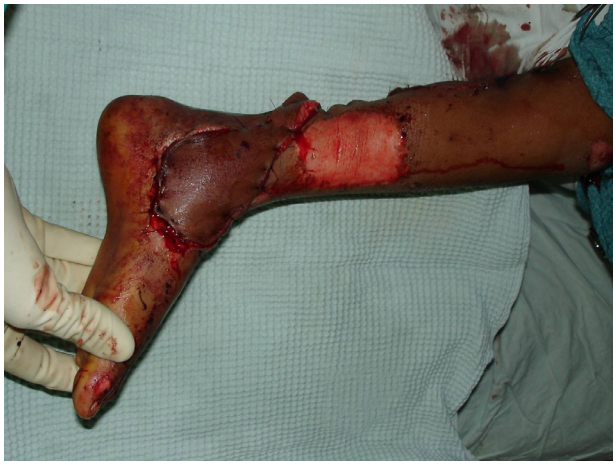

Fig. 5. Group 2 patient with extensive soft tissue injury over the dorsum of the foot in the immediate postoperative period after undergoing reverse sural artery flap.

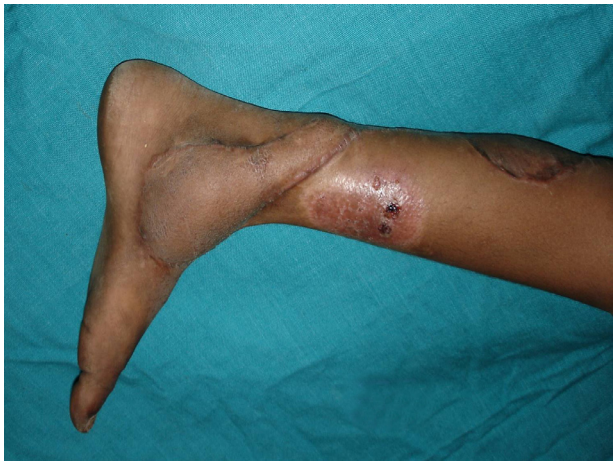

Fig. 6. Group 2 patient with extensive soft tissue injury dorsum of foot at 6 months follow-up visit.

Table 7
Comparison of flap necrosis between groups

	Proximal Ankle (n = 17)	Distal Ankle (n = 21)	*p* Value ≤.05
Tip necrosis (> 10%)	10 (59%)	2 (9.5%)	.001
10% to 50% and > 50% necrosis	7 (41%)	19 (90.5%)	

necrosis. In our series, patients with tip necrosis were managed by suturing while in the outpatient department, whereas patients who had > 10% necrosis had to be treated with operative procedures in the operating theater.

The advantage of this study is that there are 2 distinct groups with adequate follow-up. Previous reports have shown a complication rate close to 59% in patients with comorbidities (2). Patient comorbidities, as well as other demographic factors, were similar between the 2 groups in our study. All patients in this study exclusively had traumatic injuries. To our knowledge, there is no study in the English language literature, which has distinctly classified sural flap cover for traumatic injuries around the lower leg region into proximal and distal to the ankle joint groups and compared their healing with categorical findings.

A limitation of this study is its retrospective nature and the fact that surgeons are measuring their own outcomes. However, despite our appreciation of the limitations of our investigation, we believe that the results of this study could be useful in the future development of a prospective cohort study that focuses on RSA flap.

In conclusion, RSA flap for defects proximal to the level of the ankle joint has a higher rate of primary healing compared with flaps distal to the ankle joint line. Surgeons should be aware of the chances of flap necrosis when undertaking RSA flap cover for defects distal to the ankle joint line. We would suggest that when a flap is harvested close to the popliteal region for it to reach the foot, the surgeon must ensure that the sural artery, which is deep in this region, is carefully dissected out to be included in the flap.

References

1. Boopalan PR, Nithyananth M, Titus VT, Cherian VM, Jepegnanam TS. Experience of using local flaps to cover open lower limb injuries at an Indian trauma center. J Emerg Trauma Shock 2011;4:325–329.
2. Baumeister SP, Spierer R, Erdmann D, Sweis R, Levin LS, Germann GK. A realistic complication analysis of 70 sural artery flaps in a multimorbid patient group. Plast Reconstr Surg 2003;112:129–140.
3. Price MF, Capizzi PJ, Watterson PA, Lettieri S. Reverse sural artery flap: caveats for success. Diabet Foot Ankle 2002;48:496–504.
4. Kneser U, Bach AD, Polykandriotis E, Kopp J, Horch RE. Delayed reverse sural flap for staged reconstruction of the foot and lower leg. Plast Reconstr Surg 2005;116:1910–1917.
5. de Rezende MR, Saito M, Paulos RG, Ribak S, Herrera AK, Cho ÁB, Mattar Jr R. Reduction of morbidity with a reverse-flow sural flap: a two-stage technique. J Foot Ankle Surg 2018;57:821–825.
6. Boopalan PR, Jepegnanam TS. Reverse sural flap cover within a ring fixator. Acta Orthop Belg 2010;76:684–688.
7. Follmar KE, Baccarani A, Baumeister SP, Levin LS, Erdmann D. The distally based sural flap. Plast Reconstr Surg 2007;119:138e–148e.
8. Foran MP, Schreiber J, Christy MR, Goldberg NH, Silverman RP. The modified reverse sural artery flap lower extremity reconstruction. J Trauma 2008;64:139–143.
9. Hasegawa M, Torii S, Katoh H, Esaki S. The distally based superficial sural artery flap. Plast Reconstr Surg 1994;93:1012–1020.
10. Ríos-Luna A, Villanueva-Martínez M, Fahandezh-Saddi H, Villanueva-Lopez F, del Cerro-Gutiérrez M. Versatility of the sural fasciocutaneous flap in coverage defects of the lower limb. Injury 2007;38:824–831.
11. Akhtar S, Hameed A. Versatility of the sural fasciocutaneous flap in the coverage of lower third leg and hindfoot defects. J Plast Reconstr Aesthet Surg 2006;59:839–845.
12. Rajacic N, Darweesh M, Jayakrishnan K, Gang RK, Jojic S. The distally based superficial sural flap for reconstruction of the lower leg and foot. Br J Plast Surg 1996;49:383–389.
13. Farooq HU, Ishtiaq R, Mehr S, Ayub S, Chaudhry UH, Ashraf A. Effectiveness of reverse sural artery flap in the management of wheel spoke injuries of the heel. Cureus 2017;9:e1331.

14. Grandjean A, Romana C, Fitoussi F. Distally based sural flap for ankle and foot coverage in children. Orthop Traumatol Surg Res 2016;102:111–116.
15. Cheon SJ, Kim IB, Park WR, Kim HT. The proximally-based sural artery flap for coverage of soft tissue defects around the knee and on the proximal third and middle third of the lower leg. Acta Orthop 2008;79:370–375.
16. Sugg KB, Schaub TA, Concannon MJ, Cederna PS, Brown DL. The reverse superficial sural artery flap revisited for complex lower extremity and foot reconstruction. Plast Reconstr Surg Glob Open 2015;3:e519.
17. Tsai J, Liao HT, Wang PF, Chen CT, Lin CH. Increasing the success of reverse sural flap from proximal part of posterior calf for traumatic foot and ankle reconstruction: patient selection and surgical refinement. Microsurgery 2013;33:342–3429.
18. Tu YK, Ueng SW, Yeh WL, Wang KC. Reconstruction of ankle and heel defects by a modified wide-base reverse sural flap. J Trauma 1999;47:82–828.
19. Masquelet AC, Romana MC, Wolf G. Skin island flaps supplied by the vascular axis of the sensitive superficial nerves: anatomic study and clinical experience in the leg. Plast Reconstr Surg 1992;89:1115–1121.
20. Ayyappan T, Chadha A. Super sural neurofasciocutaneous flaps in acute traumatic heel reconstructions. Plast Reconstr Surg 2002;109:2307–2313.
21. Parrett BM, Pribaz JJ, Matros E, Przylecki W, Sampson CE, Orgill DP. Risk analysis for the reverse sural fasciocutaneous flap in distal leg reconstruction. Plast Reconstr Surg 2009;123:1499–1504.
22. Li Y, Xu J, Zhang XZ. Lowering the pivot point of sural neurofasciocutaneous flaps to reconstruct deep electrical burn wounds in the distal foot. Burns 2013;39:808–813.
23. Wei JW, Dong ZG, Ni JD, Liu LH, Luo SH, Luo ZB, Zheng L, He AY. Influence of flap factors on partial necrosis of reverse sural artery flap: a study of 179 consecutive flaps. J Trauma 2012;72:744–750.
24. de Blacam C, Colakoglu S, Ogunleye AA, Nguyen JT, Ibrahim AM, Lin SJ, Kim PS, Lee BT. Risk factors associated with complications in lower-extremity reconstruction with the distally based sural flap: a systematic review and pooled analysis. J Plast Reconstr Aesthet Surg 2014;67:607–616.
25. Al-Qattan MM. The reverse sural fasciomusculocutaneous “mega-high” flap: a study of 20 consecutive flaps for lower-limb reconstruction. Ann Plast Surg 2007;58:513–516.
26. Tajsiς N, Winkel R, Hoffmann R, Husum H. Sural perforator flap for reconstructive surgery in the lower leg and the foot: a clinical study of 86 patients with post-traumatic osteomyelitis. J Plast Reconstr Aesthet Surg 2009;62:1701–1708.