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Recommended Citation

Hashmi, P., Musaddiq, A., Ali, M., Hashmi, A., Zahid, M., Nawaz, Z. (2021). Long-term clinical and functional outcomes of distally based sural artery flap: A retrospective case series. *JPRAS Open, 30*, 61-73.
Available at: https://ecommons.aku.edu/pakistan_fhs_mc_surg_orthop/155

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JPRAS Open 30 (2021) 61–73

Contents lists available at ScienceDirect

JPRAS Open

journal homepage: www.elsevier.com/locate/jpra

Long-Term Clinical and Functional Outcomes of Distally Based Sural Artery Flap: A Retrospective Case Series

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ARTICLE INFO

Article history:
Received 1 November 2020
Accepted 20 January 2021
Available online 31 July 2021

Keywords:
Sural artery flap
surgical flap
foot and ankle
reconstructive surgical procedures
wound healing

ABSTRACT

Background: Reconstruction of soft tissue defects around the lower leg, foot and ankle is a challenge for orthopedic surgeons. These defects commonly occur as a result of trauma, infection and tumor excision. Sural artery neurovascular island flap is a relatively thin, pliable and insensate flap with minimum donor-site morbidity and acceptable aesthetic outcome.

Methods: A retrospective analysis of a case series was conducted, all operated by a single surgeon over a period of 25 years from July 1996 to February 2020. Data were collected through a structured proforma; the variables included were as follows: demographic data, mechanism of injury, defect site and size, size of flap, hospital stay, complications, outcome of flap and functional status of limb. Data analysis was performed by using SPSS version 25.0.

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https://doi.org/10.1016/j.jpra.2021.01.013
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Results: We included 89 patients out of 106, with 92 distally based sural artery flaps. The flap coverage was divided in two groups: group I for leg (n=41) and group II for foot (n=51). The mean flap dimension in leg was 9.98 ± 2.2 cm and 12.15 ± 3 cm in foot. Postoperatively functional outcomes were assessed using a self-designed tool and graded as excellent in 79 cases (leg=38; foot=41), good in 10 cases (leg=2; foot=8), fair in 3 cases (leg=1; foot=2) and poor in zero cases. All flaps survived uneventfully.

Conclusion: The reverse sural artery flap is versatile and reliable, and can be performed easily with good knowledge and using a microsurgical technique. It is useful for the reconstruction of soft tissue defects around the lower third of the leg, dorsum of the foot, malleoli and hind foot. The functional range of motion of the ankle is not compromised because of the flap's supple and pliable nature. The reverse sural artery flap is ideal for the coverage of the foot, ankle and lower one third of the leg. This flap is insensate and not suitable for the weight-bearing area of the heel.

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Introduction

Soft tissue defects around the lower extremities commonly occur as a result of road traffic accidents (RTA) that may involve the bone, tendon and neurovascular structures[1]. Other causes of these defects include blast injuries, machine/industrial injuries, resection of tumors and neuropathic ulcers[2]. The incidence of lower limb injuries in Karachi (an industrial and heavily populated city) is quite high because of a large but poor road-traffic system, ranked 4th in road-traffic accidents in the world[3]. These cases pose a great challenge due to underlying infections, limited local soft tissue availability and the need for secondary reconstruction of the involved structures (bone, tendons, nerves and vessels) that require initial coverage with thin, pliable soft tissue for restoration of limb functions[4,5].

Reconstruction of soft tissue defects of the leg, foot and ankle depends on the location, size, and depth of the wound. Various locally available options include local muscle flap, fasciocutaneous flap, perforator flap, supra-malleolar flap and sural artery flap[6,7] The remote options are cross leg flap (obsolete) and various free flaps. Free skin grafts are often unsuitable because of their tendency to contract and their poor resistance to pressure. Local skin flaps would be preferable but not suitable due to the small availability of skin and limited arc of rotation and reliability due to poor circulation[7]. Cross leg flaps require immobilization in cumbersome positions and free flaps have their own pros and cons. Free flaps require expertise in microsurgical techniques and have a failure rate of 10–15%. Distally based sural artery perforator flaps harvested from the sural region and calf region are ideal. This flap is based on the sural neurovascular bundle and pivoted around an isolated perforator from the peroneal artery 5–7 cm above the ankle joint with 180 degrees arc of rotation for foot and ankle reconstruction. It provides robust axial blood perfusion to the flap with a significantly greater surface area and ease of rotation[8]. It has been widely used since Pontin's 1981 report[9]. The cutaneous artery running along the sural nerve, known as the superficial sural artery, has great variation with regard to its location and the origin of the vessel.

Masquelet and Hasegawa et al[10-11] have reported a distally based neuroskin flap with reverse flow through the anastomosis between the median superficial sural artery and the lowermost perforator of the peroneal artery that can be designed without a doppler flowmeter and scarification of the major arteries. There are only a few more reports on this technique[12-17]. Most of the published flaps were

used to cover soft-tissue defects in the ankle area, heel or dorsum of the foot. In 1992, Bertelli, Khoury and Masquelet et al. found through dissection that there was a longitudinal chain-like vascular plexus around every cutaneous nerve in the extremities, which not only supplied the cutaneous nerve but also gave off branches to the surrounding skin[18,19]. Therefore, they proposed that the vascular supply to the skin partially depended on the vascular supply of the cutaneous nerves, and including a cutaneous nerve and its vascular plexus in turn strengthens the vascularity of the flap. Due to the reliability of the vascular supply of the neurocutaneous flap, it has received wide popularity in the reconstructive field, becoming a workhorse for resurfacing soft-tissue defects in the extremities in either an anterograde or a retrograde manner[20-24] or even in a free approach[25]. In 1998, Nakajima et al[26] reported that cutaneous veins also had their accompanying nutrient arteries and he put forward the concept of neuro-veno adipofascial-pedicled flaps, which have dual blood supply from both the nutrient arteries of the cutaneous nerves and veins. Since then, neuro-cutaneous flaps, or neuro-veno fasciocutaneous flaps, especially in the extremities, have been widely employed to cover soft-tissue defects, due to their reliable blood supply and ease of dissection. We conducted a retrospective analysis of sural artery flaps performed for the coverage of defects around the lower leg, ankle and foot. Our main objective was to promote the surgical concept of the distally based sural artery flap and to evaluate the clinical and functional outcomes of distally based sural artery flaps in terms of viability, coverage of the defect, cosmetic appearance and functions of the foot and ankle.

Materials and Methods

A retrospective analysis of sural artery flaps was conducted; all flaps were performed by a single surgeon over a period of 25 years from July 1996 to February 2020. All patients who had coverage of soft tissue defects around the lower leg, foot and ankle with distally based sural artery flap were included in this study. All other patients who had coverage of such defects with other flaps such as supra-malleolar, perforator flap, medial sural artery flap and free flaps were excluded. Excluded also were those patients who were lost to follow-up and could not be traced. The data were collected from the Hospital Inpatient Management System and a review of medical records. The variables included demographic parameters, mechanism and duration of injury, mode of soft tissue defect, site and size of soft tissue defects, associated injuries, comorbidities, operative procedures, concomitant fixation of bone, complications and final outcome in terms of survival of the flap, cosmetic appearance, weight-bearing status and functional outcome of the foot and ankle.

Follow-up records of patients were taken from medical records; these included immediate complications such as venous congestion, hematoma formation, partial or complete necrosis and wound dehiscence. The functional outcome of each patient was assessed by a self-designed assessment tool based on flap survival, cosmetic acceptance of patient, the range of motion of the foot and ankle and the weight-bearing status of these patients. The final evaluation was done in the clinic by two researchers based on this self-designed assessment tool. The tool has four components (flap survival, cosmetic appearance, activities of daily living and weight-bearing status) and each component has four grades. Based on these four components, the results are classified into four categories: excellent, good, fair and poor (see Table 2).

Data were recorded on a preformed structured proforma. Data were checked for normality via the Shapiro–Wilk test and found to be normally distributed. Categorical variables such as gender and mechanism of injury were recorded as frequency and percentages. Discrete and continuous variables such as age and flap size were recorded as means and standard deviations. The data were divided into two groups: group 1 comprised sural artery flaps performed for the coverage over the lower leg defects and group 2 consisted of the flaps performed for the foot, ankle and heel defects. The differences in the two groups were analyzed using the chi-square or Fisher's exact test and the independent *t*-test for categorical and continuous or discrete data, respectively. All analyses were performed using SPSS version 24. A *P*-value of 0.05 or below was considered as statistically significant with 95% confidence interval.

Figure 1. 22 year's old professional foot baller who sustained bi-malleolar fracture of left ankle, operated outside our institute and had subsequent infection. Wound was debrided twice and had coverage of defect with sural artery flap. Figure A: shows skin defect at time of first debridement, B: shows per-operative flap rotation and C: show postoperative results at 12 weeks.

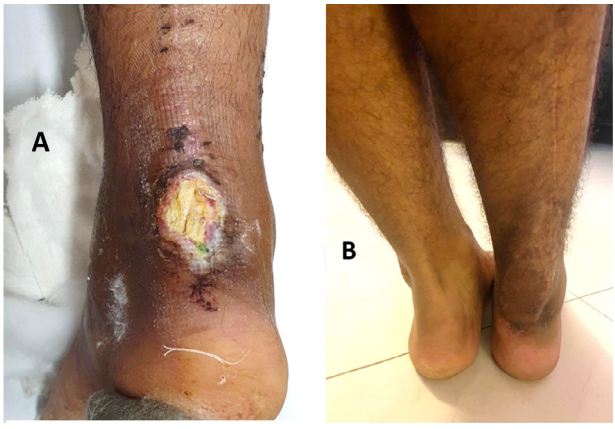

Figure 2. (A) 24 year old gentleman with Tendo-Achilles repair with tendon transfer of peroneus brevis to heel outside our institute with skin necrosis and exposed tendon (B) was covered with sural artery flap

Surgical Techniques

After the administration of anesthesia (general or spinal) depending upon the patient's condition and the American Society of Anesthesiologists (ASA) classification level, the patient is positioned in supine or lateral decubitus position with the involved side up. The supine position is opted if a

Figure 3. 9 year old girl with history of RTA, had extensive soft tissue injury over dorsum of foot and lateral aspect of ankle. A: shows wound after multiple debridements; B: illustrates 3 weeks post flap coverage; C&D: shows the flap after 12 weeks post-operatively.

concomitant procedure is planned on the foot and ankle; in this situation, a sandbag is placed underneath the buttock. A high-up tourniquet is applied, flap marking is performed, and the level of perforators are marked along the fibula almost 1–1.5 cm posterior to the fibular border (Diagram 1.1). The neurovascular axis of the flap is marked looking at the surface anatomy of the short saphenous vein; roughly, the axis starts from the midpoint between the lateral malleolus and the attachment of the Achilles tendon (TA) to the middle of the calf in between the two heads of gastrocnemius in the upper one third of the leg posteriorly. The pivot point of the sural neurovascular island flap is around the last two perforators, audible with ultrasound.

The last peroneal artery perforator is almost 5–7cm above the tip of the lateral malleolus. After anesthesia, preparation and draping are performed with a sterile technique. The procedure is performed under tourniquet with a pressure of 300–350 mmgH. Appropriate antibiotics are admin-

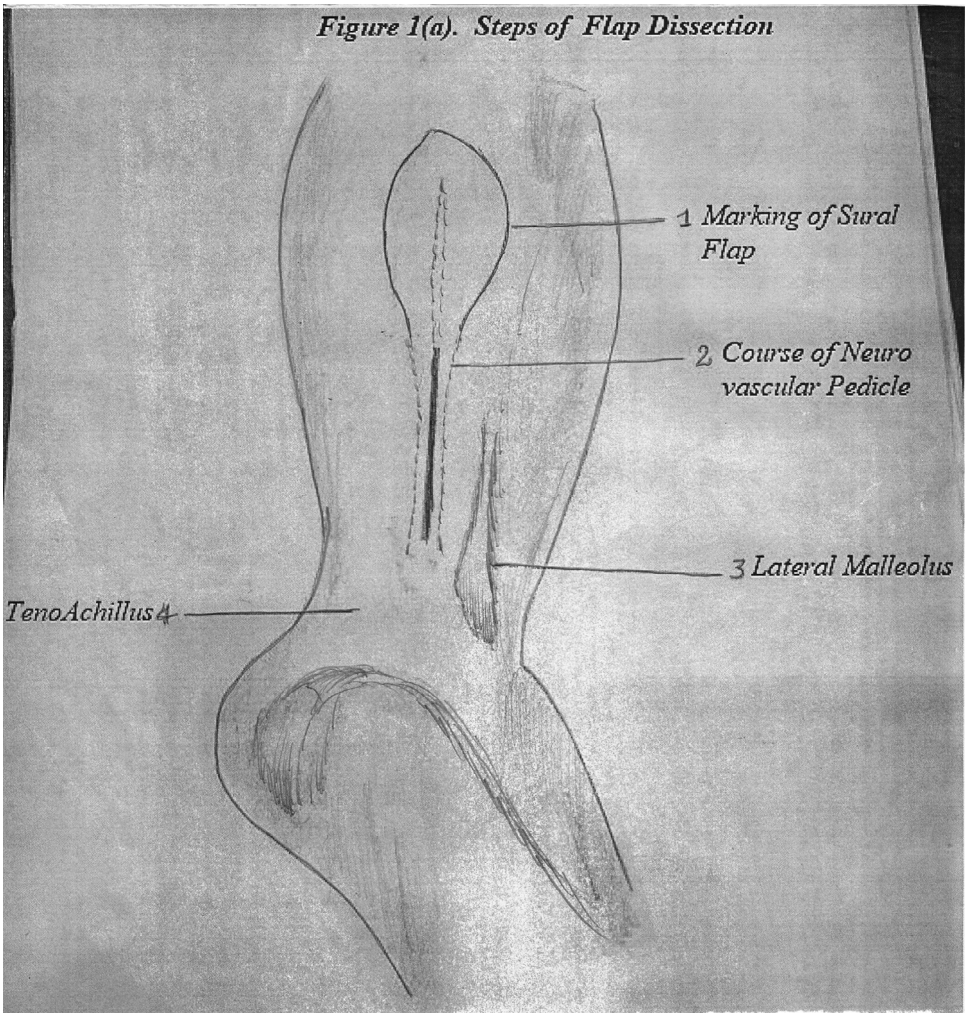

Diagram 1.1. you Marking of the sural neurovascular island flap: 1) outline of the flap, 2) marking of the neurovascular bundle, 3) lateral malleolus, 4) heel attachment of Achilles tendon.

istered intravenously 20–25 minutes before inflating the tourniquet. First, the defect site is debrided if required and the dimension of the defect size is measured and documented. The flap outline is marked around the axis of the sural neurovascular pedicle. Then the gauze piece is placed around the marked linings of the outlined flap; this gauze piece is cut around the marking of the flap and rotated at the pivot point of the last perforator. The flap size is kept 2–3 cm c longer in length and 1–1.5 cm wider in dimension. The first incision is made along the posterior margin of the flap. After cutting the skin and subcutaneous tissue skin margins are undermined away from the flap almost a couple of centimeters. Then the deep fascia is cut, and the flap is dissected up and down the posterior incision (Diagram 1.2). As the flap is raised deep to the fascia towards the fibula, the short saphenous vein and sural nerve are identified with their small feeding vessels and lifted with the flap towards the fibula.

Close to the fibula, various perforators are identified and dissected carefully till the last major perforator is encountered around the pivot point of the flap rotation, which has to be saved and protected. After this, an anterior incision of the flap is made, skin and subcutaneous tissue are un-

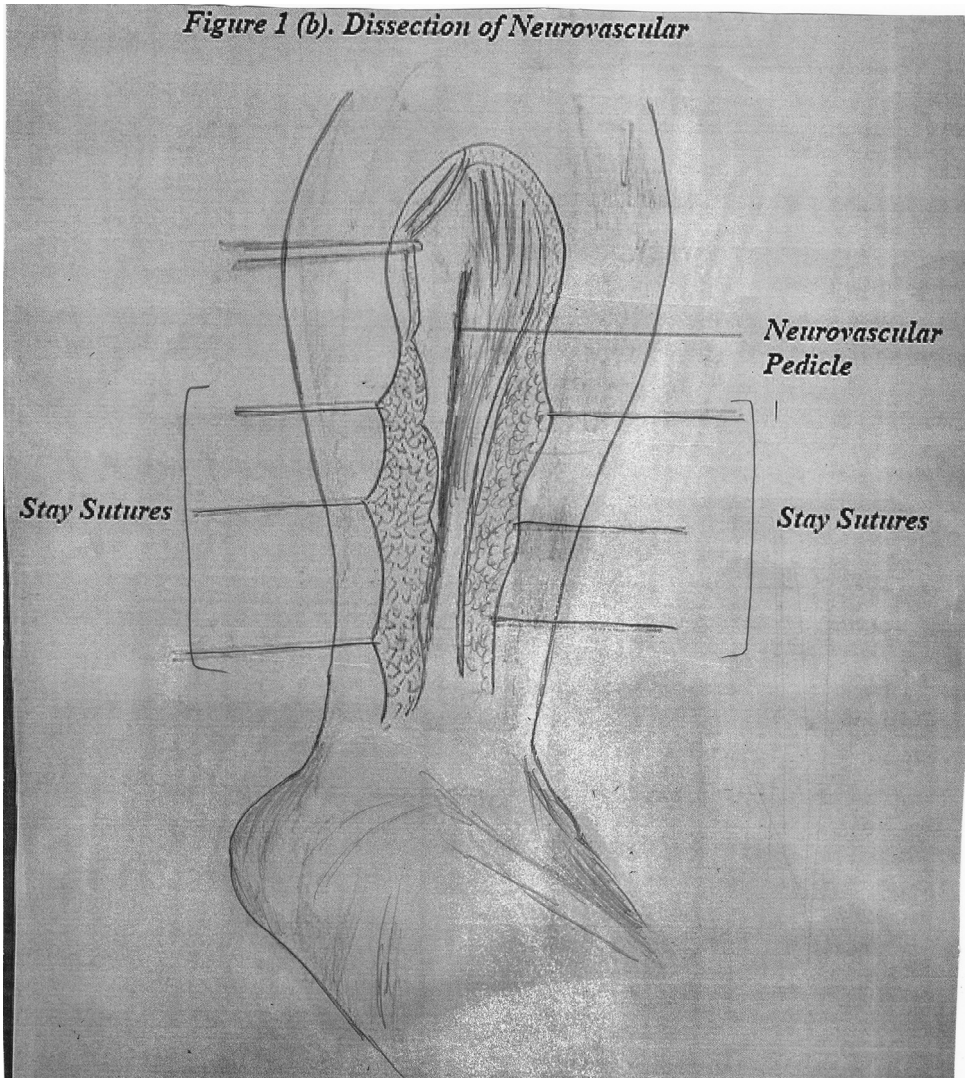

Diagram 1.2. Dissection of flap with deep fascia and veno-neurovascular bundle.

dermined away from the flap; the deep fascia is cut and that deep fascia is incorporated in the flap. The flap is raised with the deep fascia with blunt dissection towards the fibula. During this dissection, one must be careful not to cut the perforators already identified. In the meantime, the saphenous vein and sural nerve are identified at the upper limit of the flap and ligated with a suture. After this, the upper perforators are ligated, except for the last one of the pivot point of rotation that acts as the main source of the retrograde circulation. Once the flap has been raised, the tourniquet is released and removed to avoid venous congestion. The operating surgeon for this series notes that identifying the short saphenous vein near the pivot point and putting a silk ligature around it but not ligating the vein is an important step; the end of the free suture around the vein is left outside of the wound. Once the flap has been rotated to the recipient site and the flap is sutured to the skin of the recipient area, the donor site is closed primarily or with a skin graft taken from the same thigh (Diagram 1.3). The ends of that free suture around the vein are left free in the dressing. Postoperatively, if the flap

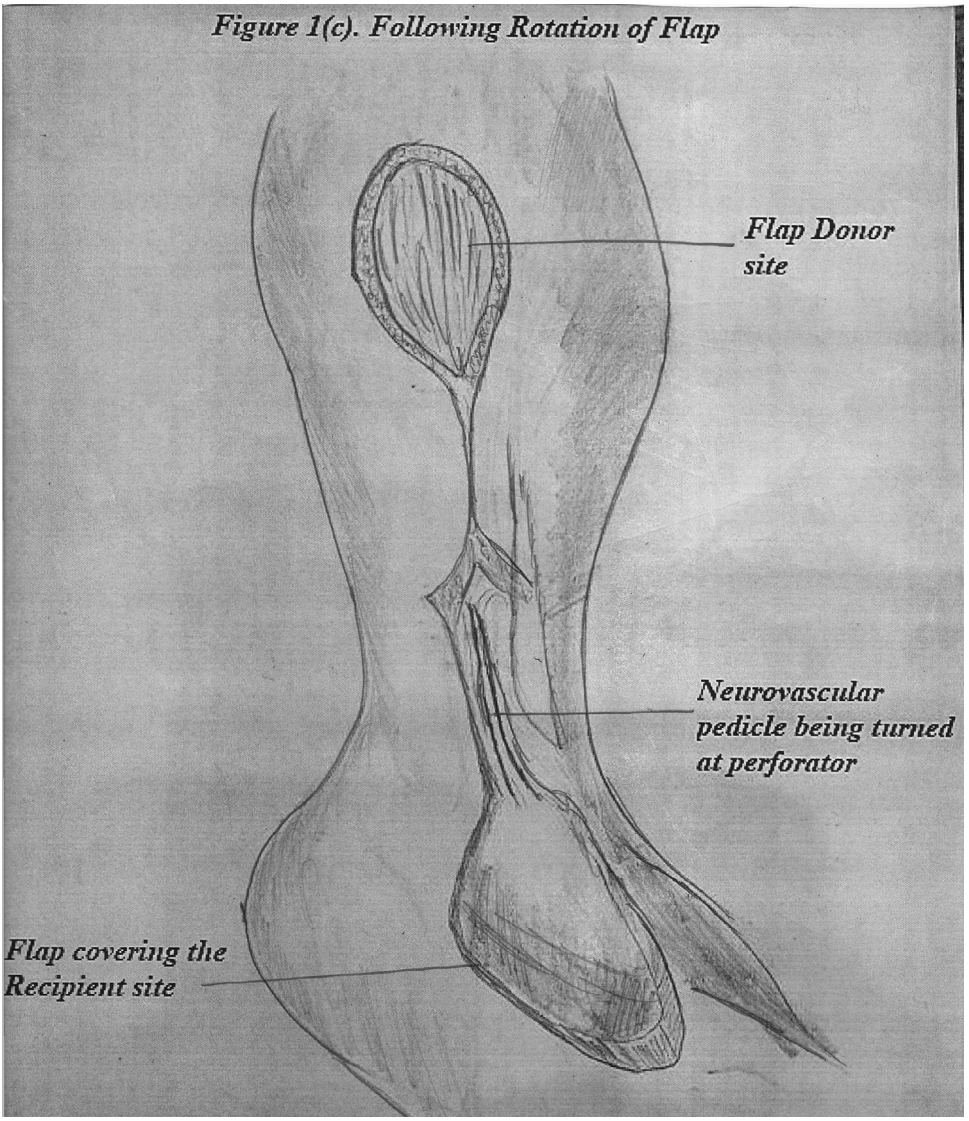

Diagram 1.3. Rotation of the flap to heel area and partial closure of the defect.

develops venous congestion due to venous drainage of the short saphenous vein, then this vein can be ligated through its free ends outside the wound. In this way, we do not have to take the patient to the operating room for exploration of the vein and subsequent ligation.

Results

During the period from 1996–2020, data on 106 patients, who underwent reverse sural artery flaps, were collected, but only 89 patients with 92 flaps were traceable for the final evaluation. Three male patients had bilateral flaps due to involvement of both legs in a bomb blast injury. Medical records and follow-up notes were available for all the patients, but only 89 patients participated in the final

Table 1
Clinical details of 92 patients in two groups

S.no	Variables		Group ILeg (N=41 cases)	Group IIFoot/ankle/heel (N=51 cases)	Significance P-value
1	Gender	Male	36 (87.8%)	31 (61%)	0.005
		Female	5 (12.2%)	20 (39%)	
2	Age	Mean ± SD (in years)	37.4 ± 17	33.3 ± 20	0.285
3	Mechanism of injury	Trauma	23 (56%)	25 (49%)	0.007
		Blast injury	12 (29%)	4 (8%)	
		Infection	6 (14.6%)	15 (29%)	
		For Contracture release	0	5 (10%)	
		For TA coverage s/p repair of TA	0	2 (4%)	
5	Flap Size	Mean in cm (L+B)/2	9.98 ± 2.2	12.15 ± 3.0	0.000
6	Complications	Partial necrosis	2 (5%)	1 (2%)	0.591
		Infections	2 (5%)	1 (2%)	
		Venous Congestions	0	2 (5%)	
		No Complications	37 (90%)	47 (92%)	
7	Flap Survival		99.75% ± 1.6	99.01% ± 5	0.316

follow-up evaluation; 17 patients out of 106 were not traceable. 64 patients were males, whereas 25 patients were females, with the mean age of 2- to 78-year-old patients being 34.91 years.

The study population was divided into two groups for the purpose of clinical and functional assessment: group I (n=41) included sural artery flaps for leg coverage and group II (n=51) comprised those flaps done for the coverage of the foot, ankle and heel area (see Table 1).

Out of 92 flaps, 37 in group I (90%) and 47 (92%) in group II showed complete healing and functional recovery with no complications. Flap complications were recorded in 8 (8.6%) out of 92 flaps, i.e. 3 patients developed partial necrosis (leg=1; foot=2) and required subsequent skin grafting, 3 patients developed infections (leg=1; foot=2) and 2 patients showed venous congestion around the foot region that recovered without skin necrosis. Three patients with infection required debridement and settled with appropriate antibiotics. The donor site defects were closed primarily by undermining the skin in 23 (25%) cases, while skin grafting was done in 69 (75%) cases.

All these patients were followed up in clinic until the time of wound healing and final ambulation. Some of the cases have been shown in Figure 1,2, and 3 Final follow-up and clinical assessment was done in the clinic based on four parameters:; survival of the flap and coverage of the defect in terms of percentage, cosmetic appearance, weight-bearing status, activities of daily living, sports activities and limitation in the function of the involved limb.

The overall flap survival rate was 96.8%; 3 patients developed partial necrosis that required skin grafting for the necrosed part of the flap. All 41 patients in group I were satisfied with the functional and cosmetic outcomes of the flap as 40 out of 41 (99.75%) patients had a good survival rate. Two out of 51 patients in group II developed partial necrosis with 80% coverage of defects and required skin grafting for the necrosis of the flap tip. The functional status was assessed by a self-designed assessment tool (see Table 2) in which the outcomes of the flap in terms of survival, coverage, cosmetic appearance, activities of daily life (ADL) and weight-bearing status were determined for each patient and the corresponding scores and a subsequent grade were provided. Grades were categorized as excellent, good, fair and poor and were given a score of 5, 4, 3 and 2 respectively, in each category of the four parameters of assessment (coverage, cosmetic appearance, ADL and weight-bearing status), as shown in Table 2. A collective score of 17 to 20 was considered as an excellent result, a score of 13 to 16 as good, a score of 9 to 12 as fair and a score of 8 as poor. Based on these assessment criteria, group I (leg) showed excellent results in 38 cases (92.6%), good in 2 cases (4.8%) and fair in one case (2.4%). In group II, there were 41 out of 51 cases (80.4%) in the excellent category, 8 cases (15.6%) in the good category and 2 cases (4%) in the fair category. There were no cases in the poor category in either group.

Table 2
Flap Outcome Grade by Dr. Pervaiz Hashmi (Showing Relation b/w flap coverages, cosmetic appearances, Daily life activities and Weight bearing status of limb.)

Variable	Excellent (5)	Good (4)	Fair (3)	Poor (2)
Coverage	100%	90 -100%	80-90%	50-70%
Cosmetic Appearance	Highly acceptable	Acceptable with slight raised skin margin	Acceptable with raised skin margin	Not acceptable due to thick and hairy skin
ADL	No issue in ADL and sports	No issue in ADL, difficulty in sports	Mild issue in ADL, cannot play sports	Difficulty in ADL and sports
Weight bearing	Full weight bearing	Full weight bearing, mild discomfort in sport	Discomfort in full weight bearing	Pain on full weight bearing
Total	20	16	12	8

Table 3
Outcomes based on Table 2

Outcome Scores/Grades	Group I (Leg) N=41	Group II (Foot/Ankle/Heel) N=51	Significance
Excellent	38 (92.6%)	41 (80.4%)	0.224
Good	2 (4.8%)	8 (15.6%)	
Fair	1 (2.4%)	2 (4%)	
Poor	0	0	
Mean score ± S.D	19.29 Ø1.7	18.45 Ø2.5	0.064

Discussion

Reconstruction of soft tissue defects around the lower leg, foot and ankle with exposed tendons and bones presents a great challenge due to the limited availability of local tissue and weight-bearing requirements. Replacement with thin, sensate and similar skin type is almost impossible. To cover these defects, most reconstructive flap procedures provide thick and hairy skin to this region that may cause problems in shoe wear, weight bearing, ADL and cosmetic acceptance. It is vital for a

foot to support standing and walking. Coverage of such defects with skin grafts may cause post-skin graft contracture and stiffness in the foot that impedes the normal activities of patients. Until now, a great number of reconstructive alternatives have been reported in the literature. In 2005, Zun-Li Shen[1] reported that the distally based fascio-cutaneous flap could not cover the forefoot reliably. In his series of 25 patients with extensive soft tissue defect in this region, there was 5% failure.

Our study spans a period of almost 24 years, and it has proved that flaps work well for the coverage of defects in the lower leg, foot and ankle, except for the weight-bearing area of the foot and heel[11-20]. By analyzing our results, it is evident that the main cause of soft tissue defects in the lower extremity remains trauma, followed by infections and blast/gunshot injuries. The complexity of problems increases when patients present late with underlying infections and mismanaged injuries. Such cases require multiple debridement procedures, skeletal stabilization, systemic antibiotics and subsequent flap reconstruction. Our series deals with these difficult areas of soft tissue reconstruction. There are a few salient features of this series. First, we performed the largest flaps (21cm long) to cover the whole dorsum of the foot in degloving injuries; second, the flaps were also performed in very young children, the youngest age being 2 years, and third, we conduct long-term follow-up of our patients. The flap is always harvested with an elliptical piece of skin, while the underlying adipose-fascial tissue is harvested according to flap size. Raising the flap in an elliptical way facilitates donor site skin closure. The beauty of this flap is that, contrary to the belief that it cannot cover the dorsum of foot[9], it can cover the whole dorsum of the foot and reach up to the toes. This is the largest series described so far, with 92 flaps in 89 patients; before this, the largest series was reported with 86 patients[27].

One of the major complications of flap surgery is venous congestion due to the drainage of venous blood in the short saphenous vein that we encountered in the early days of flaps from 1996 to 2000. Because of this, we encountered a few cases of flap congestion and flap tip necrosis. After this, we started to ligate the short saphenous vein at the pivot point of rotation to prevent venous congestion and the subsequent necrosis of flap that helped to reduce this complication. Nowadays, the primary surgeon puts a silk suture ligature around the vein, and both ends of the free suture are left outside in the dressing. In case the flap develops venous congestion during postoperative periods, one can ligate the vein through those free suture ends left outside without opening the wound.

The most important feature of this study is an objective clinical and functional analysis of flaps based on the coverage of defects, cosmetic appearance, weight-bearing status and ADL. This analysis was performed using a self-designed scoring tool; such an objective assessment has not been done before. All previous studies have discussed only about survival and complications. In this study, we have designed an objective tool to assess the coverage of the defect site (percentage), cosmetic acceptance of the patient, weight-bearing status and ADL (see Table 2).

Based on this tool, the majority of our cases from group I (41) fall in the excellent category (92.6%) because in these cases, the functional range of motion of the foot and ankle was not affected. The percentage of cases in the excellent category in group II was 80.4%, slightly lower than that in group I because these cases required coverage of defects around the foot and ankle affecting the functional outcome.

We observed few complications (8%): partial necrosis of the flap distal part that required subsequent skin grafting, three cases showed deep-seated infections and two cases showed venous congestion. The rate of complication was comparable to international data. In one series by Shi-Min Chang[8], 16% postoperative complications were observed. Direct closure of the donor site is only possible for flaps less than 4 cm in width, and the result is aesthetically undesirable if the donor site is grafted. We compared our series with another large series of Akhter S. and Hameed A.[27] who had performed flaps on 84 patients with 21.4% complication and 78.5% survival rates. We found that our series is the largest series reported so far in the literature, which is done by a single surgeon and has the longest follow-up of all cases. Our series shows better results in comparison with the published international literature in terms of survival (97%), functional outcome, cosmetic appearance and complications.

Based on our results and compared with international literature, we can safely say that the sural artery flap provides excellent coverage around the lower leg, ankle and foot, except for the weight-bearing area of the foot.

The advantages of this flap are easy dissection, robust pliable skin and flexibility in rotation of the flap around the lower leg, ankle, heel and foot up to the toes. Several articles have described the effectiveness and usefulness of a distally based superficial sural artery flap[11-16]. The disadvantages are that it is thick, hairy and insensate and requires good knowledge of anatomy and proper dissection. It causes an ugly scar on the back of the calf not acceptable to patients, especially women, and leads to permanent loss of sensation in the distribution of the sural nerve on the lateral border of the foot and fifth toe. The donor site usually requires skin grafting, and occasionally it can be closed in the case of smaller flaps and older age groups when the skin is lax. The flap vascularity can be increased when both neurocutaneous and venocutaneous vessels (sural nerve and saphenous vein) are incorporated in the pedicle of the flap. The last dominant perforator from the peroneal artery should be the pivot point of rotation that forms the basis of flap circulation.

Conclusion

Our series of 92 flaps had a better survival rate (96.70%) and a much lower complication rate compared with the published literature, as only three patients had partial necrosis. We have developed an objective assessment tool to assess the clinical and functional outcomes of these flaps, which needs to be reviewed and used by other researchers to standardize it. This may help in the comparison of results in future studies. Our series demonstrates the reliability of sural artery flaps for the coverage of defects around the lower leg, ankle and dorsum of the foot.

Conflict of interest

None

Funding

None

Ethical approval

Approved by the ERC committee and the ERC number is 4452.

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