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Distal Leg and Foot Reconstruction By Using Lateral Supramalleolar Flap

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ABSTRACT
Treatment of soft tissue defect in the foot and ankle is a challenge. Various locoregional options such as reverse sural artery, reverse peroneal artery, peroneus brevis muscle, perforator based and fasciocutaneous flaps have been used, but each flap type has limitation. The use of a lateral supramalleolar flap is a promising technique for reconstruction. The aim of this study is to present our experience with lateral supramalleolar flap that was used for reconstruction of the distal leg and foot defects and to evaluate its versatility and reliability in 12 patients. Eight male and four female patients were followed up for a period of 4-18 months postoperatively from June 2022 to May 2024 in emergency and OPD of plastic surgery department, PMCH, Patna. The age range of the patients were 31-50 years. Island flap was used in 5 patients and peninsular flap was used in 7 patients. Twelve flaps were used in the study. Average flap length was 12 centimeters. The maximum size of the flap was 104 cm^2 with an average of 48.2cm^2. Venous congestion occurred in 2 flaps leading to partial necrosis. Overall success rate was 90%. Lateral supramalleolar flap is a versatile and reliable method for the reconstruction of soft tissue defect of the lower extremity.

INTRODUCTION

Reconstruction of soft tissue defect around distal leg and foot is challenging because of lack of muscle cover due to which bone, tendon vessels and nerve get exposed. A typical defect involving multiple component of distal leg and foot usually requires staged reconstruction. Skeletal stabilization first followed by a stable cover with thin pliable soft tissue and if required repair and reconstruction of the bone after the flap cover has settled[1]. For optimum recovery and salvage of distal leg and foot defect, early intervention is key in the form of debridement and plan for definitive reconstruction. The assessment of distal vascularity is another major step in deciding our treatment modality[2]. Various options are available for the coverage of distal leg and foot defect such as graft, local flap, perforator flap and free flap. Use of skin graft to cover the site is not possible and even if possible, morbidity results due to cover of mobile structures thereby function is impaired. Use of fasciocutaneous flap cover these sites brings better vascularity to the site thereby provides stable cover to vital structure. The free flaps have been proposed as a solution to cover the wound in this region but it has some disadvantages like, it needs expert surgeon proficient in microsurgery, high quality instrumentation and extended operative durations[3]. The lateral supra malleolar flap first introduced by Masquelet et al. in 1988. Valenti et al. refined the technique by elevating the subcutaneous pedicel.

Aims and Objectives: The aim of this study was is to present our experience with lateral supramalleolar flap that was used for reconstruction of distal leg and foot defect and to evaluate its versatility and reliability. The specific objectives of our study were to study the adequacy, reach and usefulness of a lateral supramalleolar flap for distal defects of the dorsum of the foot., to observe various complications encountered with the flap and to study the functional outcomes of reconstruction.

MATERIALS AND METHODS

Eight male and four female patients were followed up for a period of 4-18 months postoperatively from June 2022 to May 2024 in emergency and OPD of plastic surgery department, PMCH Patna. The age range of the patients were 31-50 years. Island flap was used in 5 patients and peninsular flap was used in 7 patients.

Study Design: Patients with an injury to the intended flap area (lateral perimalleolar area), the anterior tibial artery, or in areas of communication between the anterior tibial and anterior lateral malleolar arteries were excluded from the study. After an initial work up and hemodynamic stabilization, patients were taken for skeletal stabilization by orthopedic surgeons. Debridement of the wound and defect analysis were performed and the defect was reconstructed with a distal lateral supramalleolar flap[4]. The postoperative position was maintained with splint support or external fixation. The flap was clinically monitored postoperatively and complications were analyzed. Demographic parameters were recorded, including age, sex, defect site, defect size, defect extent, dimensions of the flap, the distance of the anterior perforating branch of peroneal artery from the tip of the lateral malleolus, distal communication with the anterior tibial artery and postoperative complications.

Surgical Anatomy: The skin of the lateral aspect of the leg is supplied by terminal branches arising from the perforating branchof the posterior peroneal artery. It has been demonstrated (Masquelet[5]) that this perforating branch is constant, always emerges 5cm above the lateral malleolus in the groove between the tibia and the fibula and gives two or three ascending cutaneous branches. These branches perforate the fascia and continue as a vascular network in the lateral aspect of the leg. It is possible to isolate this subcutaneous vascular network to provide the blood supply to the skin flap on the lateral aspect of the leg. With this subcutaneous pedicel, it is not necessary to site the skin paddle over the origin of the perforating branch of the peroneal artery under the skin paddle, as described by Masque let *et al.* in their initial paper. The skin territory of the flap can therefore be designed more proximally on the lateral aspect of the leg but should not go above the middle third or extend beyond the tibia1 crest medially and the posterior border of the fibula laterally. The point of rotation is the origin of the perforating branch of the posterior peroneal artery. If needed, the subcutaneous pedicle can be elongated by dissecting the descending branch of the peroneal artery which runs anterior to the ankle to the sinus tarsi, giving the flap a wide arc of rotation[6].

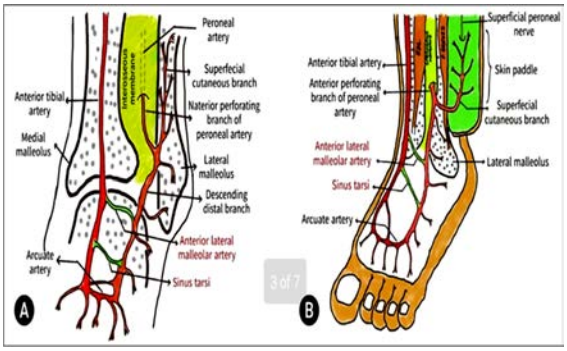

Fig 1: (A, B) Communications of the Peroneal Artery with Anterior Tibial Artery Branches

Surgery Technique: Position-Supine with a sandbag under the ipsilateral buttock. A tourniquet is applied. Station 1-Planning in reverse done. Upper limit is at

middle of leg. Anterior border is just medial to palpable subcutaneous border of tibia. Lateral border extends upto fibula. Skin paddle marked. Superior incision made. Superficial peroneal nerve identified in the anterolateral septum, divided and tagged with skin paddle. Rest of the incision completed. In peninsular flap, subfascially flap is raised till pivot point (1-2cm above tibiofibular syndesmosis) where subperiosteal dissection done over fibula at lower one third of the leg to safeguard ramus perforans. In island flap, sub dermal flaps are raised preserving adipofascial layer about 2cm on either side of vascular pedicle. In this blood supply to the flap is by anastomosis of ascending branch of ramus perforans with superficial peroneal nerve artery. In station 2-Same as the above procedure except, incision extended anterior to lateral mallotus till sinus tarsi and Ramus perforans divided. Here blood supply to the flap is from the anastomosis between descending branch of peroneal artery with anterior lateral malleolar artery, branch of anterior tibial artery. Closure of the wound-suturing the peroneal and extensor muscles together to provide a well-vascularized bed for the graft. The flap is then transferred to the recipient site. Then flap is sutured loosely to prevent post-operative swelling. A split thickness skin graft is applied over the donor site. Finally, a careful inspection was made to be sure the pedicle was not under traction. A cast was used to stabilize the ankle to protect the flaps from unnecessary stress.

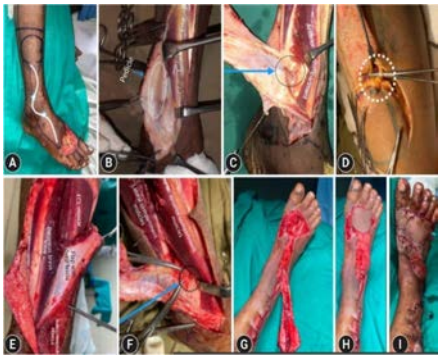

Fig 2: Operative Steps

Post-Operative Follow-Up: Within 8 hours after surgery, the flap colour, temperature and capillary refill were evaluated carefully. Patients and their relatives were instructed to keep the affected limb in an appropriate position to avoid pressure on the pivot point, flap pedicle inset and recipient site. After 5 days, the gauze covering the skin graft at the donor site was removed. An additional closure was made, if necessary, with a minor surgery. In this way, the patient was often discharged on the seventh day. In case necrotic flaps are unrecoverable through minor surgical interventions, necrotic tissue is debrided, followed by a skin graft.

RESULTS AND DISCUSSIONS

Lateral supramalleolar flap was used in 12 patients for reconstruction of the distal leg and foot defects. There were 8 males (66%) and 4 (34%) females and age ranged from 31-50 years. In all cases bone, joint or Achilles was exposed. The follow-up period ranged from 4-18 months postoperatively. In 5 (42%) cases, we used the island flap and in 7 (58%) cases peninsular flap. 2 (16%) flaps developed partial superficial necrosis. After excision of the necrosed part, the soft tissue defect healed spontaneously. In 2 (16%) cases, venous congestion was present but resolved. All the patients were able to leave the hospital within a very short period after surgery (8-day average).

Station 1:

- Ramus perforans-branch of Peroneal artery.
- Lies just above tibio fibular syndesmosis.
- When raised based on first station it can cover defects over medial malleolus, lateral malleolus, Posterior heel, Lisfranc and Chopart's amputation.

Station 2:

- Anterior lateral malleolar artery-branch of anterior tibial artery.
- When raised at this level it is based on anastomosis of anterior lateral malleolar artery, branch of anterior tibial artery with descending branch of ramus perforans.
- When raised at this station it can cover defects of tarso metatarsal amputation defects.

Station 3:

- Lateral tarsal artery-branch of Dorsalis Pedis artery.
- Lies at the level of Sinus tarsi.
- When raised at this station it can cover defects over base of toes.

The standard approach to foot reconstruction should optimize recipient site benefits and minimize donor site morbidity. In cases of severe foot trauma, the choice flap is the flap that can be used to cover the tissue defect, while bone fracture and tendon rupture can be managed simultaneously. Until now, there has been no optimal method for reconstructing foot areas although some techniques were proposed and performed[7]. Despite its popularity, the sural flap remains cumbersome for mid foot and forefoot coverage due to its pivot point situated behind the ankle, approximately 2 cm above the lateral malleolus. The dorsal metatarsal artery perforator flap has been recently introduced, but it was used predominantly for forefoot reconstruction. While free flaps offer a viable option for foot reconstruction, they necessitate specialized expertise in microvascular techniques[8]. As an alternative approach, In this study, the LSM

Sr. No	Age(Years)	Sex	Area of defect	Size of Defect in cm2	Type of area	Vascular supply station	Complication
1	35	M`	Dorsum of right foot	10x8	Island	2	nil
2	43	M	Over it medial Mallotus	8x9	Peninsular	1	nil
3	46	F	Over letral malleolus	9x5	Peninsular	1	Venous congestion
4	40	M	Heel defect	10x6	Island	2	nil
5	34	M	Dorsum of foot	12x10	Island	2	nil
6	38	M	Letral malleolus	10x7	Peninsular	1	Marginal necrosis
7	49	F	Medial malleolus	12x5	Peninsular	1	nil
8	37	M	Wound over heel	6x5	Peninsular	1	Venous congestion
9	39	F	Medial aspect of ankle	7x6	Peninsular	1	nil
10	49	M	Dorsum of foot	11x5	Island	2	nil
11	33	M	Letral malleolus	8x6	Island	2	Marginal necrosis
12	43	F	Medial malleolus	8x9	Peninsular	1	nil

technique was used and it provided good coverage to soft-tissue defects. This technique effectively covers soft-tissue defects in various foot subunits, including the forefoot, mid-foot, medial malleolar and heel. Because the LSM flap starts anterior to the ankle, the distance from it to the regions of the dorsal foot was short. This study had a mean total flap length of (ranging from 7-14 cm)., these lengths were chosen so that they were suitable for the wound. In this study, for all cases of the wound settled in the forefoot, the length of the flap reached the wound easily. The surgical procedure took a reasonable time, averaging about 90 minutes. The identification of the surface landmark of the pivot point was very important in flap design and anticipation of flap viability. In this study, the pivot point was at the intersection of the fourth metatarsal bone's axis and the line connecting the two malleoli. This placement, approximately 2 cm higher than the sinus tarsi point as suggested by previous authors, facilitates the preservation of the inferior extensor retinaculum during flap pedicle dissection.

Fig 3: Third Failure Case with Partial Flap Necrosis
(A) Wound Before Surgery
(B) First Operative Day
(C) Severe Venous Congestion Led to Partial Flap Necrosis
(D) Result After the Second Skin Graft Procedure

Fig 4: Heel Reconstruction by Retrograde Lateral Supramalleolar (LSM) Flap
(A) Wound Before Operative
(B) Flap Dissection
(C) Flap Healing in the Recipient Site 20 Days Post Operation
(D) At 14 Months Post Operation

Fig 5: Combined Flap Dissection with Bone Fixation in One Procedure
(A) Expose Medial Malleolus Fracture
(B) Bone Fixation by Plate and Flap Elevation
(C) Closing the Wound by Retrograde Lateral Supramalleolar (LSM) Flap
(D) X-Ray Image of Bone Fixation
(E) Donor Site Healing By a Skin Graft
(F) Flap Healing

Preservation of this retinaculum is crucial for maintaining normal extensor tendon function and preventing the bow-string phenomenon, which may compromise foot function and postoperative aesthetic outcomes. Following the pivot point, the flap lengths can be up to 17cm enabling enough coverage of various foot subunits, including the distal margin of the dorsal forefoot[9]. The island LSM flap, based on this pivot point, had a remarkable versatility. It can be used to cover soft-tissue defects in multiple foot subunits, encompassing the fore-foot, mid foot, medial malleolus area and even the heel region. For the defects in the mid foot and forefoot, the sural flap had been usually used. However, the sural flap's posteriorly located pivot point necessitates the subcutaneous pedicle to traverse around the ankle to reach the anterior region, thereby compromising aesthetic outcomes in forefoot reconstruction. Similarly, the sural flap is primarily utilized for heel reconstruction, but in the cases where the heel defects involve injury of the sural flap's perforators, island LSM flaps serve as reasonable alternative procedures[10]. In this study, such cases had excellent results, contrary to prior reports indicating challenges with island LSM flap use in heel reconstruction. This study showed the potential efficacy of island LSM flaps in heel reconstruction and offered valuable insights for future clinical applications. Commonly, patients with bone fractures and soft-tissue defects will be repaired with a flap before bone fixation. In this study, a triple malleolus fracture was fixed and a soft-tissue defect was covered with peninsular LSM flap simultaneously on a patient. The patient was a 37-year-old woman, involved in a traffic accident and presented with a triple malleolus fracture and a soft-tissue defect at the medial malleolus area. The medial malleolus bone fixation was performed, and a retrograde LSM flap was applied using the same approach utilized for fibular reduction and plate internal fixation. The flap was then transferred to the recipient site through a skin tunnel. The bone was healed and the flap was integrated. This case illustrates the feasibility of simultaneously executing the LSM flap with bone fixation techniques. It gives an approach for patients with foot tissue defects associated with bone fractures involving the medial malleolus, metatarsal and heel. Although the overall success rate of the study was high, there were failed cases. Two of the failed cases had pedicle tunnel techniques in which long flaps (17cm in total length) were passed through a tunnel to the recipient site. This tunnel might be small and cause pressure on the pedicle, compromising the blood supply to the flaps. Additionally, maybe the flaps failed because their dimensions were large (60 cm2) and they covered soft-tissue defects far in the forefoot. It was wondered whether using vasodilators, maintaining a warm temperature around the postoperative flaps and local heparin could help prevent venous congestion, rescue these flaps, and enhance flap survival. The results of this study show that the LSM flap can be used in retrograde patterns, while previous authors extensively used it in a mixed pattern and smaller-scale studies focused on the retrograde pattern. The results also show that the retrograde LSM flap can be used successfully for forefoot defects. This study has some limitations. As a cross-sectional observational study, it lacked a control group for comparative analysis of the method's effectiveness. So it is difficult to determine whether this method is superior to others in covering soft-tissue defects in the foot and ankle region or not. The landmark surface of the pivot point used in the study is subjective. Despite it being exact in every case, it was not linked to any anatomy report. An anatomy study should be performed to find out the best pivot point.

CONCLUSION

Depending on the requirement of reach, the same flap can be raised based on different stations of the main source vessel for the coverage of distal third defects of leg and foot. Lateral supramalleolar flap is a versatile local flap for distal third defects of leg and foot. It can reach as far as the base of the toes with good wound healing and without major complication. islanding the flap makes it a single stage procedure. It can be used in all age group and safe following acute trauma. It can be used as a lifeboat or even as a substitute or alternative to free flaps.

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