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Study of versatility of reverse sural fasciocutaneous flap for reconstruction of lower third leg defect

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Abstract
Soft-tissue defects of the lower extremity usually result from trauma, infection, vascular insufficiency, or surgery. The sural flap proved a considerable versatility at the level of the lower leg (from the knee to the ankle and heel) as well as for other anatomical regions. The most common usage of the flap is for the distal-third defects of the leg. Here, the reverse sural flap permits the soft tissue reconstruction without the need for microsurgery. It does not sacrifice any of the three major arteries to the distal extremity. Sparing the major artery, the relatively simple dissection and the low donor site morbidity are among the most important advantages of using this flap. This study is a retrospective review of the sural fasciocutaneous flaps carried out in 14 patients): 11 men and 3 women with an average age of 41 years (ages 16-61) and a postoperative follow-up between 1 years and 2 years. Most of the patients had sustained road traffic accident. Nine (9) of the defects were over the lower 1/3rd leg, three (3) of the defects were around the medial malleoli, One(1) over the anterior ankle, and 2 over lateral malleoli. There was an underlying bone, fracture, implant or tendon exposed in 9 patients. 3 of this patients underwent standard reverse sural island flap and rest 11 patient underwent reverse sural fasciocutaneous flap. The size of the defects for island flaps ranged from 5x5cm to 9x8cm. The length of sural fasciocutaneous flaps ranged from 7 to 25cm from the tip of lateral malleolus. All the defects were covered successfully, without major complications. In our conclusion, reverse sural artery fasciocutaneous flap distally based on peroneal perforators is a good option to cover the soft tissue defect of distal third leg, ankle, heel and dorsum of the hind foot.
The present study was planned in the Department of Plastic Surgery, Pulse Emergency Hospital, Patna, Bihar. Total 14 cases of the operated from June 2016 to Dec 2017 were included in the present study.

Keywords: reverse sural flap, lower third leg, reverse sural artery flap, fasciocutaneous flap

Introduction
Soft-tissue defects of the lower extremity usually result from trauma, infection, vascular insufficiency, or surgery. In the past, defects that could not be treated by primary closure or skin grafts have been allowed to "fill in"-a slow process of granulation, contraction, and epithelialization.
Reconstruction of soft tissue defects on the lower pre-tibial surface of the leg remains a challenge to the surgeons. If the defect is large and complicated by bone defects, free tissue transfer of cutaneous or muscle flaps is well established and the results are satisfactory [1-2]. However, a local flap is still popular because it is a simple, one-stage and reliable operation. When the soft tissue defect is small. an available local flap is more convenient and economical than free tissue transfer. Since Ponten' introduced the "super flap", fasciocutaneous flaps have been demonstrated to be good local faps for reconstruction of small to medium sized soft tissue defects of the leg." [3]. With further detailed knowledge of the circulation of the skin. other variations were reported in the last decade.
The potential of the medial calf integument, as donor site for a free flap based on musculocutaneous branches of the medial sural artery, was first identified by Taylor and Daniel, following cadaver investigation [4]. In 1981, Pontén [3] described the fasciocutaneous sural flap as a reconstructive option for soft tissue loss of the lower extremity, particularly around the knee. Two years later, Donski and Fogdestram [5] presented the distally based fasciocutaneous flap from the sural region followed by Montegut and Allen who considered the sural artery perforator flap as a viable alternative for the gastrocnemius myocutaneous flap [6]. In 1992, Masquelet *et al*. introduced the concept of neurocutaneous island flap and described the sural neurocutaneous flap [7], lately referred to as retrograde sural nerve flap [8]. Hallock and Cavadas further investigated the vascular anatomy of the sural perforator flap and reported a series of clinical cases successfully managed by using it [9-11].
In the last decades, multiple modifications of the sural flap have been reported and a plethora of often puzzling denominations appeared. According to various classification criteria, but mostly determined by the surgical technique for harvesting and using this flap in various defects reconstruction, the sural flap has been referred to as reverse sural artery flap [12, 13], delayed sural flap [14], supercharged reverse sural flap [15], sural fasciomusculocutaneous flap [16], distally based sural flap [17, 18], cross-leg distally based sural flap [17], distally based sural neurocutaneous flap [19], distally based sural neuro-fasciomyocutaneous flap [20], distally based sural neuro-lesser saphenous veno-fasciocutaneous compound flap [21], nerve sparing distally based sural fasciocutaneous flap [22], etc.
Summarizing, one can state that what is generally meant by "sural flap" is a variant of the reverse sural flap or distally based sural flap [23] (the word "sural" describing the sural angiosome, meaning the site where the flap's skin island is

harvested).

The sural flap proved a considerable versatility at the level of the lower leg (from the knee to the ankle and heel) as well as for other anatomical regions. The most common usage of the flap is for the distal-third defects of the leg. Here, the reverse sural flap permits the soft tissue reconstruction without the need for microsurgery. It does not sacrifice any of the three major arteries to the distal extremity. Sparing the major artery, the relatively simple dissection and the low donor site morbidity are among the most important advantages of using this flap.

On the other hand, there are some critical aspects to be considered. The most important one concerns the venous congestions and flap ischemia. Flap delay [14, 17, 24, 25, 26], supercharging [15], harvesting the pedicle with 3 cm of tissue on either side and with the overlying skin intact [27] are some procedures that help overcoming this complication. Most authors mention the unaesthetic scar at the donor site, mainly if the closure needs a skin graft. Because the flap is harvested with the nerve, the loss of sensibility on the lateral aspect of the foot might pose certain problems [8].

Anatomical basis of flap: Masquelet *et al*1 described the anatomical details for this flap in 1992. The reverse flow sural artery neuro fasciocutaneous flap is based onthe medial superficial sural artery [28]. This artery is a branch of the superficial artery originating from the popliteal or sural arteries and then following the course of the sural nerve 2-3 cm distal to its origin and emitting numerous branches along its suprafascial path towards the skin at the lower leg. Popliteal artery in the popliteal region gives off a dominant arterial branch each to the medial and lateral heads of gastrocnemius. In addition to these muscular branches it also gives sural artery which divides into median, lateral and medial branches, the first one being constant and the last one being quite variable. Sometimes these medial and lateral branches may be derived from inferior genicular arteries or the muscular sural artery supplying the gastrocnemius. These medial and lateral branches are reciprocal to each other in size. There is also a reciprocal relation in size between the direct cutaneous sural vessels and muscular arteries supplying the two heads of the gastrocnemius. The median sural artery generally accompanies the sural nerve and short saphenous vein in the proximal calf [29]. Branches of the median sural artery supply the skin and the subcutaneous area of the posterior part of the middle 1/3 of the calf. This suprafascial plexus of vascular network arborises both longitudinally and radially and anastomoses with the septocutaneous perforators of the peroneal artery inthe distal 1/3 of the calf. It is this reliable suprafascial anastomoses of vascular network of 2 different sources that forms the basis of distally based adipofascial pedicled fasciocutaneous flap from the middle 1/3 of the calf. Peroneal septocutaneous perforators are quite constant in number and the most distal one is given off well within 5 cm proximal to the tip of the lateral malleolus Fig 1. Hence the pivot point of this distally based flap can be as distal as 5cm from the tip of the lateral Malleolus. Careful dissection and mobilization of these perforators can permit further distalisation of the pivot point of the flap to cover the defect of the dorsum of the hind foot and mid foot.

Recent concept of venocutaneous perforators from the arterial branches accompanying the short saphenous vein can also supply these distally based flaps independent of the neurocutaneous perforators. Hence theoretically and practically these distally based flaps can include the skin and subcutaneous tissue of the proximal 1/3 of the calf (Type B1 and D1 lesser saphaenous VA flaps of Nakajima) provided the flap is raised with the short saphenous vein without damaging accompanying artery [29].

Methodology

The present study was planned in the Department of Plastic Surgery, Pulse Emergency Hospital, Patna, Bihar. Total 14 cases of the operated from June 2016 to Dec 2017 were included in the present study.

This study is a retrospective review of the sural fasciocutaneous flaps carried out in 14 patients (Table 1): 11 men and 3 women with an average age of 41 years (ages 16-61) and a postoperative follow-up between 1 years and 2 years. Most of the patients had sustained road traffic accident.

The soft-tissue defect in the lower limb in this study was located, on the malleolar and paramalleolar area in three cases each, and on the distal tibia in rest of the eight cases. Two patients were diabetic and suffered from diabetic foot ulcer. The associated fractures were treated with external fixator. The flap size is measured in length and breadth and recorded. All the patients underwent basic laboratory investigations (CBC, Hb, RBS, Electrolytes, RFT, Chest X-ray, ECG) and peroneal perforators were identifi ed by using handy Doppler flow meter.

Table 1

Case	Age /sex	Etiology	Site	Size of defect (cm)	Size of flap	Flap morbidity	Result
1	24/M	RTA	distal tibia	10x7.5	12x8	N/A	Good
2	18/M	RTA	Distal tibia	8x7	10x8	N/A	Good
3	34/M	RTA	Distal tibia	16x9	10x8	N/A	Good
4	48/M	RTA	Distal tibea	12x8	14x10	N/A	Good
5	16/M	RTA	Para malleolar	8x5.5	10x7,5	N/A	Good
6	35/M	RTA	Supra malleolar	6X8.5	8x10	N/A	Good
7	36/M	RTA	Supra malleolar	8x12	10x14	N/A	Good
8	19/F	RTA	Para malleolar	5x5.5	6x8	N/A	Good
9	57/M	Diabetic ulcer	Supramalleolar	4x4,5	6x6	N/A	Good
10	39/M	RTA	Distal tibia	9.5x7	12x9	N/A	Good
11	16/F	RTA	Distal tibia	11x6	14x8	N/A	Good
12	23/M	RTA	Distal tibia	5x4.5	6x6	N/A	Good
13	61/F	Diabetic ulcer	Para Malleolar	4x6	5x7	N/A	Good
14	27/M	RTA	Distal tibia	8x5	10x7	N/A	Good

Procedure

With patients in the prone position under spinal anesthesia the size of the defect is measured and a cutaneous island to be transferred is marked out on the middle or distal third of leg, depending on the length of pedicle necessary to reach the wound. The pedicle is kept centralised with regard to the flap. A line is marked from a point halfway between the Achilles tendon and the lateral malleolus extending to the midline between the two heads of gastronemius which roughly marks the course of the pedicle.

The pivot point is approximately 5cm proximal to the lateral malleolus and posterior to the fibula. The axis of the pedicle is oblique and can be located precisely by the coarse of the lesser saphenous vein. A reliable fasciocutaneus pedicle should not exceed the ratio of 4:1.

The incision begins over the proximal border of the skin island and is carried down to the sub fascial layer. The flap is elevated under tourniquet inflation. The sural nerve, and the accompanying short saphenous vein are identified, ligated and cut. The flap is dissected from proximal to distal, followed by the pedicle with an adjacent 1 to 2 cm width of fascia. The fascia must be included in both skin island and pedicle dissection. The viability of the flap is checked after tourniquet deflation. Hemostasis ensured. The flap is transferred with the pedicle which may be placed in a subcutaneous tunnel, open tunnel or externally placed with STG over it.

The secondary defect over donar site can be closed primarily when it is less than 4cm in diameter. It should be covered with a partial thickness skin graft when it is larger.

All the patients were informed consents. The aim and the objective of the present study were conveyed to them. Approval of the institutional ethical committee was taken prior to conduct of this study.

Fig 1(a): Open fracture Distal third tibia, Gustillo III B with large area soft tissue defect

Fig 1(b): After Debridement

Fig 1(c): Raising of Reverse sural artery fasciocutaneous Flap

Fig 1(d): Rotation of Reverse sural artery fasciocutaneous Flap by 90degree

Fig 1(e): Flap Inset/ Donor site and Pedicle site covered with STSG

Fig 1(f): Post operative

Fig 1: (Case 1) Tibial defect covered by Reverse Sural Artery Fasciocutaneous Flap.

Fig 2(a): Open fracture Distal third tibia, Gustillo III B with large area soft tissue defect

Fig 2(b): Raising of Reverse sural artery fasciocutaneous Flap

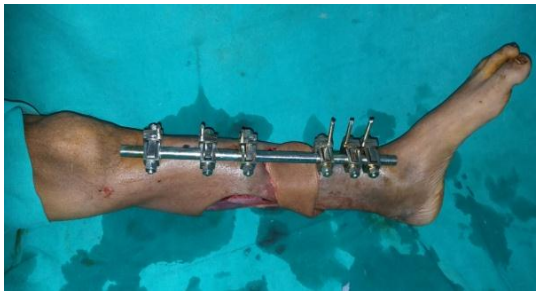

Fig. 2(c): Flap Inset/ Donor site and Pedicle site covered with skin graft

Fig 2(d): 10 th day Post Operative

Fig 2: (Case 2) Tibial defect covered by Reverse Sural Artery Fasciocutaneous Flap.

Fig 3(a): Open fracture Distal third tibia, Gustillo III B with large area soft tissue defect

Fig 3(b): Raising of Reverse sural artery fasciocutaneous Flap

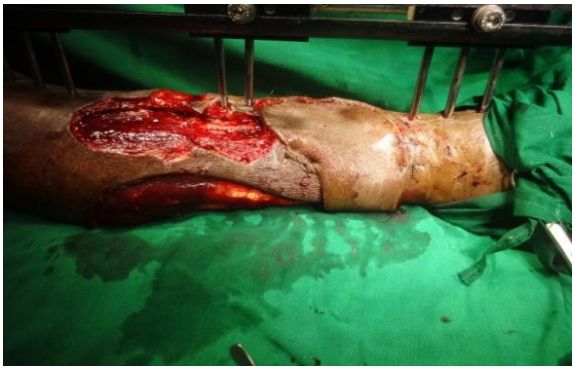

Fig 3(c): covered with reverse sural fasciocutaneous Flap

Fig 3: (d) Immediate Post Operative

Fig 3: (Case 3) Tibial defect covered by Reverse sural artery fasciocutaneous flap.

Fig 4(a): Open fracture Distal third tibia, Gustillo III B with large area soft tissue defect

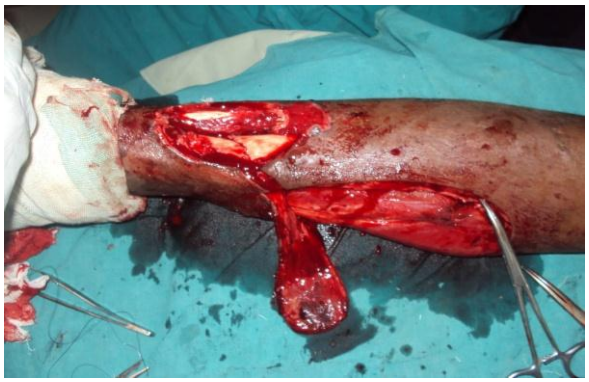

Fig 4(b): Raising of Reverse sural artery fasciocutaneous Flap

Fig. 4(c): Flap Inset/ Donor site and Pedicle site covered with STSG

Fig 4(d): Immediate Post Operative

Fig 4: (Case 4) Tibial defect covered by Reverse Sural Artery Fasciocutaneous Flap.

Fig 5(a): Anterior Ankle Defect

Fig 5(b): Raising of Reverse sural artery fasciocutaneous Flap

Fig 5(c): Flap Inset/ Donor site and Pedicle site covered with STSG

Fig 5(d): Immediaate Post Operative

Fig 5: (Case 5) Para Malleolar Tibial defect covered by Reverse Sural Artery Fasciocutaneous Flap.

Fig 6(a): Supra malleolar Tibial Defect

Fig 6(b): After Debridement

Fig 6(c): Raising of Reverse sural artery fasciocutaneous Flap

Fig 6(d): Flap Inset/ Donor site and Pedicle site covered with STSG

Fig 6: (Case 6) Supra Malleolar Tibial defect covered by Reverse Sural Artery Fasciocutaneous Flap.

Fig 7(a): Supra malleolar Tibial Defect

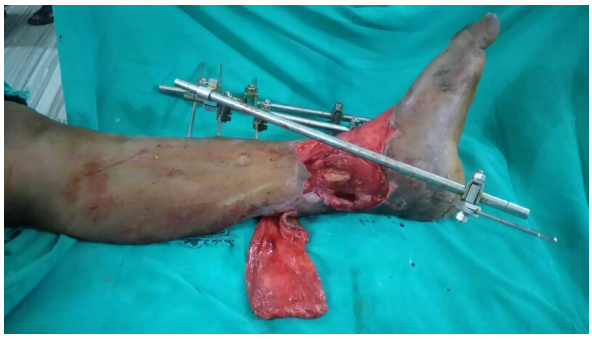

Fig 7(b): Raising of Reverse sural artery fasciocutaneous Flap

Fig 7(c): Flap Inset/ Donor site and Pedicle site covered with STSG

Fig 7(d): 12th Day Follo Up

Fig 7: (Case 7) Supra Malleolar Tibial defect covered by Reverse sural Artery Fasciocutaneous Flap.

Fig 8(a): Medial malleolar defect

Fig 8(b): 21st day Follow up

Fig 8(c): Flap Pedicle Detached in 21 days.

Fig 8: (Case 8) Paramalleolar Tibial defect covered by Reverse Sural Artery Fasciocutaneous Flap.

Results

Out of the 14 patients operated with reverse sural artery flap, 11 were male and 3 female patients with age group ranging from 16 to 61 years. The etiology of the defects included post-traumatic, post infective, and diabetic ulcers over distal third tibia and ankle. Nine (9) of the defects were over the lower 1/3rd leg (Fig. 1, Fig. 2, Fig. 3, Fig. 4), three (3) of the defects were around the medial malleoli (Fig.6. Fig 7, Fig. 8), One (1) over the anterior ankle (Fig.5), and 2 over lateral malleoli. There was an underlying bone, fracture, implant or tendon exposed in 9 patients. 3 of this patients underwent standard reverse sural island flap and rest 11 patient underwent reverse sural fasciocutaneous flap. The size of the defects for island flaps ranged from 5x5cm to 9x8cm. The length of sural fasciocutaneous flaps ranged from 7 to 25cm from the tip of lateral malleolus.

All the defects were covered successfully, without major complications. Usually, only a minor margin of the tip of the flap was lost, which was easily solved with a guided secondary healing. Most flaps showed a slight venous congestion, which cleared in a few days. There were no complaints related to the sacrifice of the sural nerve – the paraesthesia on the lateral border of the foot did not create major problems and disappeared within two months.

The average surgery time was 60–100 min (including flap dissection) and the average size of the flap 5×15 cm. The flaps provided a successful coverage in all cases. Between 1.5 months and 3 months postoperatively, all patients walked without crutches. The functional result was very good in all the patients, while the aesthetic appearance was acceptable even in female patients.

Discussion

Reconstruction of the lower leg and ankle continues to be one of the most challenging tasks for the reconstructive plastic surgeon. An unreliable lower limb subdermal plexus translates to notoriously poor wound healing using cutaneous flaps [30]. Following the developments in flap surgery, pedicled fasciocutanous flaps and free flaps have been used. The introduction of distally based sural fasciocutaneous flap provides reliable and effective method to cover skin defects of distal leg, foot and ankle [31, 32]. The defects reported in the literature that needed repair, include those resulting from road traffic accidents, non healing skin wounds, chronic venous ulcers, chronic osteomyelitis in diabetics, contractures, gangrene, unstable scars, cancer resections, and electrical burns [33, 34]. The major cause of defects in our patients included trauma due to road traffic accidents, similar to some other studies [35, 36].

The flap can be used to cover exposed vessels, bones,

tendons, and internal fixation hardware. It has been shown to be more reliable and a better choice than the lateral supramalleolar flap (another distally based fasciocutaneous flap used in the distal lower extremity). The flap has been shown to be successful in diabetic and medically compromised patient [37]. Anterior and posterior tibial vessels occlusion and varicose leg veins are not considered an absolute contraindication to the use of a distally based sural flap [38, 39]. An occluded peroneal artery is however considered a contraindication.

Various techniques have been adopted to increase the blood flow and hence the survival of the flap. These are: keeping the pedicle at least 4 cm wide, including a gastrocnemius muscle cuff especially when the flap is designed higher in the leg and sural flap delay procedures especially when large flaps are planned or if very distal foot defects need coverage [40-43]. Al-Qattan has also used the muscle cuff as a plug for small lower limb defects following debridement of infected/necrotic bone [44, 45]. The complete survival observed in our flaps used over the anterior heel or dorsum of foot defects could be due to these modifications. Many studies have suggested that venous congestion, and not lack of arterial supply, is the most significant reason for flap necrosis [46]. The fundamental problem is the presence of venous valves that can prevent the retrograde flow of blood out of the flap in spite of the venous collateral vessels. The methods reported to improve venous outflow are exteriorising the pedicle [47], intermittent drainage of short saphenous vein [48], leaches, and the supercharging of the flap by anastomosing the proximal end of the lesser saphenous vein to a vein in the recipient defect [49].

Conclusion

In our conclusion, reverse sural artery fasciocutaneous flap distally based on peroneal perforators is a good option to cover the soft tissue defect of distal third leg, ankle, heel and dorsum of the hind foot. As the flap can cover the larger area of the defects, does not require modern advance technique and team of expertise and the procedure itself is easy and quick to harvest, it has become the versatile flap to cover the distal third leg and foot defect. Due to its constant and reliable arterial network the survivability of the fl ap are high and does not require sacrificing any major arteries. Its long pedicle helps more distalization of the flap. This flap is a good alternative to microsurgical procedures where such modern advance appliances are not available and the surgeon is not so much familiar with microsurgical procedures.

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