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Original Research Article

Anatomical and clinical evaluation of perforator-based flaps of lower limb

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ABSTRACT

Background: Wound of lower leg have a poor and delayed healing due to paucity of blood supply. Coverage of defects of leg and foot has always posed a problem for reconstructive surgeon. The objective of this study was to evaluate anatomical basis of various perforator-based flaps in lower limb and their clinical outcome and usefulness.
Methods: All patients with post traumatic defects with exposed bones/tendons in the leg and ankle region presenting in MLN Medical college, Allahabad from August 2011 to July 2012 were included in the study.
Results: A total 12 patients were included in study. Majority of cases are of compound fracture following accidents involving lower one third of leg. Majority of flaps were based on peroneal artery (5) and posterior tibial artery (5), only 2 flaps were based on anterior tibial artery. Maximum flap length was 21cm and maximum flap rotation was 180º. Complications occurred more in cases having maximum rotation. Result were good in 11 patients and satisfactory in 1 patient with coverage of the defect leading to healing of the wound. More time gap between injury and flap reconstruction leads to more complications and longer hospital stay. Graft site complication occur in 5 cases include partial flap necrosis, infection and venous congestion. There was no complication at the donor site.
Conclusions: Perforator based flaps can be used for all large lower leg defects provided there is correct measurement and anatomical knowledge of various perforators, with good functional and cosmetic results.

Keywords: Delayed healing, Flap reconstruction

INTRODUCTION

Wound of lower leg have a poor and delayed healing due to paucity of blood supply. Coverage of defects of leg and foot has always posed a problem for reconstructive surgeon. Restoration of an intact cutaneous covering is the primary surgical requisite following trauma of lower extremity because deep healing can be no better than surface covering.[1] Flaps of acceptable proportion that easily survived elsewhere on the body soon became necrotic on lower leg.[2] With the advents of microvascular surgery and increasing availability of detailed information about anatomy of vessels of skin, subcutaneous tissue and underlying muscles, it has now become possible to obtain large flap of viable material to cover even sizeable defects of lower limb. Ponten B was first to introduce concept and practice of fasciocutaneous or "Super-flaps" of leg.[3] Various modifications of fasciocutaneous flaps have been introduced by Wee JTK and Amarante J et al, for reconstruction of leg and foot defects.[4,5] Lower limb reconstruction has certainly benefited from development of perforator flaps, both pedicled and free. Distally based island fasciocutaneous flap, based on a single perforator, has allowed defects on the often awkward distal third of

lower limb to be covered reliably. Distal reach of this flap has meant that areas previously considered unreachable by a local flap can now be resurfaced. Obvious advantages include a much quicker procedure which can be performed with the simplest of instruments with functional preservation of the underlying muscles.

This is particularly attractive to any plastic surgeon who may be working in isolation, sometimes in remote regions without access to sophisticated microsurgical facilities. This study was aimed in assessing perforator flaps of leg on anatomical basis and their clinical use, for reconstructive procedures of lower leg defects.

METHODS

This study was carried out in Department of Surgery, M.L.N. Medical College, Allahabad on defects of leg with exposed bone/tendons requiring flap coverage for their management. No such defects in thigh region were encountered. Peripheral arterial disease, other chronic diseases affecting the vessels, vascular insufficiency in the leg are excluded and smoking if present is immediately stopped. Blood supply to leg skin by sept-cutaneous perforators was examined by doppler USG (8Hz) to identify origin and location of sept-cutaneous perforators. All perforators were marked, and axis of flap was marked in between perforators. Patients were studied under the following headings

- Particulars and history of patients (etiology of defect/injury and its duration),
- Clinical examination- general, systemic and local Examination,
- Investigations- routine blood, urine examination, X-ray chest (when required), electrocardiogram, X-ray leg and foot (Table 1).

Table 1: Points assess in local examination.

Site and size of defect
Condition of wound-infection, pus discharge, and necrotic tissue.
Condition of exposed bone - whether periosteum is intact or not.
Exposure of deep structures, such as bones, muscles and tendons.
Associated fractures of bones and presence of any orthopaedic implant such as external fixators, plates and screws.
Vascular status of limb - presence of palpable pulsations of femoral, popliteal, anterior tibial, posterior tibial and Dorsalis pedis arteries.
Condition of surrounding skin for any scar, external fixator, pins and their location.
Functional status of limb, movements of knee and ankle joints.

Treatment

Operative technique

Debridement and flap elevation were done under tourniquet control. While inflating tourniquet, popliteal veins were blocked so as to prevent complete venous exsanguination of limb as some amount of venous stasis helps in perforator identification and dissection. Width of flap depends on width of defect and rotation angle of flap.

Width of flap equals the vertical height of defect, if the flap is rotated 90 degrees, while it equals the anteroposterior diameter of the defect in case of 180-degree rotation. Flap can be extended posteriorly up to midline of calf. Superior margin of the flap was determined intraoperatively, after mobilization of the pivot perforator.

Length of flap proximal to pivot perforator equals the length from to the edge of the defect to be closed plus 1cm. This 1cm was added to allow tension-free closure. After excision of ulcer, posterior incision was made through skin and deep fascia. Because dominant or primary cutaneous arteries emerge from the deep fascia near where the fascia was fixed to bone or anchored by intermuscular septa, these sites, as revealed by natural skin crease lines, were explored first. Sub-fascial sharp dissection proceeds anteriorly until intermuscular septum was reached.

On reaching intermuscular septum, perforators were exposed and mobilized by dissecting septum. Pivot perforator was completely mobilized, and its integrity was determined. Anterior incision was opened, and proximal end of flap was measured and cut. At this stage, flap was attached to leg by perforators only, 3-5 in number.

Table 2: Criteria used to evaluate results.

Category	Characteristics
Good	Complete coverage of defect.
	No necrosis of the flap.
	Minor complications such as wound infection or discharging sinus (managed conservatively).
Satisfactory	Coverage of most of the defect except at margins.
	Marginal necrosis of distal 2-3cm of the flap.
	Complete coverage achieved by a revision/ secondary procedure
Poor	Coverage of the defect not achieved.
	Flap necrosis beyond 2-3cm.
	Patient and surgeon both unsatisfied with final result.

All extra perforators were clamped with microclamps. Viability of flap, shown by refilling of vessels and bleeding from flap. If viability was good, then clamped perforators were ligated and cut. Based on clinical

experience, reliable perforator sprouts from carrier muscles or septum with a visible pulsation. Flap was an island attached only by its pivot perforator artery and its venae comitantes. Flap was rotated on axis of this perforator up to 180 degrees to cover defect. After rotation, viability of flap was reassessed. If there was any compromise, further dissection was done to ensure that pedicle vessels were completely mobilized. Perforator dissection to their origin from donor vessel was not done in all cases. It was only done in cases where there was inadequate mobility and torsion on perforator due to its short length. Flap was sutured in its new position, and donor area was covered by split skin graft. Initial two sutures were placed on the side of perforators so as to prevent torsion and stretch on perforator. Light dressings cover flap, which can be monitored easily for any change in color. A posterior splint keeps leg extended and immobilized for ten to twelve days postoperatively. Foot was kept elevated on one or two pillows during this period. Pressure dressings in the form of crepe bandage were started from postoperative day seven.

Important technical considered in study

- Preoperative marking of dominant perforator,
- Wide exposure of surgical field and bloodless dissection,
- Skin island must be centered on the top of perforator or following direction of main branch of perforators within flap,
- Dissection of perforators under loupe or microscopic magnification,
- Avoid drying and spasm by constant irrigation with lignocaine and saline solution,
- Thin rim of fat can be left around perforator for additional support and to prevent kinking
- All fibrous strands have to be dissected and the perforator denuded to prevent kinking due to any strand,
- Initial sutures that were to be taken when suturing the perforator flap in place were the two sutures on both sides of the perforator so that there was no kink and torsion on the pedicle,
- Before transection of extra perforators, most dominant perforator was identified by clamping the perforators,
- Flap was inset without tension to avoid circulatory disturbances at distal part (Table 2).

RESULTS

Arterial trunks of leg are anterior tibial, posterior tibial and peroneal arteries which give rise to direct branches from their main trunks. These branches run in intramuscular septa to reach deep fascia of leg which they pierce, to supply subcutaneous tissues and skin. These are direct branches of the arterial trunks and not from collateral vessels. These branches are sept-cutaneous perforators and their number and location are variable. These perforators supply the subcutaneous tissues and skin by dividing and anastomosing to form a plexus after piercing the deep fascia of the leg.

The perforators may sometimes give small muscular branches in the leg before piercing the deep fascia. Table 3 shows anatomical study observations regarding sept-cutaneous perforators. Besides these sept-cutaneous perforators, the fasciocutaneous vessels and the musculocutaneous vessels also contribute to the blood supply of the leg. They join the anastomotic arcade which is superficial to the deep fascia and supply the skin of the leg.

Table 3: Observations of anatomical study regarding sept-cutaneous perforators.

Characteristics	Anterior tibial artery	Posterior tibial artery	Peroneal artery
Site	Antero-lateral perforators in lower leg	Medial perforators along the medial border of tibia	Postero-lateral perforators near posterior border of fibula
Location	Between extensor digitorum longus and the peroneus brevis in anterior crural intermuscular septum	Between soleus and gastrocnemius in transverse intermuscular septum	Between soleus and peroneal muscles in posterior crural intermuscular septum
Number of perforators	7	6	5
Distance from lateral/ medial malleolus	Distance from lateral malleolus	Distance from medial malleolus	Distance from medial malleolus
	4.5-5.5cms	4.5-5.5cms	4.5-5.5cms
	6.5-7.5cms	6.5-7.5cms	6.5-9.0cms
	7.5-10cms	7.5-10cms	10-15cms
	10-15cms	10-15cms	15-20cms
	15-20cms	15-20cms	21-25cms
	20-25cms	20-25cms	
	25-30cms		

Table 4: Observations of clinical study.

Characteristics	No. of patients	%
Age Group (in years)		
Less than 20	2	16.67%
21-30	6	50%
31-40	3	25%
41-50	1	8.33%
Sex		
Male	10	83.33%
Female	02	16.67%
Causes of defects and type of injury		
Road traffic accident (Compound # with external fixators)	9	75%
Household accidents (Compound # with external fixators)	2	16.67%
Post-surgical (Exposure of implant)	1	8.33%
Site of leg defects		
Proximal one third	4	33.33%
Middle one third	3	25%
Lower one third with or without extension to ankle area	5	41.67%
Complications		
Marginal flap necrosis	1	8.3%
Wound infection	2	16.67%
Venous congestion	2	16.67%
Results		
Good	11	92%
Satisfactory	1	8%

Table 5: Defect size with type and size of flap used (all flaps are fasciocutaneous flaps).

Details of defects				Details of flaps			
Age /sex	**Site**	**Size (L×W)**	**Artery**	**Flap size (L×W)**	**Rotation**	**Complications**	**Result**
24/M	Lat. lower 1/3 leg	5x4cm	Anterior tibial	16x6cm	90º	Venous congestion	Good
21/F	Ant. middle 1/3 leg	4x4cm	Peroneal	15x5cm	90º	Wound Infection	Good
28/M	Ant. middle 1/3 leg	5x4cm	Peroneal	15x6cm	90º	NIL	Good
39/M	Med. lower 1/3 leg	6x3cm	Posterior tibial	18x7cm	180º	NIL	Good
48/M	Med. lower 1/3 leg	6x2cm	Posterior tibial	21x7cm	180º	Marginal necrosis	Satisfactory
19/M	Med. lower 1/3 leg	5x3cm	Posterior tibial	15x6cm	120º	Venous congestion	Good
27/F	Ant. medial middle 1/3 leg	5x3cm	Peroneal	10x6cm	90º	NIL	Good
36/M	Lat. lower 1/3 leg	6x2cm	Anterior tibial	17x8cm	90º	NIL	Good
25/M	Ant. lateral proximal 1/3 leg	4x2cm	Peroneal	12x5cm	90º	NIL	Good
18/M	Lat. proximal 1/3 leg	5x3cm	Peroneal	15x6cm	90º	NIL	Good
31/M	Medial proximal 1/3 leg	6x3cm	Posterior tibial	16x7cm	120º	NIL	Good
28/M	Ant. medial proximal 1/3 leg	5x2cm	Posterior tibial	15x6cm	90º	NIL	Good

Table 4 shows that majority of patients were young males. It is due to more active outdoor life of these young men, being more exposed to trauma and injury resulting in the defects of the leg and foot. Common cause of defect in this

study was trauma. As a result of trauma patients had compound fractures of leg or injuries resulting in exposure of bones and tendons for which it required coverage. Perforator based fasciocutaneous flaps were used to cover the defects in this study, after stabilization of the compound fracture by external fixators or plates. Perforator based flaps were used in 12 cases in this study and of these 6 were on medial side and 6 on lateral side of the leg. These flaps are based on the septocutaneous perforators from the arterial trunks of leg.

Table 5 shows that majority of flaps were based on peroneal artery (5) and posterior tibial artery (5), only 2 flaps were based on anterior tibial artery. Maximum flap length was 21cm. Maximum flap rotation was 180º and complications occurred more in cases having maximum rotation. Table 6 shows that more time gap between injury and flap reconstruction leads to more complications and longer hospital stay. There was partial flap necrosis of distal 1cm of flap in 1 case. It was managed by debridement and dressings. Infection was present in 1 case and was controlled by dressings and antibiotics. Venous congestion was managed by limb elevation and compression bandage. There was no complication at donor site in all our cases and healing was good with split thickness skin grafting.

Table 6: Relation between time since injury and postoperative complications.

Time since injury (in days)	Post op Stay (in days)	Follow up period (in months)	Complications	Result
24	16	3	Venous congestion	Good
43	18	2	Wound infection	Good
29	24	4	Nil	Good
7	11	2	Nil	Good
30	14	6	Venous congestion	Good
62	20	4	Marginal necrosis	Satisfactory
7	13	3	Nil	Good
21	14	2	Nil	Good
32	18	3	Nil	Good
15	14	4	Nil	Good
33	16	6	Wound infection	Good
27	15	2	Nil	Good

DISCUSSION

Perforator based flaps of leg are easy to raise, safe and provide satisfactory coverage to defects of leg and foot. They provide an excellent cover for defects, having a single staged procedure with no post-operative discomfort. They are capable of covering large defects and long flaps can be raised with a ratio beyond 1:3 without any complications. Advantage over muscle and myocutaneous flaps in being able to cover large defects on any part of the leg and foot, and there is no disturbance or loss of function, as underlying muscles are left undisturbed.

Perforator based flaps have advantage over free flap reconstructive procedure in being simple to perform, less time consuming and hospital stay and do not require any special instruments and equipment or specially trained personnel. Perforator based flaps are supplied by the septocutaneous perforators and venous drainage is via accompanying venae comitantes to deep veins. These perforators are present as low as 5cm above from the malleoli, on which the inferior flaps are based. Rotation of flap at base causes slight kinking but does not compromise the arterial supply or the venous drainage. Long flaps are also raised based on a single perforator which supplied the flap via the arterial plexus superficial to the deep fascia.

Operative time taken for perforator propeller flaps is not significantly higher than that for fasciocutaneous flaps. Exclusion of muscle from perforator flap makes it a more reliable flap because of absence of fibrosis of muscle in long term follow up. Perforator propeller flaps form an important substitute for muscle flaps for providing excellent blood supply to the recipient area along with preservation of the muscles. Perforator based flaps are used in cases of compound fractures with external fixator, plates and screws and conditions requiring coverage of large defects in the leg and provide very good functional and aesthetic results.

In this study, author have studied various perforators arising from main vessels of leg. Blood supply of leg skin is by three main arterial trunks i.e anterior tibial, posterior tibial and peroneal arteries which give rise to septocutaneous perforators which travel in intermuscular septa to reach the deep fascia of the leg which they pierce to form a plexus and supply the skin of leg. Skin supply is further supported by blood supply via the

musculocutaneous perforators and a few axial type vessels.[6]

In this study anterior tibial artery gives rise to 6-10 perforators with at least 2-3 perforators within 10cm of lateral malleolus, passing along the anterior crural intermuscular septum. Posterior tibial artery was found to give rise to 4-7 perforators on the medial side of leg with at least 2-3 perforators within 7.5cms from the medial melleolus and at least 1 perforator within 5cms from the medial malleolus. Peroneal artery was found to give rise to 4-6 perforators passing along the posterior crural intermuscular septum on the lateral side of leg. This finding is supported by the studies of Carriquiry C et al.[6]

There is a relatively avascular plane deep to deep fascia which provides an excellent plane for flap dissection, a finding confirmed by Ponten B, and Haertsch P.[3,7] In this plane the blood supply of the skin is protected. Fasciocutaneous flaps on the medial and lateral side of the leg are an example of "Type A" flaps according to the Cormack GC et al, classification that is a pedicled fasciocutaneous flap dependent on multiple fasciocutaneous perforators at the base and oriented with the long axis of the flap in the predominant direction of the arterial plexus at the level of the deep fascia.[8] This anatomical study clearly establishes presence of septocutaneous perforators arising from main arterial trunks of the leg, which supply the skin of the leg. Based on these perforators long flaps can be raised on leg in a plane deep to the deep fascia without any damage to the blood supply of the skin and used for reconstructive procedures on the leg and foot as perforator flaps which can be rotated up to 180° which is not possible with type A fasciocutaneous flaps.

Posterior tibial artery-based perforator based flaps were used to provide cover in lower medial 1/3rd of leg for compound fracture with external fixators and for exposed bones and tendons in five cases. These flaps were of variable length depending on the requirement and the width at the apex of the flap covered the length of the defect after the rotation of flap. Base of flap had one or two septocutaneous perforators form the posterior tibial artery and is drained by accompanying venae comitantes. Base of pedicle was at least 5cms from medial malleolus so that at least one septocutaneous perforator be present in the pedicle to supply flap. Results in 4 cases with posterior tibial artery-based flaps were good and one was satisfactory. Results are similar to those reported by Amrante J et al, who used the distally based flaps on perforators from the posterior tibial artery for lower leg, ankle and foot defects.[5]

Anterior and lateral defects were covered with flaps based on peroneal and anterior tibial artery. They were used to provide coverage of defects in middle and lower third of the leg for compound fractures with external fixators, and for exposed bones and tendons in seven cases. Base of flap is kept at least 5cms from lateral malleolus to include at least one perforator to supply the flap. Width of flap covers length of the defect after rotation.

Results were good in seven cases in this study. Results are comparable with Donski PK et al, who used successfully, the distally based fasciocutaneous flaps from the sural region based on the peroneal artery in 3 cases.[9] In this study flaps of a maximum length of 21cms have raised, based on the septocutaneous perforators of the main arterial trunks, without any 'delaying' of the flap. Results were similar as reported by Amrante J et al.[5]

In this study, partial necrosis of distal 1-2cms of flap occurred in 1 case but the final result was satisfactory following debridement, and dressings of the flap. Wound infection occurred in 1 case which were managed by dressing and antibiotics, after pus swab culture and sensitivity. Venous congestion occurred in two cases which was managed by limb elevation and compression bandage. In these cases, results were good due to energetic management. These results were similar to study conducted by D'arpa S et al, from 2004 to 2010.[10] Average time since injury in this study was 28days, hospital stay was 16days and average follow up period was 1.3months (approx. 38days). In this study, defects covered early with flaps suffered less complications and shorter postop hospital stay. Cases having delayed coverage suffered more complications and longer hospital stay. Donor site from where fasciocutaneous flap were taken was covered by split thickness skin graft. Healing of donor area was good with no complications due to rich vascular supply of muscles. Final result was good in 92% cases, with only few minor complications such as would infection, and venous congestion and satisfactory in 8% cases which had marginal necrosis and were managed to achieve closure of the defect by a revision. These results are comparable as reported by Amrante J et al.[5]

CONCLUSION

Perforator based flaps can be used for all large lower leg defects provided there is correct measurement and anatomical knowledge of various perforators, with good functional and cosmetic results.

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