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Case Series

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Using recipient vessels distal to the zone of injury in free flaps for lower limb injuries

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ABSTRACT

This is a retrospective study of free flaps done in injuries of the proximal leg where the microvascular anastomosis was done using recipient vessels "distal" to the defect. 4 of the 5 patients had compound fractures of the upper-middle third of the leg, 1 of the distal third of the femur and 1 patient had a post traumatic unstable leg scar. 3 of the cases were acute, 2 were subacute and 1 was chronic. The anterior tibial and posterior tibial vessels were used in 2 and 4 cases respectively; both the venous and arterial anastomoses were antegraded. The latissimus dorsi was used as the donor flap. There were no flap failures. During the same period there were 34 free flaps for similar defects in the upper third leg or the lower third of thigh, that were done using conventional anastomosis with vessels "proximal" to the defect. The authors review the existing literature and define the indications for safely using a "distally" based micro-anastomosis in compound leg injuries.

Keywords: Free flaps, Compound leg fractures, Distal anastomosis, Recipient vessels

INTRODUCTION

Many lower extremity wounds resulting from trauma, are high-energy injuries with a substantial "zone of injury." This refers to a "thrombogenic zone" of recipient vessels, that is known to extend variably beyond what is macroscopically evident. Khouri et al reviewed 304 lower limb trauma free flaps and found an 8% flap failure rate in contrast to less than 3% in non-lower limb cases- they point out the "zone of injury as the single most predictive factor for flap success or failure.[1]

Logically, it follows that the surgeon would prefer to access recipient vessels at varying distances from the proximal edge of the defect to overcome this problem. The classic paper by Godina et al stresses the proximo-distal approach in identifying the healthy vessel, suitable for a safe microanastomosis to "beat" the entity -zone of trauma; the latter is a cause for anastomotic blockage leading to flap failure.[2]

Despite the inherent logic of this approach, a proximal anastomosis may not always be practical or even feasible. As one ascends the leg, the axial vessels are at an increasing depth, leading to difficulty in exposure and performing an anastomosis.

Stompro et al described 23 free flaps with anastomosis to recipient vessels distal to the defect, in leg trauma defects with only 2 failures, based on the observation of 'preserved blood flow' through the zone of injury.[3] They also defined three criteria for adoption of this technique- location of

defect making it amenable to such an anastomosis, clinical demonstration of antegrade arterial inflow and use of preoperative venous Doppler, especially in acute reconstructions. In addition to the technical advantages of the distally based free-tissue transfer, the authors state 'distally based anastomosis' does not interrupt the proximal blood flow to the fracture or soft-tissue defect site, avoiding compromise of fracture or wound healing.

It may not be technically impossible to do a proximal anastomosis even in proximal leg injuries in select situations; but anastomosis distal to the defect offers an alternative but safe way to tackle free flap coverage in severe proximal leg injuries, as this article seeks to show (Figure 1).

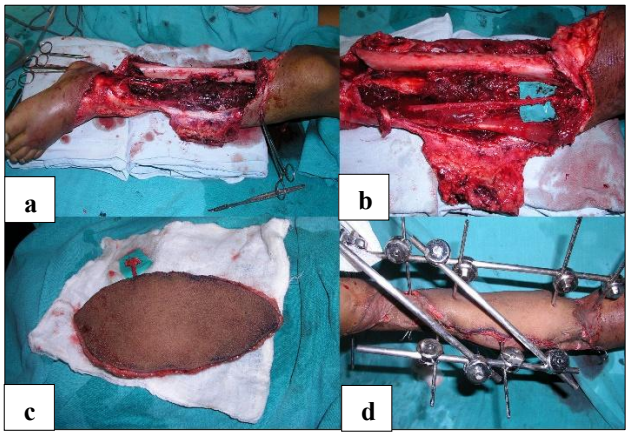


Figure 1: (a and b) Proximal recipient selection, anterior tibial vessels in segmental leg compound fracture; arrow indicating the proximal anterior tibial vessels, and (c and d) anterolateral thigh flap used for whole leg defect.

CASE SERIES

The records of patients who underwent lower extremity reconstruction for defects of the upper- middle third leg and the lower end of the femur, where the recipient vessels were selected distal to the defect, were reviewed retrospectively.

Age, location of defect, time between injury and reconstruction, type of free flap, choice of recipient vessels, type of anastomosis-end to end or end to side were recorded; postoperative outcome related to re-exploration and its outcome were recorded.

The time to free flap coverage since injury decided whether it was acute, subacute or chronic (acute <21 days, subacute-21 to 60 days, and chronic >60 days). Clinical examination of peripheral pulses was done and compared to the opposite normal lower limb. Direction of flow in the posterior and anterior tibial artery was done by blocking either vessel as in the Allen's test for the upper limb.[4]

Arterial integrity was checked intra-operatively by pulsatile flow from the severed proximal end while the adequate venous patency was checked by the free passage of the heparinized saline into the antegrade cut ends of the venae comitantes. Since an end-to-end anastomosis was done in 5 of 6 cases, it was routine practice to clamp the dissected recipient artery, release the tourniquet to check adequacy of distal circulation through alternative vessels before executing the microvascular anastomosis.

During the same period, data of 34 patients with similar injuries of the upper third of the leg or the distal third of the thigh, wherein an anastomosis was done in the conventional manner, proximal to the defect, were also retrieved and compared for flap failure rates (Table 1). All the patients were males with a mean age of 33 years. Out of the 6, three cases were acute, two subacute and one chronic. 5 patients had compound fractures (4 in the proximal tibia and 1 in the distal femur) and one, an unstable scar following prior degloving leg with fracture, where skin grafting had been done. 3 of the 6 patients had a latissimus dorsi muscle flap done and 3 had a latissimus dorsi myocutaneous flap. All the anastomoses were performed distal to the defect.

Table 1: Time, fracture location, defect size, flap choice and recipient vessels data.

S. no.	Timing	Fracture location	Defect size	Flap choice	Recipient vessels	Rationale for not using conventional proximal anastomosis
1	Subacute	Proximal third leg	15×25 cm knee, upper third leg	Latissimus dorsi muscle flap with skin paddle	Posterior tibial vessels, end to end	Granulating wound
2	Acute	Distal third thigh	15×15 cm distal thigh, knee and upper third leg	Latissimus dorsi muscle flap with skin paddle	Posterior tibial vessels, end to end	Technical ease of accessing vessels distally
3	Acute	Proximal third leg	12×17 cm knee and upper third leg	Latissimus dorsi muscle flap	Posterior tibial vessels, end to end	Technical ease of accessing vessels distally
4	Subacute	Proximal and middle third leg	15×12 cm knee, upper and middle third leg	Latissimus dorsi muscle flap	Anterior tibial vessels, end to end	Granulating wound

Continued.

S. no.	Timing	Fracture location	Defect size	Flap choice	Recipient vessels	Rationale for not using conventional proximal anastomosis
5	Acute	Proximal third leg	20×15 cm knee, upper and middle third leg	Latissimus dorsi muscle flap	Anterior tibial vessels, end to end	Technical ease of accessing vessels distally
6	Chronic	Proximal and middle third leg	18×16 cm proximal- upper and middle third leg	Latissimus dorsi muscle flap with skin paddle	Posterior tibial vessels, end to side	Chronic scarring

In 2 of the cases the anterior tibial vessels were used and in the other 4, the posterior tibial vessels were used; 5 of the 6 anastomoses were end to end with 1 artery and 1 vein. Only 1 of the 6 had a second venous anastomosis using the serratus tributary. In all cases both the venous and arterial anastomosis were antegrade. There were no re-explorations and all flaps survived completely.

One had a partial loss of skin graft that healed with dressings. During the same study period there were 36 flaps that were done using vessels proximal to the defect in a conventional manner. 30 were acute, 4 subacute and 2 chronic; all the flaps were latissimus dorsi muscle flaps. There were 4 re-explorations and 2 of 34 flaps failed.

Case 1 (subacute)

38-year male presented with Grade IIIb proximal third tibia and fibula fracture with wound around the distal thigh, knee and proximal leg, following motor vehicle accident. Primarily, debridement and external fixator was followed by approximation of local muscles and patient referred for further management after the 40th day. Debridement of exposed dead bone fragments and unhealthy granulations was done to achieve a clean wound.

The posterior tibial vessels were exposed in the middle third of the leg, distal to the defect to avoid difficulty of access proximally. The vessels were dissected free for 7 cm to facilitate orienting in a gentle loop before completing an end-to-end anastomosis to the pedicle of the contralateral latissimus dorsi muscle flap with skin paddle (Figures 2 and 3).

Case 2 (acute)

32-year male hit by a lorry presented with grade IIIb distal third femur fracture with defect over the posterior aspect of knee and proximal thigh. He underwent debridement with fixation of the distal femur with cortical screws and a joint spanning external fixator.

Since the defect extended to the middle third of the thigh, difficulty in access in the depth of the thigh was circumvented by accessing the posterior tibial vessels at the junction of the proximal and middle third of the leg below the soleal origin. Coverage was achieved with a contralateral latissimus dorsi myocutaneous flap and split skin graft (Figures 4 and 5).

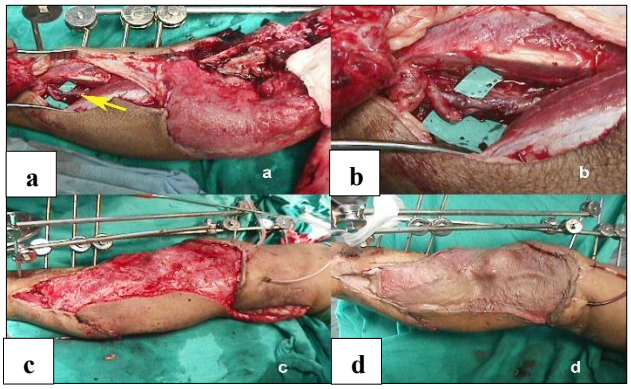


Figure 2: (a and b) Intraoperative images of distally based micro-anastomosis using latissimus dorsi myocutaneous flap before being rotated 1800 to cover the defect(yellow arrow refers to the posterior tibial vessels dissected in middle third leg); (c and d) at the completion of flap inset and split skin grafting.

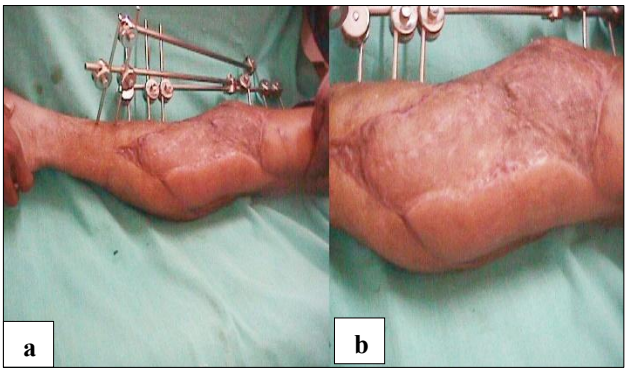


Figure 3 (a and b): Follow up images of completely healed wound.

Case 3 (chronic)

32-year male presented with unstable scar over the proximal and middle third of the leg involving half the leg circumference. Primary management of the Grade IIIb compound fracture of the upper third leg involved debridement, external fixation and approximation of local muscles.

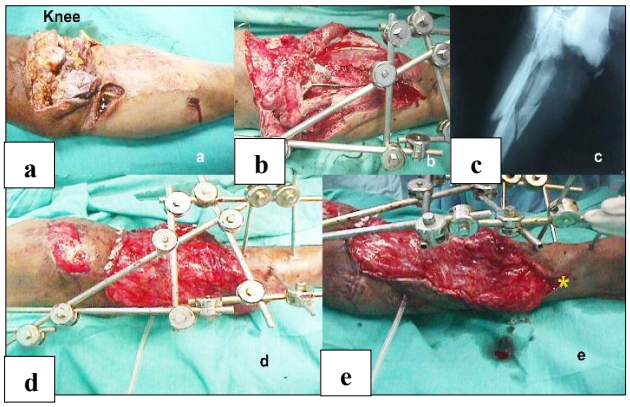


Figure 4 (a-c): Intraoperative images and X-ray of acute wound with segmental fracture upper third leg, and (d and e) coverage with latissimus dorsi muscle flap (*refers to use of anterior tibial vessels distal to the defect at the junction of middle and lower third leg).



Figure 5 (a-c): Follow up images of completely healed wound.

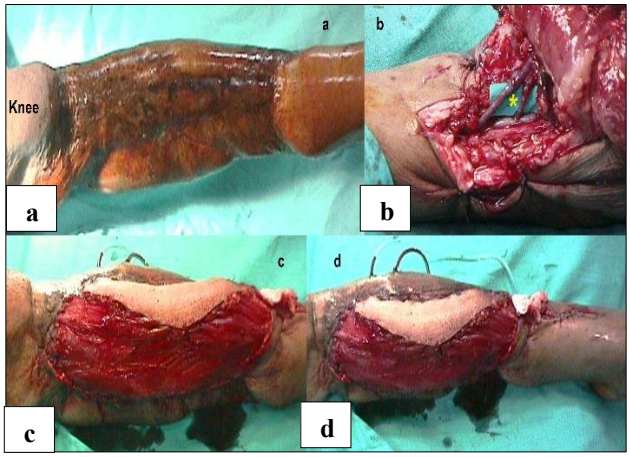


Figure 6 (a and b): Unstable chronic scar upper and middle third of leg 60% circumference (*refers to use of the posterior tibial vessels distal to the defect at the lower third leg), and (c and d) latissimus dorsi myocutaneous flap after inset in recipient defect.

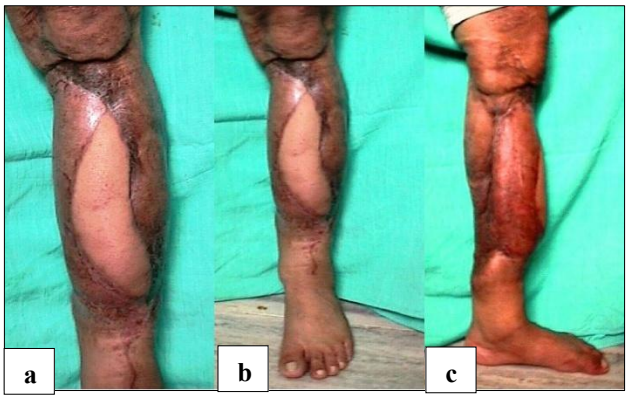


Figure 7 (a-c): Follow up images of completely healed wound.

After granulations appeared, the wound was grafted. Coverage of the unstable grafted skin was planned with a latissimus dorsi myocutaneous flap. The length of the defect implied that choosing recipient vessels in the distal thigh may not achieve coverage in the distal third of the defect. Hence the posterior tibial vessels were dissected at the lower third of the leg in an unscarred location. An end to side anastomosis was done but the recipient vein was done end to end antegrade; sufficient length of proximal vein had been mobilized to prevent any kinking of the venous anastomosis (Figures 6 and 7).

DISCUSSION

It is a standard practice to explore recipient vessels proximal to the defect using an extensible incision and choose the site of anastomosis at a normal level for successful free tissue transfer. Choice of recipient vessels in lower limb trauma was studied by Yazar 2012 with a total cohort of 574 free tissue transfers in open tibial fractures.[5] The anterior tibial artery was used as a recipient artery in 61.7%, and the posterior tibial artery was used in 29.8% cases; in less than 5% of cases, the genicular or sural vessels were used. Hence axial vessels are the recipient vessels of first choice as recipient vessels due to their predictable location and possibly larger caliber.

In the presence of significant zone of trauma recipient vessel reach can be extended using long vein grafts or AV loops; in the largest series of primary AV loops by Lin et al, 3 of 28 flaps failed but there was a re-exploration rate of 28%; isolating only proximal leg compound injuries, this method yields 5 successful flaps in 6 cases (83%).[6] This could probably be related to the length of the vein graft used- shorter in defects that are more proximally situated.

Though Stompro in 1994 had a favourable outcome using vessels distal to zone of trauma, Hallock conducted a retrospective analysis with an overall success rate of proximal as against distal anastomosis being 85% and 58%.[7] The confounding data in the study is due to: mixed indications for upper and lower limb, and mixed

techniques - some of the distally based flaps were converted to proximally based flap (3 in number) and two had a venous supercharging using vein grafts, on observing venous congestion post anastomosis. They hypothesize that the chance of a venous compromise is more in the acute phase rather than when done for chronic indications.

Since the orientation of the venous anastomosis is not mentioned we can only speculate that it was retrograde leading to a higher incidence of venous problems. Lower limb veins are valved, and retrograde venous anastomosis may end up pumping deoxygenated blood back into the flap.

Our series followed a fixed protocol in the performance of the anastomosis distal to the defect- using only antegrade flow after adequate clinical evaluation of distal pulses.

Kolker et al analyzed 451 free flaps for lower limb defects- 35 of 451 flaps was done using vessels distal to the defect- 13 were acute, 2 subacute and 20 were chronic.[8] The re-exploration rate was 14% and 2 of 35 flaps failed- with a 94% success rate. Comparable values were obtained in proximally based anastomotic techniques. No tests of significance were used. The authors recommend use of both venous Doppler and duplex scan in the preoperative examination of patients undergoing lower extremity free flap reconstructions with special reference to distally based anastomosis. Distal anastomosis may be considered in cases where distal pulses are documented or arteriography demonstrates vascular patency through the zone of injury, The authors remark that the use of a proximally based anastomosis was more likely to need the use of vein grafts with a possible increase in the incidence of flap loss and hence dissecting vessels distally overcomes this issue.

Park et al cited that the recipient vessels become progressively deeper as one ascends the leg- the technical issue of anastomosis at depths may be challenging.[9] Further, the location and extent of the defect can put stress on the need for pedicle length. 5 of 31 flaps were done using vessels distal to defect and he comments that this technique gives rapid and safe access to healthy recipient vessels especially for defects in the proximal leg. In 2 of 5 cases, the anastomosis was retrograde (Table 2).

Table 2: Summary of studies where distal recipient vessels were used in compound leg injuries.

Author	Publication year	Patient numbers	Outcome	Author's conclusions
Stompro et al[3]	1994	23 cases	91.3%	Clinical demonstration of arterial inflow, venous Doppler in acute reconstructions
Kolker et al[8]	1997	35 of 451 cases	94% for distal and 93% for proximal	Clinical or angiographic demonstration of arterial inflow
Park et al[9]	1998	5 of 31 cases	Anterior tibial	Posterior tibial
Lee et al[10]	1999	12 cases	100%	Artery retrograde, vein antegrade diastolic distal arterial pressure of more than 50mm Hg
Minami et al[11]	1999	14 cases	100%	Both artery and vein retrograde
Spector et al[12]	2007	63 of 570 cases	97% for distal and 93% for proximal	Shorter pedicle length, superficial location of recipient pedicle
Stranix et al[13]*	2017	60 of 252 cases	90.7% in both groups	Cannot be used in Gr IIIc injuries
Present study		6 of 42 cases	100% for distal and 94.4% for proximal	Both artery and vein antegrade

*Meta-analysis study

Lee report 12 defects around the knee with a distal based anastomosis; here the authors are very clear in mentioning retrograde arterial inflow; they found pulsatile flow and the retrograde diastolic arterial pressure to predict flap success.[10] The venous anastomosis was done antegrade. They placed more reliance on arterial spurt intra-op to confirm a successful outcome. They do admit that the choice of a proximal vein for anastomosis is based on a lesser likelihood of injury to the deep veins traversing the zone of trauma, than the use of superficial veins.

Minami et al report 14 cases including 6 free fibular osteocutaneous flaps (for tibial pseudoarthrosis) using both the vein and the artery in a retrograde fashion making sure that the venous anastomosis was as far away from valvular location.[11] They also agree that a looped distally based micro-anastomosis with antegrade inflow and outflow is possible. There were no flap losses and indicate that this technique is of use in defects in the proximal parts of the limb where dissection of the deep seated anterior tibial artery is cumbersome.

Using the vessels distal to the defect implies 3 different configurations - artery and vein antegrade, both artery and vein retrograde and mixed. In all our cases we relied on antegrade flow from and to the flap to prevent the

possibility of venous congestion. The practice of unencumbered flow of heparinized saline into the cut end of the antegrade vein chosen for the anastomosis ensures successful venous drainage in our study.

Spector et al studied a cohort of 570 free flaps- 63 were done distally with a success rate of 97% as against 93% for the proximal anastomosis but there was no statistical difference.[12] Even in the flaps needing re-exploration successful salvage could be done utilizing the same distal vessels rather than changing the orientation to a proximal location as in the earlier study by Hallock. The authors cite the superficial location of the distal axial vessel to be an advantage for ease of dissection and that the pedicle length of flap can be shorter than if used as a proximally based anastomosis.

Our technique using antegrade flow distal to anastomosis is completed before turning the flap 1800 to inset the flap into the proximally placed defect; in the only case where an end to side arterial anastomosis was done the flap inset preceded the micro-anastomosis (Figure 8).

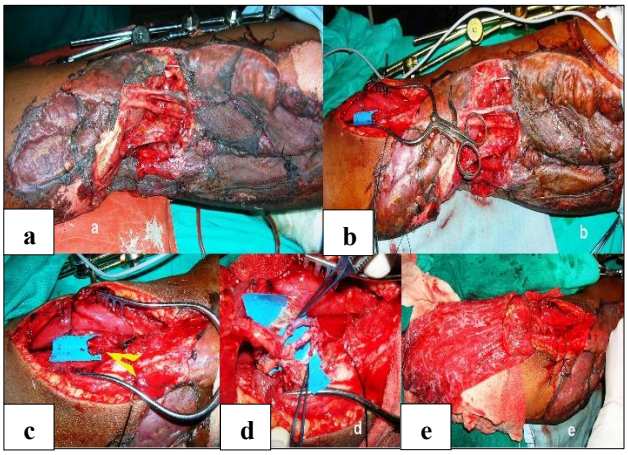


Figure 8: (a-c) Intraoperative images of defect, dissected recipient pedicle distal to the defect at the junction of the upper and middle third leg (yellow arrow), and (d and e) view of anastomosis antegrade to posterior tibial vessels end to end with an additional vein using serratus tributary; well perfused flap prior to inset maintaining a gentle loop of the pedicle.

A retrospective meta-analysis of 312 free flaps by Stranix wherein 252 were done conventionally using recipient vessels proximal to the zone of trauma as against 60 done distally and there was no significant difference in either re-exploration rates or flap failure rates-partial or total.[13] The total success rate was 90.7% in either group.

The only significant finding was that distal anastomosis was less likely to be performed when there was an arterial injury or when the fracture was graded as Grade IIIc. The authors conclude that the location of anastomosis should depend on arterial inflow, venous outflow, available pedicle length and ease of access or exposure as either technique gives comparable results.

Unlike the studies of Kolker and Spector, this study uses comparative data from only defects that were similar in location and approximate size-meaning each group contains only data from defects of upper –middle third leg and the lower thigh. This is likely to be more representative of the results of a distally based recipient vessel selection. Rigid selection criteria by clinical examination using Allen's test, confirming venous patency intra-operatively and performing antegrade type anastomosis ensured 100% flap survival.

CONCLUSION

The use of distally based free flaps is not appropriate in all patients. Defects in the proximal part of the leg, especially subacute or chronic, longitudinally large defects and patients with no evidence of injury to the axial vessels are possible candidates. The difficulty of accessing suitable recipient vessels at a deeper level in the presence of large wounds, especially in the subacute or chronic phase, is circumvented by going distal to the defect. Safety is ensured, at the least by clinical examination of the axial arteries using the Allen's test variant and flushing of the chosen vein before micro-anastomosis. This also avoids the use of vein grafts. Furthermore, describing the technique, as anastomosis distal to the defect conveys a better understanding than "distal to the zone of injury".

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