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Original Article

Utility of arteriovenous loops before free tissue transfer for post-traumatic leg defects

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ABSTRACT

Crush injuries of severe magnitude involving lower limbs require complex bone and soft tissue reconstructions in the form of microvascular free tissue transfers. However, satisfactory recipient vessels are often unavailable in the leg due to their vulnerability to trauma and post traumatic vessel disease (PTVD), which extends well beyond the site of original injury. In such situations, healthy recipient vessels for free flap anastomosis can be made available by constructing temporary arteriovenous loops with saphenous vein grafts, anastomosed to corresponding free flap vessels. Our study included 7 patients with severe crush injuries of leg due to rail and road traffic accidents. Long and short saphenous vein grafts were anastomosed to Femoral artery in the subsartorial canal in 2 cases and to large muscular branches and accompanying veins in rest of the cases. Free flap transfers were performed in the same sitting in 6 cases. One case showed insufficient dilatation of the vein loop and hence free flap transfer was staged. Free Latissimus dorsi, Gracilis and Rectus abdominis flaps were performed. There were two cases of flap necrosis – one in the case of a pathologic vein graft with staged flap transfer which showed vein thrombosis on re exploration. The other case of flap failure was caused by a hematoma underneath the flap. In another patient, secondary haemorrhage occurred on day 18, without any consequence to the flap. All the other cases had complete free flap survival. We consider the use of single stage arteriovenous loops, a valuable tool to increase the applications of free flap, whenever healthy recipient vessels are not available in the periphery of the trauma.

KEY WORDS

Arteriovenous loops; staged free flaps; vein grafts

INTRODUCTION

Crush injuries of severe magnitude that require complex soft tissue and bone reconstruction with microvascular free tissue transfers are commonly encountered in lower limb trauma. The success of such free tissue transfers to cover these defects depends on the proper selection of recipient vessels. However, in lower limb trauma, the local vessels are occasionally unsatisfactory choices as recipients for free tissue transfer. This could be either due to the vulnerable position of the vessels in the defect or due to the nature of the injury. Widespread changes are seen in the walls and perivascular tissues of major vessels of the crushed limb. Collectively termed post traumatic vessel disease (PTVD), such changes affecting all the layers of the vessel wall are seen to extend well beyond the site of the original injury.[1] Recipient vessels in such cases are

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not only difficult to dissect but are also more prone to vasospasm, injury and thromboembolic occlusion.

In such situations, recipient vessels can be made available for free flap transfer by construction of temporary arteriovenous (AV) loops from vessels well outside the zone of trauma using long vein grafts, which are divided later for tension free anastomosis to free flap vessels. Taub *et al*. and Choi *et al*.[2,3] described staged AV loops in animal models using polytetrafluoroethylene grafts, to lengthen free flap pedicles. But this may not be a feasible option in a clinical setting of open leg wounds with extensive crush injury. Free tissue transfer using AV loops can be done either as a staged procedure or as a single operation. Lin *et al*.[4] states that the risk of thrombotic events at the anastomotic site may be reduced with a staged procedure by allowing time for endothelial repair in the temporary fistula. Atiyeh *et al*.[5] consider reduction in ischaemia time and freedom of flap design as benefits of preliminary AV loops when a free flap needs a long vein graft. Furthermore, the ease of patient positioning and a reduction in the time taken to perform the final free flap transfer are all considered to be the advantages of staged procedure. However, such merits have to be compared with the cost factors, multiple anaesthesia exposure, risk of infection and the technical difficulty in re exploring through the violated tissue planes to access the vein loops. The other option is to proceed with the free flap cover in the same sitting as the vein loop. The advantages are a single procedure with comfort of operating through previously unviolated tissue planes. In selected cases, the use of vein loops can radically improve the chances of free flap survival, which in turn has significant implications on the ability to salvage the limb especially in young adults with severe crush injuries.

PATIENTS AND METHODS

This study includes 7 patients over an 18-month period, in whom AV loops were required for free tissue transfer due to the lack of healthy recipient vessels around the trauma zone. Totally, 3 patients had crush injury involving both lower limbs. The indications, recipient vessels sources of vein graft, stages of surgery and the outcome are given in Table 1. Our patients consisted of 5 males and 2 females with ages ranging from 13 to 52 years. All had severe crush injury involving the lower limb with compound comminuted fracture of the tibia due to rail or road accidents. In all cases, AV loop creations and free flap transfers were done in the first 2 weeks following trauma after adequate debridement. Patients with distal vascular deficit requiring revascularisation were omitted from this study.

Surgical technique

Superficial femoral artery and vein in the sub sartorial canal were chosen as the recipient vessels for end to side anastomosis in the first 2 cases [Figures 1-4]. For 5 cases, end to end anastomosis to a muscular branch of the femoral

Table 1: Patient data

Age	Sex	Nature of trauma	Recipient vessels	Source of vein grafts	Stages	Flaps	Outcome	Notes
29	Female	Rail accident Comminuted fracture both bones left leg, soft tissue loss antero medial aspect upper half left leg	Femoral artery and vein	Right LSV	1	Latissimus dorsi	Complete flap survival	Secondary haemorrhage day 18
32	Male	RTA Compond fracture tibia middle third right leg	Femoral artery and vein	Left LSV	1	Gracilis	Complete flap survival	
62	Male	RTA AK amputation left leg requiring stump revision	Femoral artery and vein*	Proximal right LSV (distally thrombosed)	2	Latissimus dorsi	Flap necrosis	Pathologic vein graft
52	Male	Compound Comminuted fracture left tibia upper two third	Femoral artery and vein#	Right LSV	1	Rectus abdominis	Complete flap survival	Wound Infection
20	Male	Compound Comminuted fracture left tibia upper third	Femoral artery and vein#	Right SSV	1	Latissimus dorsi	Flap necrosis	Under flap
43	Female	Compound Comminuted fracture left tibia upper two third	Femoral artery and vein#	Right SSV	1	Latissimus dorsi	Complete flap survival	Hematoma/ Hemorrhage
13	Male	Compound Fracture left tibia upper third with, open knee joint soft tissue defect Lower lateral thigh and AK amputation right lower limb	Femoral artery and vein#	Left LSV	1	Latissimus dorsi	Complete flap survival	

*Muscular branch of proximal femoral artery and accompanying venous tributary; #Muscular branch of superficial femoral artery and accompanying the venous tributary; RTA: Road traffic accident; AK: Above-knee; LSV: Long saphenous vein; SSV: Short saphenous vein

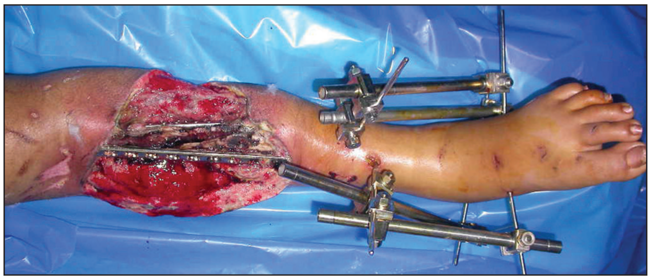

Figure 1: Patient 1 - comminuted fracture both bones with soft tissue loss along anteromedial aspect in the upper half of left leg

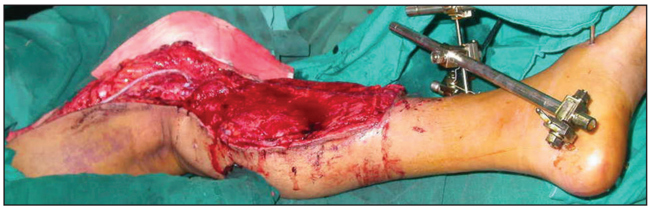

Figure 3: Patient 1 - latissimus dorsi flap inset into the defect and anastomosed to the divided vein loop ends

Figure 5: Patient 2 - open knee injury anterolateral aspect of left leg

artery and the accompanying venous tributary were performed [Figures 5 and 6]. Reversed long saphenous vein (LSV) grafts were used in 5 patients and short saphenous vein grafts in 2 patients. The vein grafts were harvested from the contra lateral lower limb in 6 cases and ipsilateral lower limb in 1 case. Vein grafts of approximately 1.5 times the required length were initially harvested, due care being taken to avoid twisting of vein and valves at anastomotic site. The vein grafts were flushed with heparinised Hartmann's solution to distend them before anastomosis and to check for leaks. Clamps were retained until both arterial and venous anastomosis were complete. Cross clamping across femoral artery in two cases lasted 15-20 mins. No distal ischaemic effects were noted in either of these cases. The vein loops were observed after clamp release for uniform distension, leaks, and twists. Once a good flow through had been confirmed, the distal end of the loop was brought into the leg wound through a wide subcutaneous tunnel. AV loops were always designed much longer than required to ensure that they do not fall short. The flaps were laid on the defect, and the AV loops were transected at the appropriate desired length. The arterial and venous ends of the loop were duly anastomosed to the donor artery and vein of the

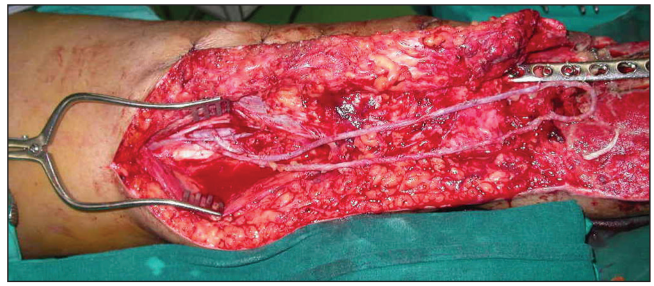

Figure 2: Patient 1 - long saphenous vein graft anastomosed to femoral vessels in the sartorial canal with the apex of the vein loop brought close to the leg defect

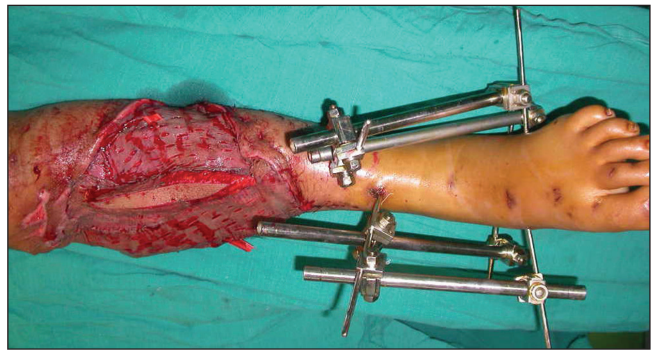

Figure 4: Patient 1 - latissimus dorsi flap after anastomosis and skin grafting

Figure 6: Patient 2 - long saphenous vein graft anastomosed to muscular branch of femoral artery and vein in superomedial aspect of left thigh with apex of vein loop brought distally

transferred flap if the flap transfer was done primarily or after 5 days in case of delayed transfer.

RESULTS

The results have been summarised in Table 1. Of the 7 case in which loop was created, 6 vein loops demonstrated good uniform distensibility encouraging us to proceed with an immediate free flap transfer. In 1 case, the distal part of contra lateral LSV showed thrombosis. Hence, an apparently healthy vein segment was harvested from proximal thigh region. However, a segment of the loop showed vasospasm after anastomosis, and it was decided to stage the procedure. During the second procedure performed after 5 days, the AV loop was found to have dilated well, and a free Latissimus dorsi flap transfer was undertaken. Venous congestion of the flap was observed after 24 h and afterward, total flap necrosis occurred. This patient subsequently required revision of his above-knee (AK) amputation stump after vacuum-assisted closure therapy. Another patient had flap failure due to haematoma and had to undergo a cross leg flap procedure. A third patient had secondary haemorrhage on day 18 without any consequence to the flap. All other patients had complete flap survival with limb salvageability [Figure 7]. Average soft tissue healing time was 4 weeks, and most patients were ambulated by 12-24 weeks. Six patients required bone reconstruction procedures. One patient with open knee injury and fracture tibia with AK amputation required free flap cover for revision of the amputation stump and took longer time to be ambulated.

DISCUSSION

Complex crush injuries of lower limbs, especially those involving mid and lower thirds of leg necessitate free flap cover as the only panacea for limb salvage. Since most patients who succumb to high-velocity injuries were young and middle aged bikers or pillion riders, saving the limb had significant social implications. Due to the nature and magnitude of the injury, the incidence of established PTVD is very high, even in the first fortnight after trauma. Identification of such diseased recipient vessels is very important before undertaking any major reconstruction in the lower limb. Acland[1] describes three hallmarks for this condition as "(i) loss of plane of dissection between vascular sheath and vessels, and in between the artery and venae comitantes (ii) loss of vaso vasorum and (iii) a marked tendency for vasospasm." These are comparable to the perivascular pathological changes and are also seen in post irradiated zones and after neck dissection in the head and neck region.

Lack of ipsilateral healthy recipient vessels has led many surgeons to employ concepts like pedicled free flaps, anastomosed to carrier vessels of contra lateral limb.[6,7] Threlfall *et al*.[8] were the first to suggest the use of a temporary AV fistula prior to free flap transfer. He suggested the use of long vein grafts anastomosed end to side to a main vessel at an accessible level, proximal to the trauma zone. The use of AV loops have subsequently been extended to trauma, cancer surgery[9] as well as limb salvage procedures in diabetic foot.[10] The femoral vessels in the sub sartorial canal are recognised as ideal recipient vessels due to large calibre, accessibility, and ease of positioning, larger pressure head and lesser chances of jeopardising distal limb vascularity especially if a large branch or tributary is used for anastomosis instead of the main vessel.[11] Freedman and MeLand[12] have described two methods for vein loop creation with LSV, namely the free vein graft and the *in situ* method. Though the latter has the advantage of lessening the number of anastomotic sites, we favoured the free vein graft method because the deep venous system was less likely to be involved in the pathologic process of crush injury to lower limb.

Figure 7: Patient 2 - latissimus dorsi flap after anastomosis to divided vein loop and inset

Advocates of the staging of AV loops allow variable maturation time in the range from 10 to 21 days.[13] Though Lind *et al*.[11] prefer a two stage approach to divide the case into two manageable procedures, Oswald *et al*.[14] advocated single stage approach based on a literature review showing equal complication rates. Though in staged approach, the advantages of a shorter theatre time, better reliability of the vein loop and the comfort of performing only two anastomosis in one sitting seem attractive, the potential disadvantages of two separate surgeries and anaesthetic exposure, the cost factor and a longer delay in wound closure with as serious risk of wound infection also exist. We preferred the single stage method for the definite ease of operating through a virgin field, with early wound coverage. The fact that we had a free flap failure even after allowing maturation of a doubtful AV loop further emphasises the fact that maturation time is not going to improve the prognosis of a pathological vein graft and that it would be better to immediately choose an alternate technique if the vein loop fails to work sufficiently after proximal anastomosis.

The cause for the second case of free flap failure was identified as a haematoma compressing the vein graft. Meticulous haemostasis, ligation of all side branches, creation of a sufficiently wide subcutaneous tunnel and a sound technique of anastomosis are prerequisites for success while using AV loops in free tissue transfer. Though technically more demanding, the use of AV loops can ensure a complete flap survival in a large proportion of complex lower limb injuries. The success rate can be further improved with more critical selection of patients, refinement of technique and experience. In fact, Cavadas,[15] Angel *et al*.[16] and Lin *et al*.[4] who reported large series of AV loops consider them invaluable tools in limb salvage though the success or failure are dependent on several variables including length and calibre of vein graft and arterial inflow parameters.

In summary, microvascular free flap transfers play a very significant role in limb salvage after high-velocity complex crush injuries of lower limb. Use of single stage AV loop creation is a valuable method to increase the applications of free flap whenever healthy recipient vessels are not available in the periphery of the trauma zone.

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