SAS Journal of Surgery
Abbreviated Key Title: SAS J Surg
ISSN 2454-5104
Journal homepage: https://www.saspublishers.com

OPEN ACCESS

Burn & Plastic Surgery

Posterior Tibial Artery Perforator Flap for Reconstruction of Soft Tissue Defects in the Middle and Lower Thirds of Leg and Ankle Region: A Prospective Observational Study

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DOI: 10.36347/sasjs.2024.v10i04.004 | **Received:** 23.02.2024 | **Accepted:** 28.03.2024 | **Published:** 05.04.2024

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Abstract **Original Research Article**

Background: Reconstruction of lower leg and ankle defect with exposed bone or tendon is very difficult and challenging task due to scarcity of donor areas. The posterior tibial artery perforator flap has been describedas a good option for small to moderate lower extremity defects with consistent anatomy and calibre. Different designs are found in the literature for posterior tibial artery perforator flaps and are mostly executed as propeller, transposition, and island flaps. ***Method:*** The study was a prospective observational study. It was conducted in the Department of Burn and Plastic Surgery, Dhaka Medical College Hospital, Dhaka, Bangladesh from July 2021 to June 2022. Sample size was 12. Sampling was carried out purposively. Postoperative follow up period was up to 3 months. Regarding the cause of the defect, 8 cases were traumatic wound from Road traffic Accident, 1 was post infective, 1 was post electric burn wound and 1 from bomb blast injury. Defect size was 4 cm×3cm to 18cm×9cm. Maximum dimension of the flap was 16cm×6cm and minimum size was 6cm×4cm. Posterior tibial artery perforator location was 5cm to 20cm from lowest level of medial malleolous. Rotation of the flap was 30°-180°. In all cases donor site was covered with split thickness skin graft. Operation time was 120 minutes to 180 minutes; mean operative time was 143.3±2.38 minutes. After operation hospital stay was 10 days to 21 days, mean 11.44±3.64 days. Over 1 year, twelve cases were reconstructed successfully with posterior tibial artery perforator flaps with propeller, transposition, island design. Clinical evaluation was done for all patients as well as follow-up in the outpatient clinic until complete healing of the wounds was achieved. Multiple modifications were done intraoperatively to enhance flap reach and minimize the complications, including designing, careful perforator dissection, and finally, strict postoperative course. ***Results:*** All cases healed completely but there were some complications. The average follow-up time in the clinic was 2 months. ***Conclusions:*** Posterior tibial artery perforator flap is a good option for reconstructing lower leg defects, but requires careful design and execution. The suggested steps will increase the survival of the flap and reconstruct the defect successfully. Among the 12 cases, 9 flaps completely survived, 2 cases developed partial necrosis which was secondarily healed. 1 case developed venous congestion and superficial epidermonecrolysis which were resolved by conservative treatment.

Keywords: Adipofascial flap; Posterior Tibial Artery, Distally based flap; Fasciocutaneous flap; Perforator flap; Propeller flap.

INTRODUCTION

Restoring soft tissue loss in lower extremities is considered a challenging task for the reconstructive surgeon because of scarcity of donor sites and suboptimal vascularity of the distal parts, limited skin availability and tight skin envelope [1,2]. For these defects free flaps were considered the gold standard but it is time consuming procedure, necessitates microsurgical experiences and associated facility [3]. So, it is difficult to execute in a busy center like Dhaka Medical College Hospital. Moreover, the debates between the advantages of muscle versus fasciocutaneous flaps reported similar success rates with fasciocutaneous flaps. Koshima and Soeda in 1989 were for the first time utilized the declaration of ‘‘perforator flap’’ for a paraumbilical skin flap based on a muscular perforator [4]. Hyakusoku *et al.*, in 1991 was first reported the term propeller flap as a fasciocutaneous flap rotated 90 degrees to cover post-burn contracture defects in cubital and axillary areas [5]. Afterward, Teo [6] could provide a higher amount of rotation by entirely skeletonize the perforator vessel to be based on a single pedicle. The significant improvement in perforator flaps make them a reliable option for the most challenging cases, with minimal donor site morbidity, sparing of nerves and muscles, and like-for-like coverage. The posterior tibial artery perforator flap was described as a good option for lower extremity defects with exposed bone and tendons [7]. Small defects over the distal part of the leg can be reconstructedby a V-Y advancement flap. However, larger defects with exposed bones will require either a propeller or atransposition flap and Island flap [8]. The purpose of this study was to evaluate clinical outcomes of local perforator flaps as a surgical alternative option in reconstruction of small-medium size soft-tissue defects in the middle-distal third of the leg.

PATIENTS AND METHODS

Twelve patients with complex lower limb defects were reconstructed successfully by using posterior tibial artery perforator flaps, between July 2021 and June 2022. Patient’s demographics, mechanism of injury, wound size and postoperative complications are summarized in Table 1. All patients were followed subsequently for early and latecomplications, as partial or total flap necrosis, venous congestion, infection, and flap survival. All the patients were followed in the clinic to assess healing. The mean follow up time was 2months, with no late complications related to posterior tibial artery perforator flaps.

PREOPERATIVE PREPARATION

It is important to consider three factors: the patient, the wound, and the leg. Patient was assessed regarding fitness for surgery, age (posterior tibial artery perforator flaps can be used with any age), and sex (one has to bear in mind the resulting donor site morbidity, especially in young female patients). Assessment of other medical conditions, i.e., diabetes mellitus, arteriosclerosis, and conditions such as pyoderma gangrenosum was done. The patient’s medical conditions were optimized accordingly prior to surgery. The wound should be assessed as to whether it is clean with healthy granulation tissue and for the presence of infection, while exposure of underlying structures such as bone and tendons should also be assessed. The extent of disease process or traumatized field surrounding the wound should be assessed. An absolute contraindication to a perforator flap is a degloving injury, as generally, the perforators are severed. The vascularity of the leg should be assessed before the operation by the presence of peripheral pulsations of the three major vessels of the leg. An arteriogram is helpful but not essential. In approximately 6% of patients, the posterior tibial artery is weak or absent. Before the operation, the leg is shaved and cleaned with antiseptic solution. Prophylaxis against deep vein thrombosis is given perioperatively.

FLAP MARKINGS

Flap markings depend on the site and type of wound. In traumatic soft tissue loss, there will be traumatized tissue surrounding the wound; hence, prior to marking the flap, perforators are located by using handheld ultrasound Doppler at a reasonable distance away from the traumatized tissue. Once the perforators are located, flap marking should be carried out in a reverse fashion using the perforator as a pivot point. It is important to plan an exploring incision, which is part of one of the margins of the flap. Once this is found to be satisfactory, the flap design can be adjusted, based on the location of the perforator and the defect to be covered and elevation of the flap is done.

SURGICAL TECHNIQUE

The donor area of the posterior tibial artery perforators extends anteriorly to the anterior border of the tibia and posteriorly to the midline of the posterior aspect of the leg. All the perforators of the posterior tibial artery perforate the deep fascia in a longitudinal line from the tibial tuberosity superiorly to the medial malleolus inferiorly. With hand-held Doppler, two to three perforators were identified along the posterior tibial artery course. The best perforators were located. The defect dimensions were measured, and the flap was designed 1 cm larger than the defect. However, it should be kept in mind not to exceed the tibial shin anteriorly and midline posteriorly. The key in all patients was thorough irrigation and adequate excision of the defect. A tourniquet was inflated without exsanguination for better visualization of veins. Then an exploratory incision through skin and subcutaneous tissue was committed first, and sub-fascial dissection was carried till the perforators along the septum between the flexor hallucis longus and soleus were identified. The proximal end was the soleus muscular perforator, and we did not go beyond this point in any

of our flaps. After identifying the perforators, the tourniquet was deflated and Doppler signals were checked. The average size for the chosen perforators was within the range of 1.6–2.5 mm, with good pulsation. Once the validity of those perforators was observed, we committed to full flap design, and the flap was completely elevated subfascially. The perforators were dissected meticulously to source vessel to increase the mobility, and any extra small perforators that would contribute to tension upon advancement were ligated. Finally, the intermuscular septum was elevated off the tibia from distal to proximal direction. The flap was positioned with tension-free closure via nonabsorbable sutures. There was a low threshold to apply the skin graft to the donor site, especially if tension upon closure was a concern. Noncompressible dressing with a window was applied to allow flap monitoring. Postoperative edema was minimized with leg elevation, back slap, and immobilization for 2 weeks.

RESULTS

Figure-1 shows perforators of the Posterior Tibial Artery and how perforator skin was harvested. In case of the exposed tibia, how the Posterior Tibia Artery Perforator Flap was done is demonstrated in Figure-2. The patient of this study went through the Posterior Tibial Artery Perforator Transposition Flap as well [Figur-3]. The design of the flap, skin grafting and some parts of the wound are illustrated in Figure-4. The immediate postoperative flap and split-thickness skin graft at the donor site and some parts of the wound picture are included in Figure-5. Twelve patients were operated for the reconstruction of defects localized at the lower part of the leg and ankle joint. The patients' age range was 16 to 54 years. Regarding the cause of the defect, 8 cases were traumatic wound from Road traffic Accident, 1 was post infective, 1 was post electric injury and 1 from bomb blast injury. Maximum dimension of the flap was 18cm×9cm and minimum size was 4cm×3cm. Only two patients faced partial flap loss. All the donor areas were covered by split thickness skin graft. Patients were followed up from 30 days to 3 months [Table-1].

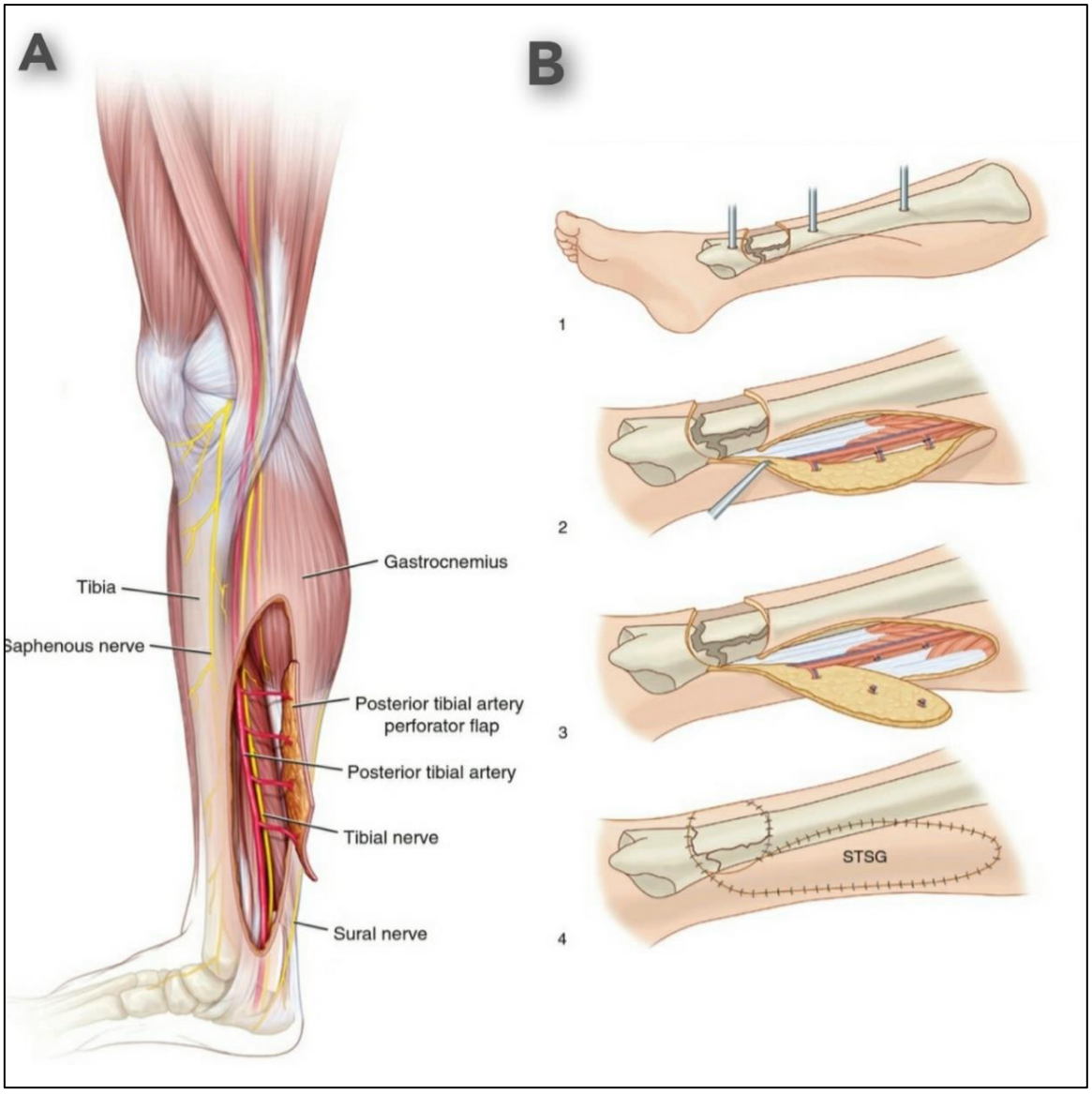

Figure 1: A, Perforators of Posterior Tibial Artery. B, Steps of harvesting the perforator skin flap
Step 1: wound with exploring incision. Step 2: elevation of the flap with deep fascia, the distal perforator selected and the other perforators microclamped. Step 3: the fasciocutaneous flap is elevated completely, pivoting on the distal perforator. Step 4: flap inset, the donor site grafted with a split-thickness skin graft (STSG)
(Ref. Wei FC, Mardini S. Flaps and Reconstructive Surgery. 2nd Ed. Page 717 & 722)

Case 1

The patient in Case 1 was a 54-year-old man. He had a Bomb Blast Injury involving Right Leg with exposed tibia and Tendons. Figure 2A and 2B show the initial soft tissue defect dimensions requiring coverage. After thorough irrigation, debridement and application of vacuum-assisted dressing (VAC), the decision was to take him for wound coverage with a posterior tibial artery perforator propeller flap. Figure 2C presents the design of the flap and the location of two perforators which were detected by hand held doppler ultrasound device.

Figure 2D presents the perforator that were preserved and incorporated in the flap design. The great saphenous vein was identified but ligated eventually. Donor site was reconstructed with split thickness skin graft. The defect was very large in relation with flap size so concentration was given to cover the exposed bone first by propeller flap and other area was resurfaced by skin graft. Figure 2E and 2F presents the immediate postoperative picture after flap inset. Collagen sheet dressing was given in the uncovered area which was resurfaced 10 days later by split thickness skin graft. Figure 2G and 2H shows the flap appearance after 3 months.

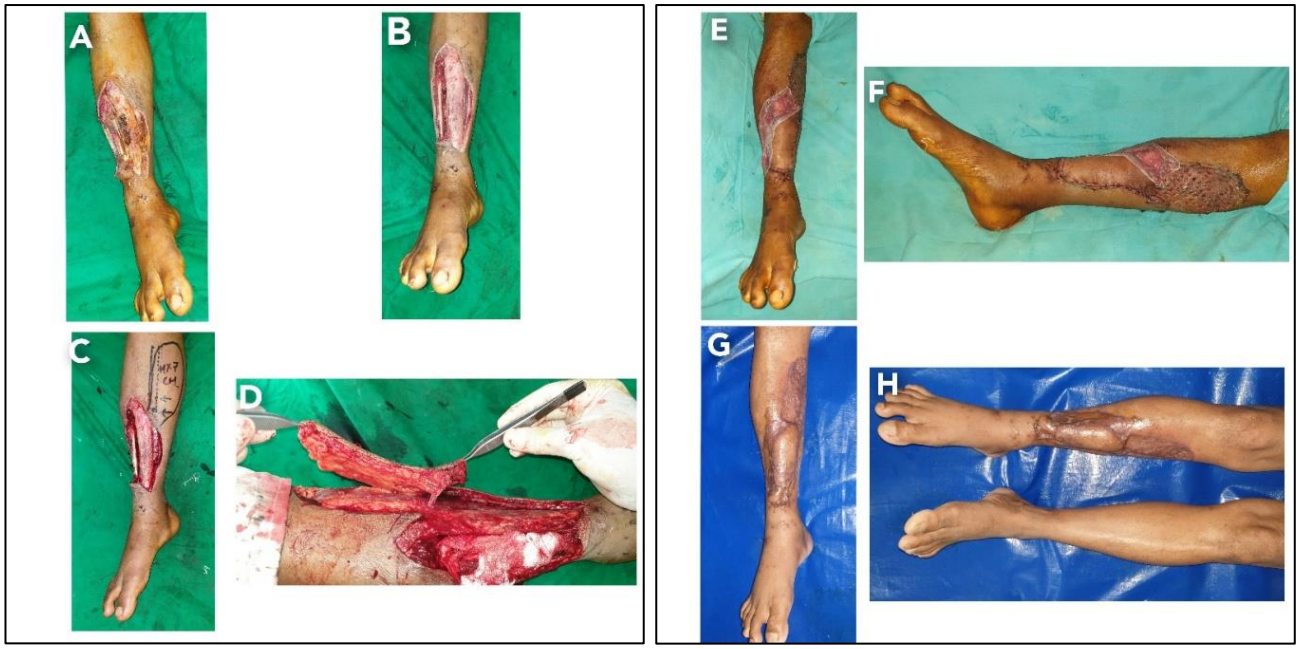

Figure 2: Posterior Tibial Artery Perforator Flap coverage in the Right Leg with exposed tibia. A, Initial defect in the right leg. B, Wound after Excision of necrotic tissue. C, Designing of Posterior tibial artery perforator flap and detection of perforators done by Doppler ultrasound. D, Elevation of Flap on a single best perforator. E & F, after flap inset. G & H, 3 months after operation

Case 2

The patient in Case 2 was a 35-year-old man, was a victim of a motor vehicle accident and sustained right tibia and fibula fracture, with exposed tibia, 4 × 3 cm open wound over the right lower leg. The wound was resurfaced by posterior tibial artery perforator transposition flap. Intraoperatively, one good-size perforator were identified and preserved. The donor site was covered with a split thickness skin graft. Moreover, his postoperative course was uneventful.

Figure 3A shows the wound in the Right leg with exposed tibia and external fixator in situ. Figure 3B shows the location of the perforator and design of the flap. Perforator was detected by a hand held doppler ultrasound device. Figure 3C shows the elevation of the flap. Figure 3D and 3E shows the immediate postoperative flap inset and Split thickness skin graft in the donor site.

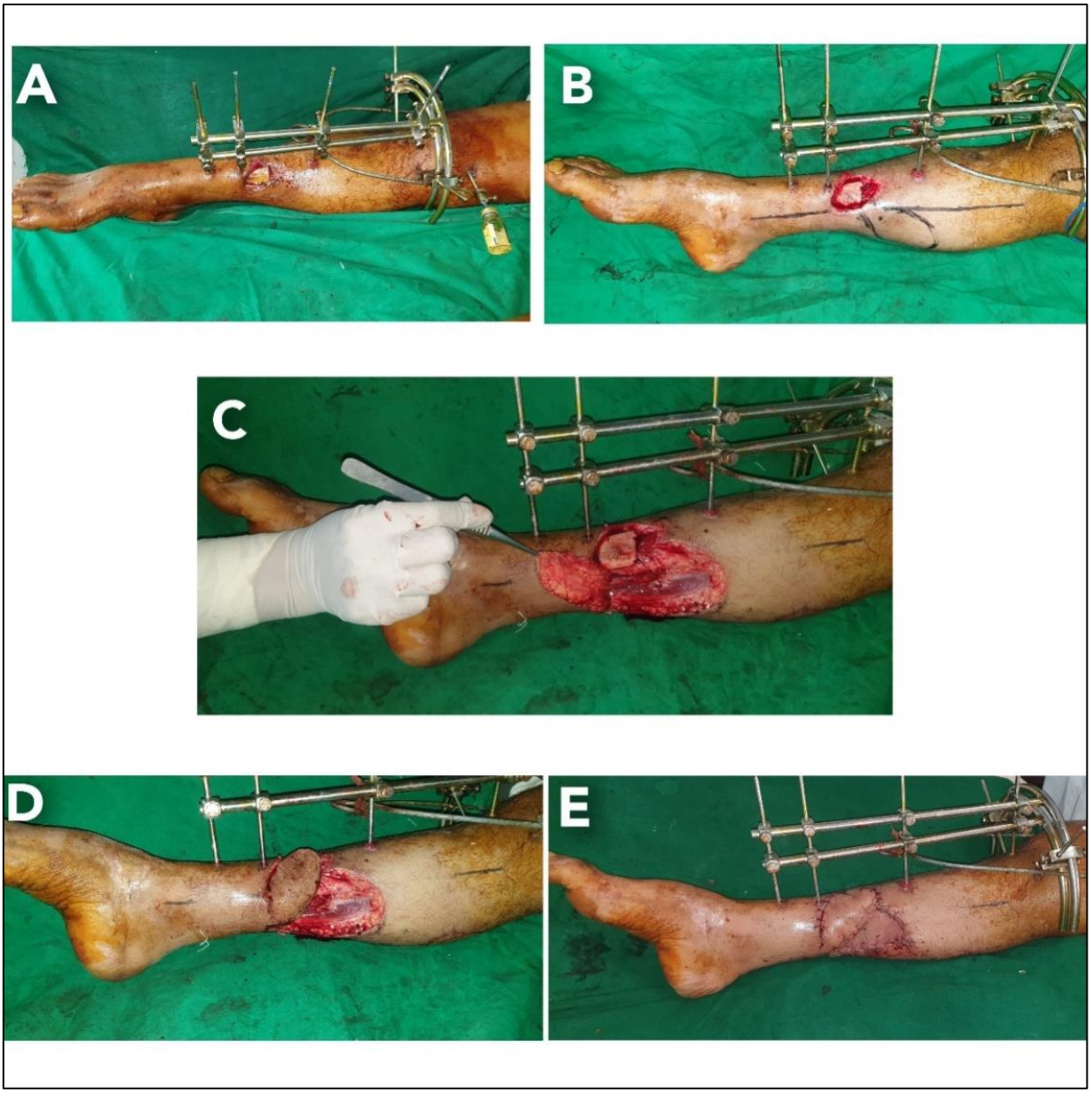

Figure 3: Posterior Tibial Artery Perforator Transposition Flap. A, initial traumatic defect in the right leg with external fixator in situ. B, Designing of the flap and location of perforator. C, Elevation of the flap. D, flap inset in the recipient site. E, split thickness skin graft at donor site

Case 3

The patient in Case 3 was a 24-year-old man who sustained a road traffic accident followed by soft tissue defect at the dorsum of Right foot and anterior aspect of ankle joint. After several trips to the operating theater for irrigation and debridement, obtaining negative cultures and preparing him for coverage with posterior tibial artery perforator propeller flap. Figure 4A and 4B shows the wound at the dorsum of Right foot. Figure 4C shows the design of the flap. Figure 4D and 4E shows the inset of the flap with split thickness skin graft for donor site and some part of the wound.

Initially, the saphenous vein was compromised to enhance flap reach after ensuring good capillary refill. His postoperative course was uneventful, and complete healing was achieved.

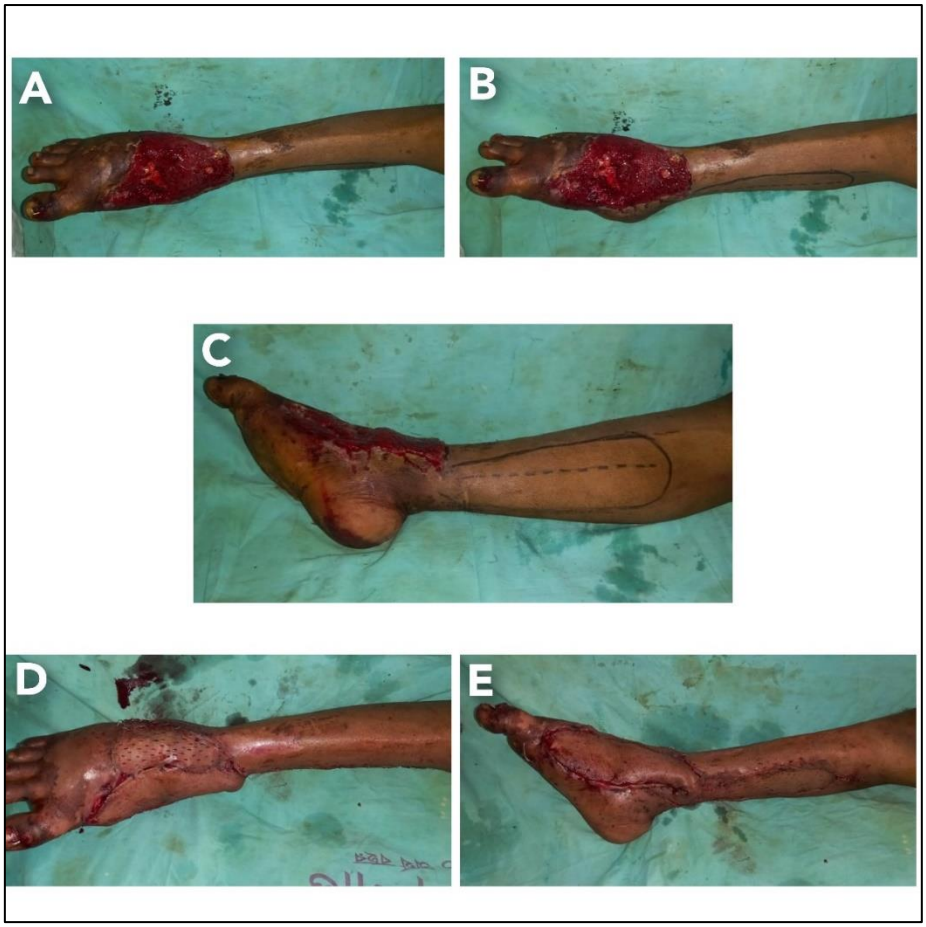

Figure 4: A and B, Wound at the dorsum of Right foot. C, Design of the flap. D and E, Flap inset at the recipient site and split thickness skin graft at donor site & some part of the wound

Case 4

The patient in Case 4 was a 42-year-old woman, was a victim of a road traffic accident and sustained injury in lower leg exposing Achilles Tendon, 12 × 8 cm open wound over the right lower leg. He was taken to the operating theater for coverage via posterior tibial artery perforator propeller flap. Intraoperatively, one good-size perforator were identified and preserved. The donor site and some part of the wound was closed with a split thickness skin graft. Moreover, his postoperative course was uneventful. Figure 5A shows the wound at the posterior aspect of lower leg exposing tendoachilles. Figure 5B shows the design of the flap. Figure 5C, 5D and 5E shows the immediate postoperative period after inset of the flap and split thickness skin graft at the donor site and some part of the wound.

Table 1: Patients information

Case	Sex/Age, y	Etiology	Defect Size (cm)	Comorbidities	Follow-up (mo)	Complications
1	M/54y	Bomb Blast Injury	18×9	HTN	3 Mon	Epidermonecrolysis
2	M/35y	Road Traffic accident	4×3	None	2 Mon.	None
3	M/24y	Road Traffic accident	10×8	None	2 Mon.	None
4	F/42y	Road Traffic accident	12×8	DM, HTN	1 Mon.	Partial Flap loss
5	M/37y	Road Traffic accident	10×5	None	3 Mon.	None
6	M/16y	Road Traffic accident	5×4	None	2 Mon.	None
7	M/22y	Road Traffic accident	8×4	None	1 Mon.	None
8	F/32y	Road Traffic accident	7×6	None	1 Mon.	None
9	M/65y	Road Traffic accident	12×9	DM	3 Mon.	Partial Flap Loss
10	M/36y	Fall from Height	15×7	None	1 Mon.	None
11	M/38y	Post infective	18×9	None	2 Mon.	None
12	M/35y	Electrical Injury	12×7	None	3 Mon.	None

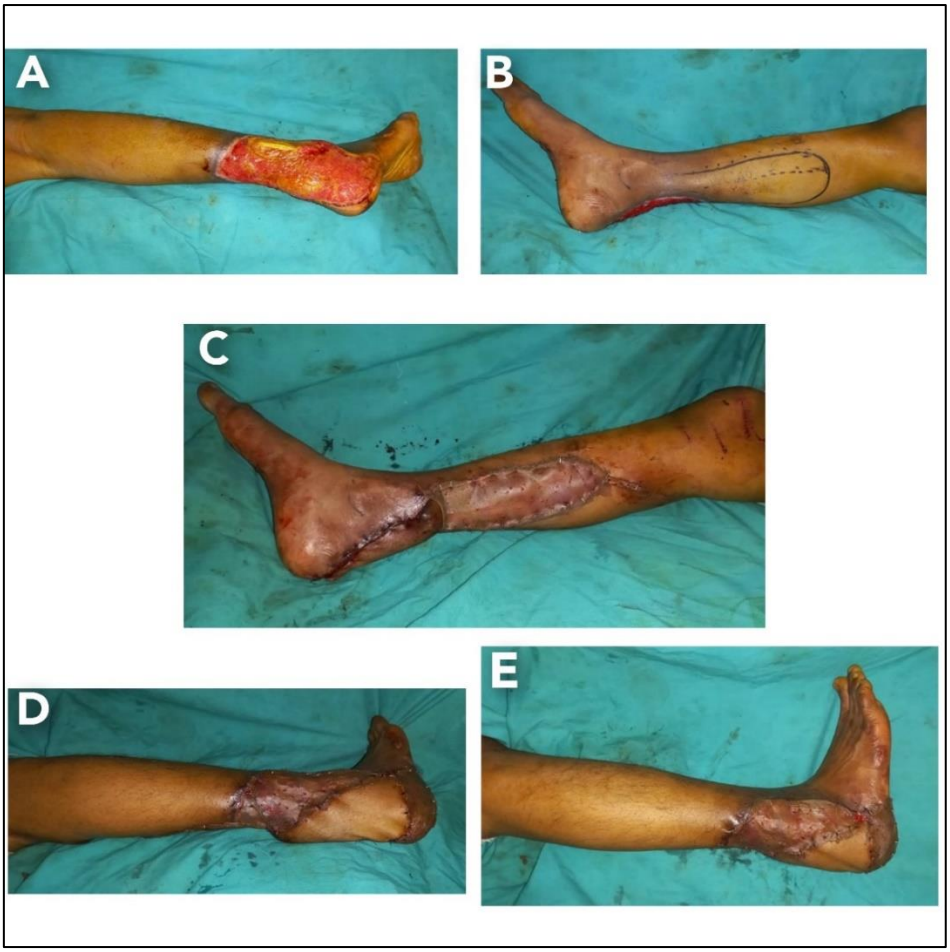

Figure 5: A, Wound at the posterior aspect of lower leg exposing tendoachilles. B, Design of the flap. C and D, immediate postoperative picture after inset of the flap and split thickness skin graft at the donor site and some part of the wound

DISCUSSION

Soft tissue defects of the lower extremities especially the distal leg continues to present a difficult reconstructive challenge to the plastic surgeon. The ideal soft tissue reconstruction of the leg should be versatile, relatively simple to accomplish, provides similar skin texture to the missing ones, with minimal donor site morbidity. The lower leg fasciocutaneous flap was first reported by Ponten in 1981 [1]. Random pattern fasciocutaneous flaps have high rate of failure due to unreliable vascularity besides its high donor site morbidity and the sequential bulky dog ear which is unappealing [9]. The principle of the free style perforator flap was well introduced in 2004 by Wei and Mardini [10] and allowed for creative independency to tailor perforator flaps to suit the reconstructive needs of any defect. Muscle flap has a restricted role with the disadvantage of sacrifice of muscle function. Cross leg flap is easy flap solution but it has high donor site morbidity with prolonged immobilization of both lower extremities and two stage procedures [11]. Although free microsurgical flaps have been the first choice for reconstructive procedures in the lower leg [12], but it is time consuming, experts are needed and difficult to perform in a busy hospital like Dhaka Medical College Hospital. Schaverien and Saint-Cyr [13] stated that there are always 3 constant perforator vessels at 4 to 9 cm, 13 to 18 cm, and 21 to 26 cm from the intermalleolar line on the medial portion of the leg. Four or 5 septocutaneous perforator vessels emerging from the septum between the soleus and flexor digitorum longus muscles and many musculocutaneous perforators emerging from the soleus derived from the posterior tibial artery supply the overlying cutaneous tissue. Single perforator-pedicled propeller flap, also called pedicled perforator flap, island perforator flap, or local perforator flap, [14] has the greatest freedom of rotation, which can reach up to 180 degrees [15]. In recent years, there is a great increasing use of perforator-based propeller flaps in limb reconstruction, especially for the lower limb, with a distal rotation [16].

Arterial inflow, even in large and long distally based propeller flaps from the lower extremity, is usually sufficient. However, venous drainage is a special concern. Veins are inherently provided with valves to prevent retrograde outflow in distally based flaps. Furthermore, the 180-degree torsion more likely jeopardizes the venous drainage because decreased venous wall thickness and lower intraluminal pressure

make veins more susceptible to collapse and subsequent thrombosis. Therefore, venous complications, such as swellingand congestion, occurred more often in distally based perforator flaps. Wong *et al.,* [17], using a finite-element simulation model, pointed out that, for a 1 mm diameter perforator after 180-degree rotation, at least 30 mm is needed to distribute the twist over a long distance to minimize kinking. This is possible for musculocutaneous perforators by intramuscular dissection. However, because the deep main artery trunk is located superficial in the distal leg, the septocutaneous perforating vessels are usually very short.

At our institution, we have been using posterior tibial artery based perforator flap in twelve patients to cover soft tissue defect with exposed bone or tendons in the middle and distal third of the leg and also the dorsum of foot. Flap dimensions were ranged from (28 $cm^2$to 96 cm^2) with average of 78.9 cm^2. Average size of perforator flaps in our study is larger than proposed by Gir *et al.*, [18] of 67.1 cm^2, and Shin *et al.*, of 63.8 cm [19]. Most of our flaps (75%) based on one perforator survived without complication or vascular compromise with good postoperative outcome. To avoid torsion of small perforating vessel during rotation of the flap, the perforator vessel dissection should be carried out carefully under loupe magnification (4X) for a short path through the muscle substance or inside the inter-muscular septa. Moreover division of all the fascial adhesions around the perforator is a necessary step to avoid compromising the blood flow during flap rotation especially the venous drainage.

We found 3 complications (25%) in our study, two cases with partial necrosis (16%), and a superficial epidermolysis (8%) in one case. Two recent systematic review articles investigated the incidence of complications of the perforator flaps which were used for lower-extremity reconstruction. These studies which performed by Gir *et al.,* [18] and Nelson *et al.,* [20] analyzed 186 and 310 perforator flaps respectively and show comparable result in terms of total flap survival. However, partial flap necrosis was 11% in both reviews which is lower than reported in our clinical series. The safe dimensional limit of the perforator flap is very difficult to predict how much is the skin size that could be nourished by one perforator [21]. In addition, perforators originating from the posterior tibial vessel, although small in number, their diameter are larger and more constant than those from the peroneal vessel, so larger flaps with more reliable vascularity can be raised on the medial side of the leg compared to the lateral aspect [22-24]. Donor area is partially covered with the distal part of the propeller flap, the rest is covered by split thickness skin graft. During follow-up, our patients showed good reconstruction with excellent skin color, texture, and thickness matching with that of the wound. All patients recovered with good plantar-flexion and walked normally. Poor cosmesis was reported as a limiting factor in posterior tibial artery propeller flaps [25]. Free flaps remain the first option for reconstruction of wide and complex soft tissue defects of the lower extremities [26], however propeller perforator flaps may represent a more suitable alternatives to cover small-to-medium size soft tissue defects over lower leg.

The main advantages of perforator flaps are we can preserve the major vascular axes and underlying muscle with limited functional deficit of the lower extremity, allowing coverage like with like tissue without the need for a microsurgical anastomosis. Moreover, these flaps provide a consistent, predictable vascular supply and associated long pedicle to permit enough transposition with minimal donor site morbidity. On the other hand, its disadvantages include a carful perforator dissection to separate it from the surrounding tissue to avoid damage of the perforating vessel. With the extended knowledge of lower limb vasculature, perforator flaps' turn to have a significant impact in lower limb reconstruction obviated the need for microsurgical transfer and minimized donor site morbidities, reduced the operative time, and allowed for relatively early mobilization.

Some Points to be noted to Enhance Mobility and Flap Survival

- Sub-fascial dissection should be done for more mobility of the flap toward the defect and provided extra blood supply to the flap by preserving the fascial plexuses.
- Preservation of the great saphenous vein will enhance the venous drainage and prevent congestion, but if tension is a problem, it can be ligated.
- Selection of the best perforator depends on many factors, but important intraoperative points for consideration include good size perforator, a pulsating perforator; and relative approximate location to defect.
- Perforator must be skeletonized from the surrounding tissue up to main feeding vessel to avoid torsion of the vessel which results venous congestion and eventually venous thrombosis.

CONCLUSIONS

Patients with skin lesions of the lower leg, ankle and foot remain a challenge for the plastic surgeon. Based on the outcomes presented in our study, we regard that perforator propeller flaps are safe, relatively simple procedure and consider as an ideal option in reconstructing small or medium defects of the middle and distal third of the leg as well as around the ankle region which provide similar skin texture with minimum donor site morbidity.

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