Original Article
Distal posterior tibial artery perforator flaps for the treatment of chronic lower extremity wounds

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Abstract: Background: Chronic lower extremity wounds due to infection, diabetes mellitus, and osteomyelitis have always been arduous to treat. Among an ocean of reconstructive techniques, the distal posterior tibial artery perforator flap has been gaining popularity in the recent years. Materials and methods: In this article, we describe our experience in the treatment of twenty-eight patients with chronic lower limb wounds using distal posterior tibial artery perforator flaps. Results: Complete survival of the flap was recorded in 23 cases, small superficial necrosis was observed in five cases, four of which were reconstructed with split thickness skin grafts, the latter was directly sutured after debridement, and all eventually healed. Conclusions: The posterior tibial artery perforator flap is a feasible option for the management of the small-to-medium sized defects resulting in chronic lower extremity wounds.

Keywords: Distal posterior tibial artery perforator flap, chronic lower extremity wounds

Introduction

The treatment of chronic lower extremity wounds produced by infection, diabetes mellitus and osteomyelitis has always been a formidable task. Free perforator flaps are usually recommended as the therapy of choice in the treatment of chronic lower extremity wounds. The application of perforator flap began in 1989, when Koshima and Soeda illustrated an inferior epigastric artery skin flap without rectus abdominous muscle for the coverage of the floor-of-the-mouth and groin defects [1, 2]. The perforator flaps stem from an extension of the concept that the skin can be divided into angiosomes [3]. Indeed, it is defined as an island flap which reaches the recipient site through an axial rotation, and the flap is supplied by perforator vessels that derived from a deep vascular system [4]. It needs to rotate around the perforator vessel through various degrees, varying from 90 degrees to 180 degrees in order to harvest a propeller flap [5], it can also be easily rotated in the other direction. A surgical technique for obtaining propeller perforator flaps in the lower leg was described by Teo [6] in 2010. However, the

failure rate of the reconstruction of chronic lower extremity wounds with the flaps is as high as 15 to 20 percent. Besides, they are time consuming and require microsurgical expertise [7-9]. For these reasons, reliable local alternatives for reconstruction of chronic lower extremity wounds are currently needed. Accordingly, the distal posterior tibial artery perforator flaps are probably a perfect choice. The posterior tibial artery is the direct terminal of the popliteal artery and it is invariably the largest branch of the popliteal artery. It supplies approximately 10 percent of the integument of the lower leg [10]. Each tibial perforator artery is accompanied by two venae that supply two to four perforators through their course in the legs [11, 12]. The muscular clearance skin arteries in the proximal, middle and distal one-third of the calf are the branches of the posterior tibial artery. The perforating point are respectively located 5~12 cm, 15~18 cm and 22~24 cm from the medial tibial to the medial malleolus tip. The cutaneous branches fit into each other in a network, and the largest caliber of the perforators are mainly located in the distal one-third leg. Through selective muscle clearance skin artery intubation perfu-

sion ink experiment, Carriquiry proved that we can obtain large-area fasciocutaneous flap in the medial leg by choosing any one of the upper, middle or lower muscle clearance skin artery as pedicle [12]. According to the study of Geddes [10], about 10±4 cutaneous perforators were distributed in that area, but other authors reported a number of 2 to 5 [13]. Some authors demonstrated that we can choose 8 cm above the medial malleolus as the bottom of the flap, 10 cm below the tibia platform is the upper bound and tibial medial edge as the przone [14].

This article reports our experience with twenty-eight patients suffering from chronic lower extremity wounds who underwent surgical reconstruction with distal posterior tibial artery perforator flaps.

Materials and methods

From April 2010 to May 2015, 28 patients with skin and soft tissues necrosis and lower extremity injuries were admitted for treatment at The Second Affiliated Hospital of Wenzhou Medical University and underwent reconstruction surgery involving the use of distal posterior tibial artery perforator flaps. The use of the data from all patients have been approved by The Second Hospital of Wenzhou Medical University Research Ethics Committee. Written consent was acquired from each patient and followed the guidelines of the Declaration of Helsinki. The patients included 21 males and 7 females, and their ages varied from 22 to 67 years, with an average age of 45.0 years. The cause of the wounds included open tibia/fibula/calcaneus fractures with secondary infection in seventeen cases, open fracture in seven, diabetes mellitus after ORIF (Open Reduction with Internal Fixation) for fractures in one, osteomyelitis in one, scald in one, and one case with Achilles tendon rupture associated with infection. The soft-tissue defect was located on the calcaneus in seven cases, the malleolar area in thirteen cases, and the lower tibia in seven cases. The defect sizes ranged from 6 to 192 cm². The wounds were debrided an average of 2.5 times (range 2 to 4 times). All cases were performed with vigorous debridement, and then distal posterior tibial artery perforator flaps were applied. The pulses of the dorsalis pedis and posterior tibial artery were palpable in all cases. Chronic

osteomyelitis was diagnosed based on patient history, physical examination, clinical and radiographic examinations, and confirmed by intra-operative cultures and histological examinations. In one case, the flap was harvested for the purpose of covering a soft-tissue defect on account of the failure of the free anterolateral thigh flap for the treatment of the soft-tissue defect caused by the malleolar fracture. One patient with Achilles tendon rupture and infection received a local tendon graft and a posterior tibial perforator flap.
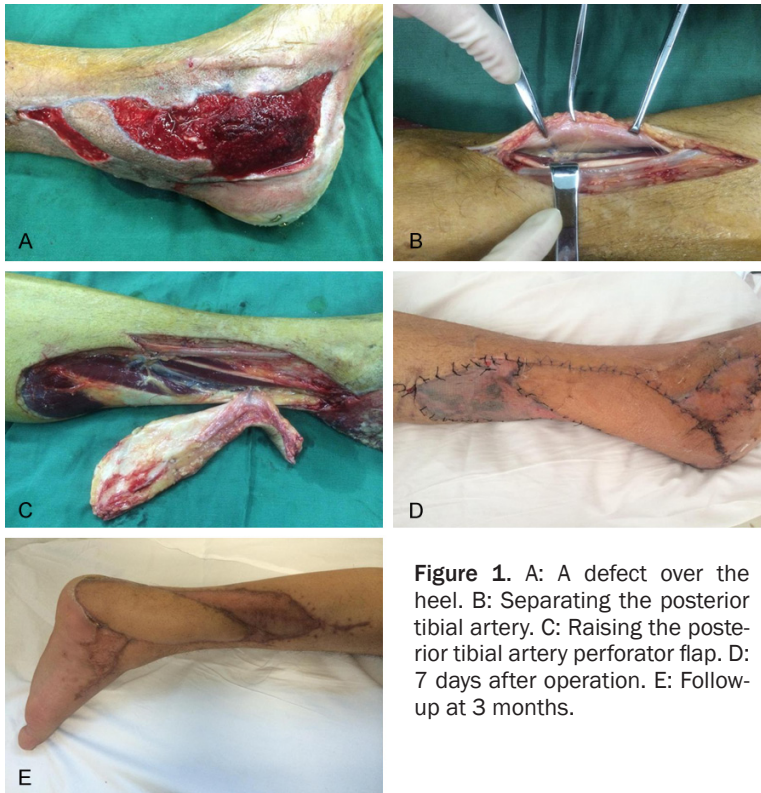
Preoperative assessment

A meticulous preoperative assessment of all patients and their wounds were made to decide whether they were suitable for the operation. Routine blood examination, strict blood glucose control, coagulation function, and close clinical monitoring of the general condition of the patient were prerequisites for surgery. Each patient required lower extremity pulse and Doppler examination and plain radiograms, and patient suspected of having osteomyelitis underwent scintigraphy. Before surgery, necrotic and infected tissues were resected and removed. A culture-based antibiotic treatment was administered to infected patients and continued postoperatively in accordance with the bacterial culture of the wound secretion and drug sensitivity test. Transcutaneous oxygen measurements were greater than 30 mmHg in cases which need reconstruction.

Surgical technique

After differentiating the most appropriate perforator vessel through the use of a Doppler probe to locate the posterior tibial artery, the flap was delineated approximately to the size of the defect, a curved line was drawn between the medial part of the middle and distal thirds of the leg. The patient was usually in a supine position with the injured leg slightly abducted and then a thigh tourniquet was applied to the proximal lower limb to allow simpler identification of the perforators during ascertaining. The first incision was made along the trailing edge of the flap and raised until the intermuscular septum between the tibialis posterior and soleus was reached. At that point, at least one of the perforators was found (**Figure 1**). The perforating artery and the concomitant

Figure 1. A: A defect over the heel. B: Separating the posterior tibial artery. C: Raising the posterior tibial artery perforator flap. D: 7 days after operation. E: Follow-up at 3 months.

monitored at regular intervals until entire healing of the donor and wound site was achieved. The vacuum device generally remained in place for five to seven days before the dressing was removed, then the flap was observed for viability. The flap sutures were generally dismantled on the 14th postoperative day.

Indications

The straight tip of the medial malleolus ranging from 3-10 cm, where the posterior tibial artery perforator constantly appears, is short and its outside diameter is relatively thin. In fact, it is fit for the reverse islanded propeller-design of the posterior tibial artery perforator flap, and the flap is often used for the reconstruction of defects in the ankle and calcaneus area. At the 10-20 cm straight tip of the medial malleolus, the posterior tibial artery perforator is long and the outside diameter is relatively thick, thus it is suitable for islanded posterior tibial artery perforator flap and free transplantation. Actually, the flap is usually appropriate for small to moderate defects of extremities (**Figure 2**).

Contraindications

Contraindications to the application of the distal posterior tibial artery perforator flap included suspicion of presence of a degloving injury or injury to the posterior tibial artery. In addition, in our study, Gustilo grade IIIC injuries in the local soft tissue within the zone of injury were excluded.

Results

Demographic information, complications, and results are presented in **Table 1**. A total of 28 distal posterior tibial artery perforator flaps were performed in patients with chronic lower extremity wounds. The average surgery time was 2.2 hours, and the average size of the flap was 53.3 cm². Complete survival of the flap

veins were easily located by passing through the muscle septum between the tibialis posterior and soleus. After verifying the perforator vessels, the flap was harvested. Then the raised flap was able to rotate around the perforator ranging from 90 degrees to 180 degrees and adapted to the defect. It should be borne in mind that the flap is slightly larger than the wound so as to assure proper tension of the flap.

All operations were carried out by the same surgical team, and in most of our cases, the donor site was covered with a split skin graft which had been derived from the thigh. The leg was elevated and soft bandage was utilized to avoid compression, an area was kept open in order to check the skin color and temperature. An appropriate antibiotic therapy was administered in all cases and continued postoperatively. Low weight molecular heparin was adopted before ambulation was achieved. We applied negative pressure therapy on all patients postoperatively for about one week. The use of Negative Pressure Wound Therapy (NWPT) could facilitate wound healing, and aid flap success, in particular, it can improve survival rate of the skin graft. All patients were

Figure 2. A: A defect with exposed calcaneus in the heel. B: Harvesting of a posterior tibial artery perforator flap. C: 20 days after operation. D: Follow-up at 3 months.

was recorded in 23 cases: small superficial necrosis was observed in five cases, four of which were reconstructed with split thickness skin grafts and the remaining one was directly sutured after debridement, and all eventually healed. The mean time to union was 5.7 months (range, 2 to 17 months). The average period of hospitalization in the plastic surgery department was 23.6 days (range, 6 to 75 days), an additional hospital stays with duration of 2 weeks was required for rehabilitation. Follow-up ranged from 6 to 47 months, with an average of 25.86 months. The median angle of rotation of the flap with regard to the perforator was 170 degrees (range, 80 degrees to 180 degrees). All flaps survived without recurrences of infection after reconstruction. The functional results were mostly agreeable, all patients could walk comfortably, the appearance was more acceptable and the level of satisfaction was generally high (**Figure 3**).

Discussion

Soft tissue defects still continue to pose a challenge for reconstructive surgeons, especially for the lower limbs, which are known for poor wound healing, as they lack adequate soft tissue coverage and have decreased distal perfusion. In addition, infection after open fracture is associated with an increase of tibia/fibula/calcaneus fractures, and the soft tissue defects of the lower extremities are often caused by this type of infection. In most cases, reconstruction surgery may be required. However, skin graft is an unfavorable selection for coverage in this region, as the loss of skin soft tissue in this area is always associated with exposure of tendons and bone. Thus, free tissue transfer is commonly used to cover this area. Though free flap reconstruction of the lower extremity is a satisfactory choice, an increased risk of failure has been associated with this procedure [7-9]. Moreover, free flap transfer involves complex surgery requiring technical expertise, and it is a time consuming operation combined with significant complications especially in patients of advanced age and with co-morbidities. Undoubtedly, free transfer of tissue for lower extremity reconstruction has been used extensively and efficiently, it has sufficient bulkiness

Table 1. Data of the patients

Patient No.	Age/ Gender	Dimension of skin flap (cm)	Size of defect (cm)	Etiology	Complication	Follow-up (months)
1	56/M	7×6	7×6	Open tibia fractures with secondary infection	Superficial necrosis treated with STSG, 1 month postoperatively	10
2	67/M	8×5	7×4	Open tibia fractures with secondary infection	Superficial necrosis treated with STSG, 2 month postoperatively	17
3	47/M	8×4	8×3	Open tibia and calcaneus fractures with secondary infection	None	6
4	56/M	14×7	6×6	Open fracture	None	40
5	36/M	8×5	5×1.5	Achilles tendon ruptures associated with infection	None	13
6	61/F	11×8	10×7	Open tibia and fibula fractures with secondary infection	Superficial necrosis treated with STSG, 1 week postoperatively	14
7	37/M	15×10	15×9	Open fracture	None	14
8	60/M	10×3	7×3	Osteomyelitis	None	6
9	49/M	10×6	8×6	Open fracture	None	45
10	45/M	11×10	10×10	Open fracture	None	37
11	41/F	6×4	5×4	Open tibia and fibula fractures with secondary infection	Superficial necrosis debridement and suturing, 5 days postoperatively	39
12	28/M	10×10	10×9	Open fracture	None	24
13	26/M	5×4	5×4	Open tibia and fibula fractures with secondary infection	None	28
14	46/M	12×8	12×6	Open calcaneus fractures with secondary infection	None	21
15	32/M	7×6	6×6	Open calcaneus fractures with secondary infection	None	36
16	35/M	12×10	11×10	Open calcaneus fractures with secondary infection	Superficial necrosis debridement and suturing, 6 days postoperatively	25
17	35/M	8×6	7×6	Open tibia fractures	None	39
18	57/M	7×6	6×6	Open fracture	None	40
19	51/M	16×12	15×12	Scald	None	45
20	52/M	8×5	12×7	Open fibula fractures with secondary infection	None	7
21	56/M	4×2	3×2	Open calcaneus fractures with secondary infection	None	10
22	55/F	8×7	8×5	Open tibia and fibula fractures with secondary infection	None	12
23	28/F	8×4	4×3	Open tibia and fibula fractures with secondary infection	None	37
24	55/F	8×8	8×7	Open tibia fractures with secondary infection	None	40
25	61/M	7×6	7×6	Open tibia and fibula fractures with secondary infection	None	35
26	28/M	10×7	8×7	Open fracture	None	31
27	37/M	8×6	9×6	Open calcaneus fractures with secondary infection	None	47
28	22/M	6×4	6×4	Open calcaneus fractures with secondary infection	None	12

Notes: M: Male, F: Female, STSG: Splint thickness skin graft.
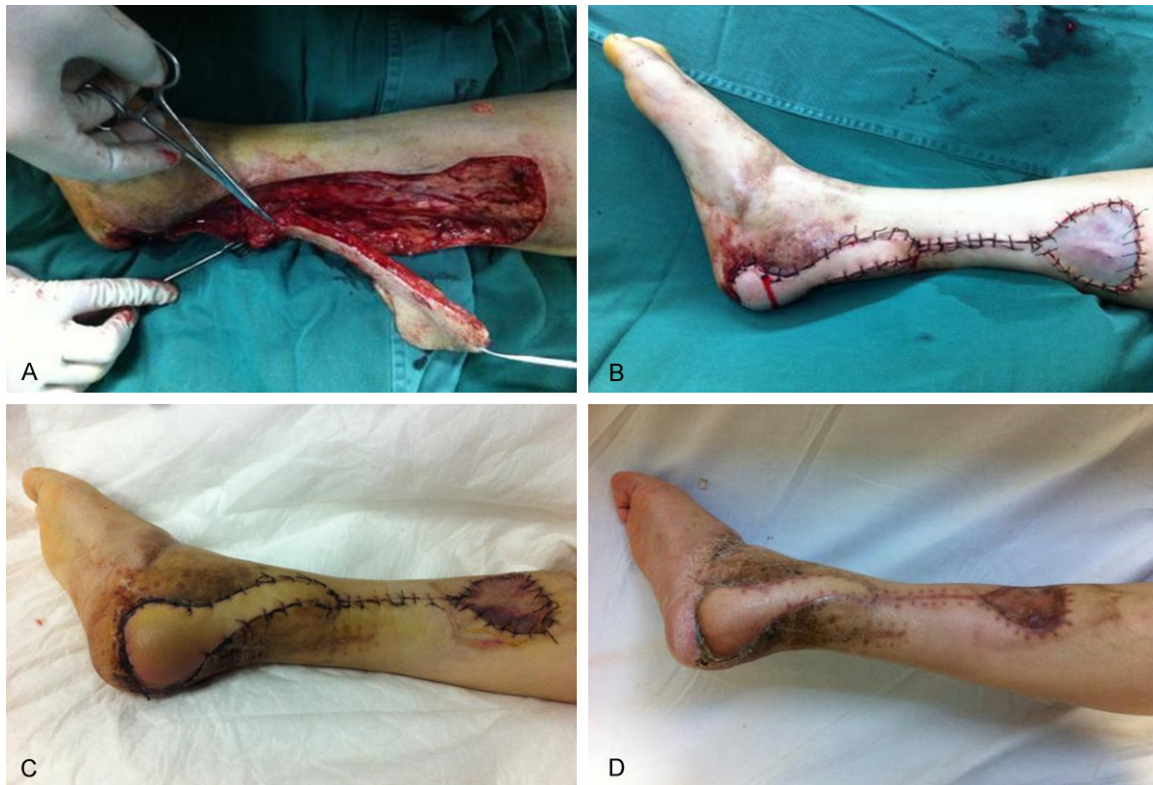
Figure 3. A: Harvesting a posterior tibial artery perforator flap. B: The flap was turned about 180 degrees to fill the calcaneus cavity and skin graft was performed. C: 7 days after operation. D: Follow-up at 1 month.

that could fill the dead space caused by its large size and sufficient vascularity to the bone fragments that it may be superior for enduring reconstruction of lower extremity osteomyelitis. Free flaps are suitable for extensive skin defects, accordingly, small to moderate defects of bone or tendons are not excellent candidates for a free flap. In addition, in selected patients, such as children and adolescences, perhaps free tissue transfer is a burden for them, therefore, local flaps should be considered first. The notion of designing local flaps on the medial leg was originally described by Hwang, Amarante and Lin from their anatomic and clinical studies [14-16], but the lower extremity defects are often small and difficult to treat by means of local flaps. Inspired by their ideas, Hong et al reported a reverse flow posterior tibial artery fasciocutaneous flap for the coverage of lower extremity defects [17].

The posterior tibial artery perforator flap is a promising option for the reconstruction of the lower limbs, especially in the coverage of chronic Achilles tendon defects. The posterior tibial artery is generally the largest terminal branch

of the popliteal artery that provides the main source of blood to the foot, and its need for micro vascular anastomosis is hardly inevitable [10]. The flap can be rotated between 90 degrees and 180 degrees of the perforator to cover an adjacent skin defect, it is also able to be proximally or distally based which enables reconstruction of a diverse scope of lower limb defects. It is most suitable for defects on the anteromedial sphere of the lower half of the tibia, and the medial flap can provide adequate tissue support for the ankle and leg region. The advantages of the flaps include time efficiency with minimal complications by preserving the principal arteries of the lower limb while being technically less demanding. Additionally, the recipient site has the most "like-to-like" tissues, improving the aesthetic results, and reducing the morbidity. Above all, it can provide different flap alternatives for reconstruction of the exposed bone and tendons on the lower limbs.

Muscle flaps are popular, and massive clinical series to reconstruct defects caused by chronic lower extremity wounds have been successfully

performed [18, 19]. It has good vascularity which can control the infection in severely contaminated wounds, and expedites bone healing in early phases of repair that provides a suitable environment for osteogenesis, a superior effect on filling complex three-dimensional defects compared to fasciocutaneous flaps. However, the use of muscle flaps for reconstruction of chronic wound-associated defects are aesthetically unflattering and can also be challenging for a secondary operation, such as bone grafting. The major disadvantages of these flaps are the long operative and hospital time, and higher functional donor-site morbidity. In the lower limbs, especially in the pretibial area, ankle, heel area, and the back of the foot, thin and pliable soft-tissue coverage of exposed joints, bones and muscle tendons are required to achieve a satisfactory aesthetic outcome. The posterior tibial artery perforator flap is thin and flexible, thus it is an appropriate candidate for this procedure. The posterior tibial artery perforator flap is a time-saving, aesthetic and safe procedure enabling successful coverage for chronic infection, and it can better tolerate the subsequent secondary surgical procedures. Numerous articles have shown that the successful treatment of chronic osteomyelitis and infectd wounds depends on adequate debridement and eradication of dead spaces, instead, the actual type of flap used for reconstruction has little impact on the final outcome [20-22]. The successful treatment of chronic wounds may depend on aggressive debridement and eradication of dead spaces with an effective flap.

In conclusion, the distal posterior tibial artery perforator flap is a beneficial and reliable technique; it will play an increasingly important role in the plastic and reconstructive surgery field, especially for the treatment of chronic lower extremity wounds.

Conclusions

A simple technique with low postoperative morbidity and relatively satisfactory aesthetic results is ideal for the treatment of chronic lower extremity wounds. It is intended to be considered the first choice for this condition. In addition, apart from reconstruction of massive defects, it is better than other more complex techniques, such as microvascular procedures.

So the posterior tibial perforator flap is a reliable alternative for the treatment of chronic lower extremity wounds.

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Disclosure of conflict of interest

None.

Authors' contribution

Xiaqing Yang and Zhijie Li contributed to the study design, study management, manuscript writing and critical revision of the manuscript; Guangjun Chen contributed to data collection, follow-up visit and data analysis; Huanbei Zeng contributed to data interpretation, figure preparation and primary manuscript drafting; Weili Wang and Yiheng Chen contributed to data interpretation and manuscript revision.

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