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ORIGINAL RESEARCH

Peroneal Artery "Terminal" Perforator Pedicled Flap for Surrounding Soft Tissue Defects: A Retrospective Cohort Study

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Purpose: To introduce a technique to reconstruct soft tissue defects around the space of lateral malleolus by using the peroneal artery "terminal" perforator flap (the lowest perforating branch of the peroneal in the posterior compartment artery of lateral malleolus), and to report its effectiveness.

Methods: From January 2018 to April 2020, 7 patients with soft tissue defects around the space of lateral malleolus were treated with the peroneal artery "terminal" perforator flap. Ultrasound was used to determine the perforating site of the peroneal artery. The lowest perforating branch adjacent to the wound margin was used as the rotation point to design the peroneal artery perforator flap.

Results: One case had venous crisis. However, no urgent operative revision was performed. All of the 7 flaps survived completely. The grafted skins at donor site survived, and primary healing of incision was obtained. The follow-up period was 6 to 17 months with an average of 10.7 months. The flaps exhibited favorable color, texture, and overall appearance. The ability to wear shoes remained unaffected, and ankle mobility was not restricted. Surgeries for thinning the flaps were not necessary. All of the patients were satisfied with the cosmetic and functional result.

Conclusion: The peroneal artery terminal perforator flap is a useful and reliable choice for coverage of soft tissue defects around the space of lateral malleolus in clinical application.

Keywords: ankle, peroneal artery, perforator flap, posterior compartment artery of lateral malleolus

Introduction

Skin and soft tissue defects in the foot and ankle are relatively common in clinical practice. The defects commonly occur as a result of different kinds of injuries that may involve bone, tendon, and neurovascular structures.[1] Defects around the space of lateral malleolus with tendon or bone exposure are still one of the most challenging problems in plastic and reconstructive surgery due to the paucity of reliable local cutaneous or muscle flaps.[2] With the advancement of technology, perforator flaps that do not damage the main vascular trunk have seen widespread clinical application. This includes the posterior tibial artery perforator flap and the peroneal artery perforator flap, among others.[3]

There have been numerous reports on the use of the peroneal artery perforator propeller flap or distal perforator pedicled flap, which has achieved good therapeutic results.[4,5] However, both of these flaps had issues with ineffective overlap, failing to minimize damage to the donor site. Therefore, we propose the concept of the "terminal perforator" of the peroneal artery, defined as the most distal perforating branch arising from the peroneal artery within the posterior compartment of the lateral malleolar region, which may serve as a reliable and viable terminal perforator for perforator flap reconstruction.[6] This perforator is situated adjacent to the wound margin at the ankle, facilitating the rotation of the

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corresponding flap in situ to effectively cover the wound. This technique aims to optimize tissue utilization while minimizing trauma to the donor site. Our experience of 7 cases of soft tissue defects around the space of lateral malleolus repaired with peroneal artery "terminal" perforator flap is reported as follows.

Patients and Methods

This report conformed to the World Medical Association Declaration of Helsinki and subsequent amendments. This report was approved by our institutional ethics committee and informed consent for surgery was obtained from patients. All the performed procedures were part of the routine care and the patients' rights were protected throughout the treatment and the report. From January 2018 to April 2020, 7 cases of soft tissue defects around the space of lateral malleolus repaired with peroneal artery "terminal" perforator flap were retrospectively studied. There are a total of 7 cases in this group, including 5 males and 2 females. The ages range from 9 to 65 years, with an average age of 40.7 years. Among them, two individuals had the comorbidity of diabetes mellitus, while three individuals have hypertension. The exclusion criteria were: 1) fractures of the lateral malleolus and calcaneus; 2) injuries to the posterior tibial artery; 3) injuries to the peroneal artery; and 4) vascular occlusion in the lower extremities. The duration of the illness varied from 5 days to 2 months. General information of the patients is shown in Table 1.

Surgical Technique

Radical debridement was performed first, and then sensitive antibiotics were given. After the bacterial culture of the local wounds had confirmed the absence of infection, a secondary flap surgery was performed for soft tissue reconstruction. The perforator in the anatomical space posterior to the lateral malleolus closest to the wound was detected and marked by Doppler ultrasound before operation. It was set as the rotation point, while the course of the peroneal artery was set as the flap axis. The flap was designed according to the size and shape of the wound, ensuring that the width of the flap was 1cm larger than the wound (Figure 1).

A tourniquet was applied to the thigh without dispersing the blood before the operation. Flap dissection commenced with an incision at the posterior aspect of the flap to reveal the space located posterior to the lateral malleolus. We use a head-mounted microscope to conduct a routine search for branches. Upon confirming that the actual position of the perforator within this anatomical region corresponded with preoperative ultrasound findings and that its diameter was adequate, a complete incision was made along the posterior margin of the flap. Sometimes, several potentially useful perforators were identified during this process, which were temporarily preserved for further evaluation. The surgical procedures were different due to the number of the perforators. If there was only one suitable perforator in the space posterior to the lateral malleolus, the flap outline was re-evaluated and adjusted according to the real location of the perforator and the perforator was set as the rotation point. Dissected the flap in a posterior-to-anterior and proximal-to-distal direction, ensuring careful separation and protection of the sural nerve and small saphenous vein. The pedicle at the base had been adequately freed

Table 1 The General Information of Patients

No.	Age/Sex	Etiology	Comorbidities	Defect Site	Defect Size (cm)	Pedicle Length (cm)	Operative Time (Min)	Follow-Up (Month)	Complications
1	18/male	Traffic accident	None	Left lateral malleolus	5×3.5	2.1	60	6	None
2	9/female	Scalded by hot water	None	Right lateral malleolus	5.5×4	2.8	124	8	None
3 Typical case	48/male	Machine impact	Diabetes mellitus	Right lateral malleolus	6×7	2.3	119	13	None
4	65/male	Traffic accident	Diabetes mellitus, hypertension	Left lateral heel	8×7	2.6	140	17	None
5	49/male	Traffic accident	Hypertension	Right lateral heel	6×4	2.4	129	12	None
6	43/female	Scalded by hot water	None	Left lateral malleolus	6.5×4	2.7	96	10	Venous crisis
7	53/male	Machine impact	Hypertension	Left lateral heel	7.5×7	2.9	135	9	None

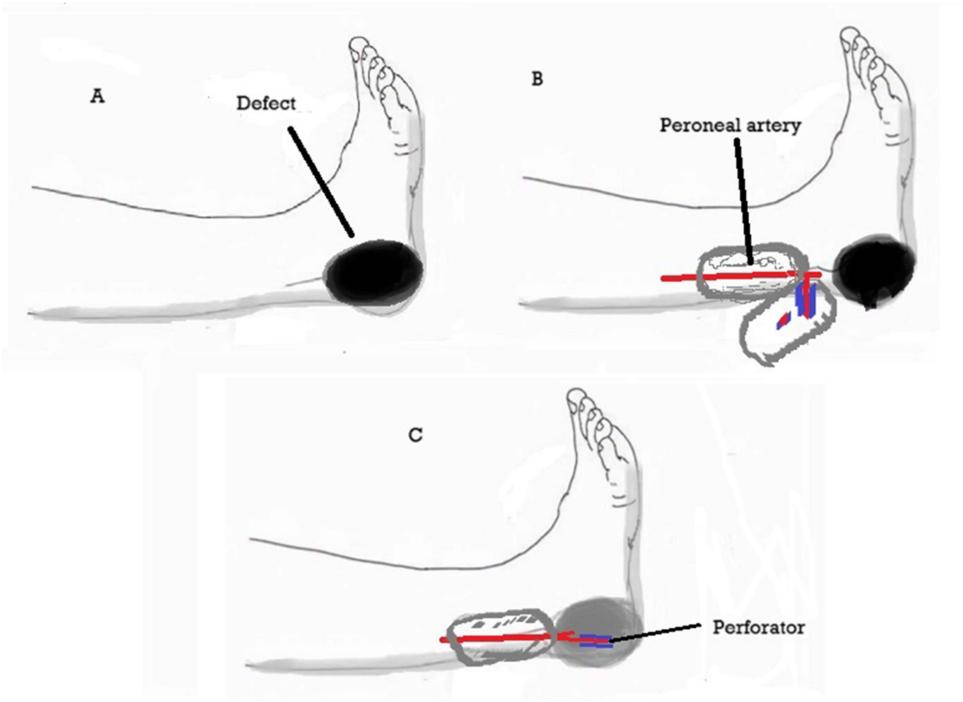

Figure 1 Schematic diagram of the peroneal artery "terminal" perforator flap. (**A**) The defect at the lateral malleolus/heel. (**B**) Arterial perforators dissection. (**C**) Flap rotation and cover.

and the flap was undermined until it was completely islanded. When it was ensured that the blood supply was adequate, the harvested flap could cover the defect. Simultaneously, in the presence of multiple functional perforators within the surgical field, all viable perforators were meticulously reserved and utilized to dissect the flap as previously described. Each peroneal perforator was occluded atraumatically using a vascular clamp. Subsequently, the clamps were removed sequentially from distal to proximal at five-minute intervals to ascertain the useful perforator, which was closest to the wound. The dissection of the perforator provided the freedom of rotation to the pedicle that was used to reach to the defects without any tension on the perforator itself or risk of twisting or kinking. The insetting of the flap and wound closure were performed using a simple interrupted suture technique with 3–0 or 4–0 sutures, while some tube drains were placed in situ. The donor site was closed with either direct sutures or a split-thickness skin graft. Routine postoperative nursing care for flap transplantation was implemented. The first dressing change for the skin graft site was carried out 7 days postoperatively. It was necessary to remove some stitches when insufficient blood supply occurred to relieve tension and promote better circulation to the affected area. Plast splint was used in postoperative period to preserve flaps till 4 weeks.

Results

Operative time ranged from 60 to 140 minutes. After debridement, the wound size ranged from 5cm × 3.5cm to 8cm × 7cm. The pedicle length ranged from 2.1cm to 2.9cm. The donor site was closed primarily in two patients, and covered with split thickness skin graft from the proximal leg of the same side in five patients.

In this cohort of seven cases, all flaps demonstrated successful survival. One case encountered a venous crisis on the second day after operation. Bleeding points were identified beneath the flap during the dressing change, resulting in a hematoma that compressed the pedicle. Following hematoma evacuation and appropriate drainage, the venous crisis was resolved. Donor sites healed primarily in all patients. Secondary revision surgery was not required. The follow-up period was 6 to 17 months with an average of 10.7 months. The flaps exhibited favorable color, texture, and overall appearance. The ability to wear shoes remained unaffected, and ankle mobility was not restricted. All of the patients were satisfied with the cosmetic and functional results.

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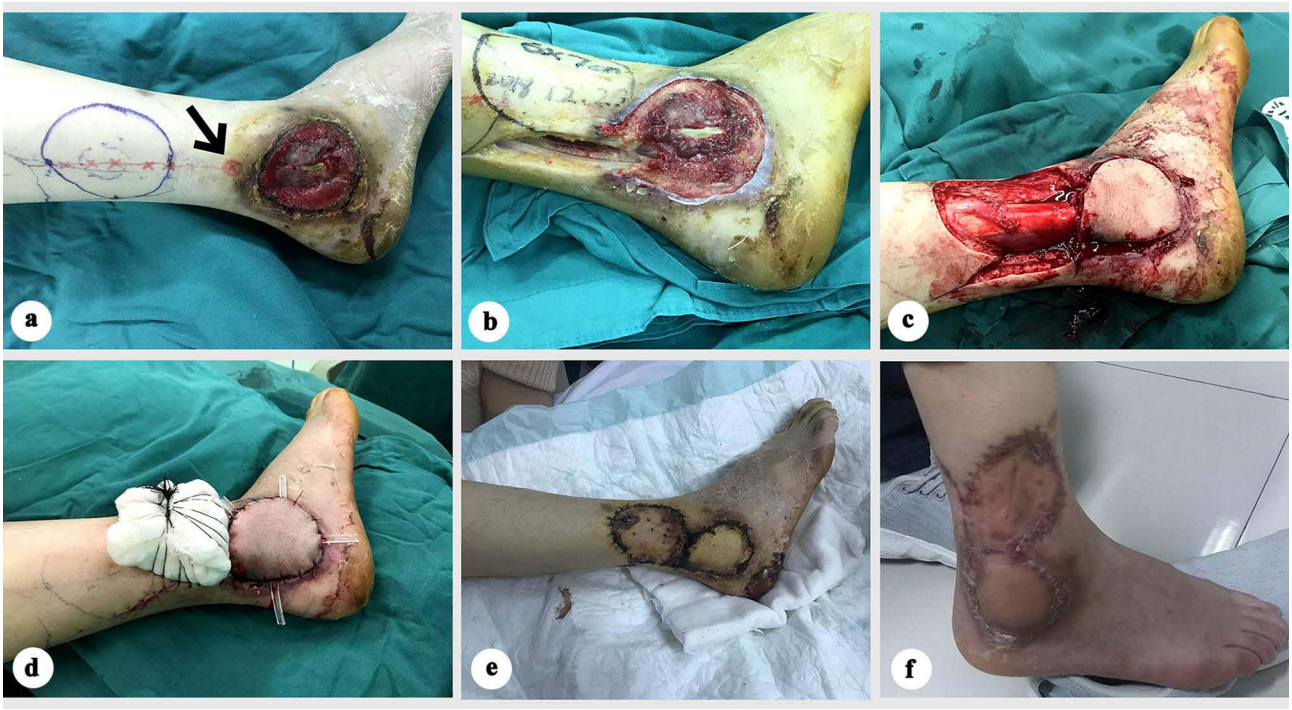

Figure 2 Appearance of the typical case. (**a**) 48-year-old male patient had a 6cm × 7cm soft tissue defect at the right lateral malleolus, and marked the perforator of peroneal artery. (**b**) The flap and perforator were marked and dissected. (**c**). The flap was rotated to cover the defect. (**d**) Drainage tubes and split-thickness skin graft with pressure dressing were administered. (**e**) 2 weeks postoperatively. (**f**) 3 months postoperatively.

Typical Case

A 48-year-old male patient with the comorbidities of diabetes mellitus had soft tissue defect at the right lateral malleolus, due to the machine impact injury. He received an emergency debridement surgery 4h after admitted to the hospital. The size of the defect was 7cm × 6cm. Then, the patient received a secondary operation with the technique of the peroneal artery "terminal" perforator flap described above. Donor site was covered with split thickness skin graft. The flap completely survived and postoperative period was uneventful. Patient was ambulated 4 weeks after the operation (Figure 2).

Discussion

The foot and ankle play a crucial role in weight-bearing, walking, and shock absorption, significantly impacting human activities and overall quality of life. With the widespread use of cars and acceleration of life pace, patients suffering from foot and ankle soft tissue defects caused by high energy injuries increased in recent years due to the lack of the paucity of reliable muscle. If left untreated, it may lead to serious infections, osteonecrosis, or even necessitate amputation.[7] For soft tissue defects around the space of lateral malleolus without vascular obstruction, flap repair is an important technical approach to gain good functions. Therefore, the surgeon should have enough knowledge of anatomy and sufficient techniques of flaps to effectively support limb salvage treatment for the patient.

To date, the anterolateral thigh flap and sural neurocutaneous flap were still the most commonly utilized options for addressing defects around the ankle.[8] However, both techniques necessitated additional surgical procedures for flap thinning, which was not aligned with patient expectations. Based on it, many perforator flaps were reported to avoid this problem.[9–11] As the technology develops, many surgeons of microsurgery around the world had consensus for the clinical application of perforator flaps: (1) the principle of repairing the main site with the secondary site; (2) the principle of high-quality flap survival; (3) pay attention to the principle of functional and morphological reconstruction of the recipient area; (4) the principle of minimizing the appearance and function damage of the flap donor site.[12] So, the peroneal artery perforator flap used for the defect around the space of lateral malleolus impressed the experts greatly.

The perforating branches of the peroneal artery are categorized into three distinct groups: the mid-intermuscular septal perforator, situated approximately 10 cm above the lateral malleolus; the distal intermuscular septal perforator,

located about 5 cm above the lateral malleolus; and the retro-malleolar perforator, found around 1 cm superior to the lateral malleolus. Throughout its course, the peroneal artery gives rise to between 3 and 8 perforating branches, each measuring from 2 cm to 7 cm in length. The proximal perforators are positioned deeper within tissue layers and run obliquely towards their distal surfaces, resulting in relatively longer vascular pedicles. In contrast, distal perforators are more superficial and oriented vertically toward the surface with shorter pedicles. Each arterial branch is accompanied by two corresponding venous structures; typically, these arteries have an outer diameter of approximately 1 mm, while their accompanying veins tend to be slightly larger. Upon emerging from either intermuscular septum or muscle tissue, these vessels bifurcate on the deep fascial layer into transverse as well as ascending/descending branches that subsequently anastomose with one another. Clinically, utilizing peroneal artery perforator-based propeller flaps for reconstructing foot and ankle defects had become a widely adopted practice with favorable outcomes.[13,14]

Someone else found that the harvested area of peroneal artery perforator propeller flaps significantly exceeds that of recipient sites.[15] To minimize donor site morbidity while maximizing harvested tissue utilization and reducing "propeller" waste associated with these flaps, we proposed introducing a concept termed "terminal perforator". Notably, rich in this region, specifically within retro-malleolar space about 1 cm above the lateral malleolus, the terminal perforators could effectively be utilized for wound repair at foot and ankle sites. By lowering flap pivot points by just 1 cm during procedures reduced overlap lengths correspondingly by up to 1 cm; additionally shortening donor site incisions by approximately 2 cm while decreasing required flap lengths similarly by this measure enhanced surgical efficiency overall. Terminal perfusion through these specific arteries effectively eliminated unnecessary overlaps, allowing the flap to rotate directly into position to cover the wound completely. This approach ensured full coverage without compromising blood supply integrity due to the anatomical proximity of the vessels to the wound edges.

The peroneal artery distal perforator flap have been applied in many cases of external ankle defects.[16,17] But the meanings of distal and terminal was different. Several perforating branches are typically observed in this region. The peroneal artery terminal perforator flap refers to a perforator flap based on the distal-most perforating branches of the peroneal artery. The peroneal artery distal perforator flap refers to a perforator flap based on the most suitable perforating branches of the peroneal artery. The meanings of distal and terminal should not be considered equivalent.

In our series of seven cases utilizing the peroneal artery "terminal" perforator flap for the repair of foot and ankle wounds, the surgical procedures were executed smoothly. Intraoperatively, the perforator vessels exhibited consistency, with vascular pedicles measuring between 2.1 and 2.9 cm in length, which facilitated high rotational mobility to accommodate torsional stress. All flaps achieved successful survival, demonstrating excellent color, texture, and aesthetic quality without necessitating reshaping, thereby resulting in favorable clinical outcomes.

When compared with the previous study conducted by Altinkaya,[18] there was no statistically significant difference in the mean skin flap size between our cohort (34 cm^2) and theirs (31 cm^2). Similarly, the complication rate in our group (1/7) did not differ significantly from that reported in their study. The duration of our surgical procedure (115 minutes) was marginally shorter compared to that of their study (149 minutes). Furthermore, the length of the terminal pedicle was 2.54 cm, which was comparable to that of the distal pedicle (2.35 cm) by Peng.[6]

The peroneal artery "terminal" perforator flap has the following advantages: (1) The perforator vessels have a consistent anatomical structure, making flap harvesting straightforward, safe, and reliable; (2) Located close to the wound edge, the retromalleolar perforators reduce unnecessary overlap, allowing for a shorter flap length and more reliable blood supply; (3) This flap technique optimizing tissue usage and minimizing donor site damage and do not injury the muscles or disrupt the sural nerve, preserving the donor site's original function; (4) Using a perforator-based pedicle eliminates the need to sever the peroneal artery, maintaining blood supply to the distal limb; (5) With a moderate thickness, the flap does not require secondary thinning.

Although the peroneal artery "terminal" perforator flap is practical and convenient, it is not a universal flap. It is limited to the wounds around the space of lateral malleolus, with relatively narrow indications. Perhaps, the perforator may have already been damaged before operation. Also, it requires a high level of microsurgical skills. Furthermore, Inflammatory responses and fibrous hyperplasia at the wound edges can adversely affect the perforator. Additionally, the relatively small sample size may potentially introduce bias into the study results. Finally, it is not a sensory flap and may have a poorer effect on the recovery of protective sensation.

In conclusion, the peroneal artery terminal perforator flap is a useful and reliable choice for coverage of soft tissue defects around the space of lateral malleolus in clinical application.

Disclosure

Yiming Lu and Peng Jin contribute equally to this work and share co-first authorship. The authors report no conflicts of interest in this work.

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