

# Fasciocutaneous flap with perforating branches of peroneal artery repairing soft tissue loss in anterior and middle parts of children's feet

## A STROBE-compliant article

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### Abstract

Repairing soft tissue loss in feet's anterior and middle parts has become a problem, especially for children. We observed the feasibility and clinical effects of superficial peroneal fasciocutaneous flap pedicled with terminal perforating branches of peroneal artery for repairing children's feet.

Between January 2015 and December 2016, soft tissue loss in anterior and middle regions of feet were repaired using superficial peroneal fasciocutaneous flap pedicled with terminal perforating branches of peroneal artery in 8 children with a median age of 6.5 [4–9, interquartile range (IQR)=3] years. The skin of lower leg was intact, and the soft tissue loss area was located in the anterior and middle regions of feet with a size of 5 cm × 4 cm to 11 cm × 7 cm combined with the exposure of tendons and joints in all the 8 children. On the basis of the conditions above, there were no indications of free skin grafting. Foot wounds were repaired all with the superficial peroneal fasciocutaneous flap pedicled with terminal perforating branches of peroneal artery (6 cm × 5 cm to 12 cm × 8 cm), and then the donor area was sutured to narrow the donor area followed by intermediate split thickness skin graft. The perforating branch trunk of peroneal artery was used as a rotation point (4 cm above the lateral malleolus) in 5 children and descending branch of perforating branch of peroneal artery as a rotation point (2 cm under the lateral malleolus) in 3 children.

All flaps survived with primary healing in the 8 children. Postoperative median 7.5-month (3–12, IQR=4.5) follow-up indicated that flap color and texture were fine, the appearances of donor and recipient areas were satisfactory, wearing shoes was not affected, and walking function and foot blood circulation were normal.

For intractable soft tissue loss in the anterior and middle regions of children's feet, superficial peroneal fasciocutaneous flap pedicled with terminal perforating branches of peroneal artery can improve recipient area appearance and walking function because it has the characteristics of reliable blood supply and convenient rotation. It is worth using this method widely in clinics.

**Abbreviation:** VSD = vacuum sealing drainage.

**Keywords:** anterior and middle regions of children's foot, perforating peroneal fasciocutaneous flap, soft tissue loss

## 1. Introduction

Skin grafting survival is difficult for soft tissue loss in anterior and middle regions of children's feet with the exposure of tendons and joints due to children's poor self-protection awareness, and tender skin as well as thin soft tissue in their feet. Repairing soft tissue loss in anterior and middle regions of feet has become a

difficult problem because the available flaps are few for this area, which is located near distal end.<sup>[1–4]</sup> In 1988, Masquelet and Romana [5] first reported external supramalleolar flap, which were mainly used in reconstructive surgery of ankle and heel.<sup>[5–7]</sup> In repairing soft tissue loss in anterior and middle regions of children's feet, the superficial peroneal fasciocutaneous flap pedicled with terminal perforating branches of peroneal artery is not widely used. The anatomical position of external supra-malleolar artery is relatively constant with thick diameter, and its ascending branches anastomose with the vascular network around superficial peroneal nerve and its descending branches anastomose with the vascular network around ankle, so it can provide blood for anterolateral area of one-third lower leg.<sup>[8,9]</sup> On the basis of these characteristics of the external supra-malleolar artery, we used superficial peroneal fasciocutaneous flap pedicled with terminal perforating branches of peroneal artery or its descending branch to repair soft tissue loss in anterior and middle regions of feet in 8 children between January 2015 and December 2016, in order to observe its therapeutic effects. Especially for the flap pedicled with descending branch of terminal perforating branches of peroneal artery, the flap rotation point moved down to 2 cm below the external malleolus, increasing flap coverage, which might extend to metatarsophalangeal joint level.

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**Table 1****Injured position, flap size, follow-up duration, and complications in 8 children.**

No.	Age, y	Sex	Injured causes	Injured position	Flap size, cm <sup>2</sup>	Follow-up, mo	Infection	Complications
1	8	Boy	Wheel crush injury	Anterior and middle regions	12 × 8	10	Yes	No
2	4	Boy	Pulley chain injury	Middle region	8 × 7	3	No	No
3	9	Boy	Wheel crush injury	Anterior region	8 × 6	6	No	No
4	9	Girl	Wheel crush injury	Middle region	9 × 6	9	No	No
5	6	Boy	Pulley chain injury	Middle region	6 × 5	12	No	No
6	7	Girl	Bruised injury	Middle region	7.5 × 4.5	3	No	No
7	6	Girl	Wheel crush injury	Anterior region	6 × 6	7	No	No
8	5	Boy	Wheel crush injury	Anterior and middle regions	9.5 × 7.5	5	Yes	No

## 2. Subjects and methods

All study methods were approved by the Ethics Committee of Shengjing Hospital of China Medical University. All patients or their family members gave informed consent to participate in this study.

### 2.1. Subjects

Between January 2015 and December 2016, repairing soft tissue loss of children's feet was performed on 8 children in the Department of Hand and Foot Microsurgery, Shengjing Hospital of China Medical University. Of the 8 children, 5 were boys and 3 girls, with a median age of 6.5 [4–9, interquartile range (IQR) = 3] years. The wound surface was located in the anterior region of feet in 3 children and in the middle region of feet in 5 children. The injured causes included pulley chain injury in 5 children, wheel crush injury in 2 children, and bruised injury by weight in 1 child. The skin of lower leg was intact and the soft tissue loss area in the anterior and middle regions of feet was 5 cm × 4 cm to 11 cm × 7 cm combined with the exposure of tendons and joints in all the 8 children. Of the 8 children, 2 had wound infection. On the basis of the conditions above, there were no the indications of free skin grafting.

### 2.2. Surgical procedures

After general anesthesia, children were in supine position. The position of the perforating peroneal artery, which is usually located 4 cm above the lateral malleolus, was fixed using Doppler ultrasound before operation. According to the areas and shapes of wounds, island flaps were designed with the anterolateral intermuscular septum of lower leg as an axial line and with the perforating branch trunk of peroneal artery or its descending branch as pedicels. The flaps pedicled with perforating branch trunk of peroneal artery were used to repair large wound near the ankle, while the flaps pedicled with its descending branch were used to repair the wound in anterior region of feet with intact soft tissue around the ankle. The proximal flap was cut to ensure that the axial line of the flap was in the median line of anterolateral intermuscular septum. After the anterior and posterior edges of flaps were cut, separation was performed to the anterolateral intermuscular septum under sarcolemma. The superficial peroneal nerve and accompanying vessels were isolated by reflecting the digitorum longus muscle as well as long and short peroneal muscle. The superficial peroneal nerve was cut off at the proximal end followed by ligation and division of its accompanying vessels. Intermuscular septa were disconnected under the superficial peroneal nerve and along the interosseous membrane from

proximal to distal, ensuring that the intermuscular septa were located near the median between flap and pedicle. Separation under dermis was performed to cut open the deep fascia followed by sharp dissociation close to the fibular periosteum and interosseous membrane, with exposure of the perforating peroneal artery. For the flaps pedicled with descending branch of perforating branch trunk of peroneal artery, after ligation and division at the bifurcation of perforating branch trunk, sharp free extended to 2 cm under the external malleolus. On the basis of specific conditions, the pedicle might appropriately extend to distal end of rotation point in order to reduce the skin graft area of donor area. After tourniquet released, if blood circulation was satisfactory, the flap was transferred to repair the wound in the shortest distance. The flap donor area was sutured to narrow the wound area followed by intermediate split thickness skin graft.

## 3. Results

All flaps survived with primary healing in all the 8 children postoperatively (Table 1). In 2 children, mild swelling in distal flap occurred and gradually disappeared 3 days later. Skin grafts for donor areas also survived in all children. Postoperative median 7.5 months (3–12, IQR = 4.5) follow-up indicated that flap color and texture were fine, the appearances of donor and recipient areas were satisfactory, wearing shoes was not affected, and walking function and foot blood circulation were normal. Neurological symptoms on the amputation stump of superficial peroneal nerve were not found in the 8 children.

### 3.1. Real cases

**3.1.1. Case 1.** An 8-year-old boy had left foot skin degloving injury caused by wheel crush injury with multiple metatarsal and phalangeal fractures as well as multiple metatarsophalangeal joint dislocation. Seven days later, necrosis occurred in the first 2 toes, dorsi pedis skin and interosseous muscle, so debridement and vacuum sealing drainage (VSD) were performed. Seven days later, VSD was removed and the exposure of tendons and joints was seen with a wound surface of 11 cm × 7 cm in the anterior and middle regions of the foot (Fig. 1A). A 12 cm × 8 cm superficial peroneal fasciocutaneous flap pedicled with descending branch of perforating branch of peroneal artery was designed and rotated 180° to repair the wound surface. The donor area was sutured to reduce the wound surface followed by free skin graft. The flaps in both donor and recipient areas survived. Postoperative 10-month follow-up indicated that flap color and texture were fine, and foot as well as ankle functions were good (Fig. 1B–F).



**Figure 1.** Left foot skin degloving injury in the anterior and middle regions of the foot in case one. (A) Soft tissue loss in the anterior and middle regions of the foot with the exposure of metatarsal bones; (B) Designing the flap; (C) Terminal peroneal artery; (D) Cutting the flap and rotating it to cover the wound with good blood supply; (E, F) Postoperative 10-month follow-up indicates that flap color and texture are fine, and foot as well as ankle functions are good.

**3.1.2. Case 2.** A 4-year-old boy had soft tissue loss of  $7\text{ cm} \times 6\text{ cm}$  in the middle region of the right foot caused by pulley chain injury with the exposure of bone and tendon as well as foot arch collapse. After debridement as well as reduction and fixation of joint dislocation, an  $8\text{ cm} \times 7\text{ cm}$  superficial peroneal fasciocutaneous flap pedicled with perforating branch trunk of peroneal artery was designed and rotated with the perforating branch trunk as a rotation point to repair the wound surface. The donor area was sutured to reduce the wound surface followed by free skin graft. The flaps in both donor and recipient areas survived. Postoperative 3-month follow-up indicated that flap color and texture were fine, and foot as well as ankle functions were good (Fig. 2).

## 4. Discussion

### 4.1. Anatomic basis and blood supply of superficial peroneal fasciocutaneous flap pedicled with terminal perforating branches of peroneal artery

An advantage of this flap is the low rotation point from 1 to 3 cm above the external malleolus to 4 to 6 cm under the external

malleolus, which may reduce flap pedicle length. Compared with the lengths of traditional flap pedicles (6–12 cm), the lengths of flap pedicles (3–7 cm) in this study were shorter due to the low rotation point, increasing coverage area, and decreasing the tension of flap pedicle with a high survival rate of flaps. The second advantage is double blood supply, including the stable and reliable perforating branch as well as chain-like blood supply network, which ensures the blood supply to flaps and reduces the incidence of flap necrosis. Third, because of the low rotation point, the pedicles become short, ensuring that the donor area is within the anterolateral area of two-third lower leg. This is conducive to flap survival and avoids excessive damage to the donor area.<sup>[3,7,10–12]</sup>

The flap repairing soft tissue loss has high successful rate because it is from distal end of the lower leg and is located above external malleolus, so skin is thin and blood supply is abundant. More importantly, the flap does not damage main vessel and does not affect blood supply to the feet. The flap may repair the wound surfaces in one-third lower leg, ankle, dorsi pedis, and heel pad. In this study, the rotation point moved to under the external malleolus, covering the wound surface in feet's anterior part in



**Figure 2.** Soft tissue loss in the middle region of the right foot in case 2. (A) Exposure of bone and tendon; (B) Intraoperative appearance; (C, D) Postoperative 3-month follow-up indicates that flap color and texture are fine, and foot as well as ankle functions are good.

some children. This resolves the difficult problem of repairing soft tissue loss in the feet's anterior part.

In fact, this flap is a neurovascular fasciocutaneous flap because its blood supply is from the chain-like anastomosis between external supramalleolar perforating branch of peroneal artery and nutrient vessels of superficial peroneal nerve, as well as fascial vascular network. The perforating branch of peroneal artery goes out of the interosseous membrane at 5 cm above external malleolus, and then is divided into ascending and descending branches. The ascending branch forms anastomoses with both superficial peroneal artery and intermuscular septum branch of the anterior tibial artery. The descending branch forms anastomoses with external supramalleolar branch of anterior tibial artery, tarsal sinus artery, lateral calcaneal artery, lateral tarsal artery, and lateral plantar artery branch.<sup>[10–12]</sup> There are 2 kinds of blood supply due to different designs for pedicles. A kind of blood supply in the flap using terminal perforating branch of peroneal artery as a rotation point (4 cm above the external malleolus) is as follows: external supramalleolar perforating branch trunk of peroneal artery→ascending branch→intermuscular septum branch of the anterior tibial artery→superficial peroneal artery. Another blood supply in the flap using descending branch of terminal perforating branch of peroneal artery as a rotation point (2 cm under the external malleolus) is as follows: vascular network in lateral ankle (external supramalleolar branch of anterior tibial artery, tarsal sinus artery, lateral tarsal artery, posterior peroneal artery, and lateral plantar artery)→descending branch of external supramalleolar perforat-

ing branch→ascending branch→intermuscular septum branch of the anterior tibial artery→superficial peroneal artery. Neurovascular plexus plays a role in reducing blood impedance and connecting the ascending branch of external supramalleolar artery with the superficial peroneal artery, which provides blood supply for donor area in anterolateral side of lower leg. In the 2 kinds of blood supply, backflow all goes through venous networks near nerve and under skin into the vein accompanying with external supramalleolar perforating branch. The area from the middle level of lower leg to the level under ankle is large and has abundant blood supply, so large flaps may be obtained here.

Indications for using the perforating branch trunk or descending branch of perforating branch were as follows: According to the position and size of the wound, we choose different rotation points. The wound is located in the anterior part of children's feet, namely the distal end of metatarsals, we should choose descending branch of perforating branch as a rotation point. The wound is located in the middle part of children's feet, we should choose perforating branch trunk as a rotation point.

#### **4.2. Advantages of superficial peroneal fasciocutaneous flap pedicled with terminal perforating branches of peroneal artery for repairing soft tissue loss in the anterior and middle regions of children's feet**

Sural neurovascular flap and free flap are usually used for foot soft tissue loss.<sup>[13–17]</sup> The rotation point of the sural neuro-

vascular flap is too high to repair the loss in the feet's anterior part. Free flap is widely used in adults, but in children, thin vessels and poor medical compliance readily lead to vascular crisis and skin flap necrosis. Therefore, the free flaps should be cautiously used in children's foot soft tissue loss.

In repairing soft tissue loss in anterior and middle parts of children's feet, the advantages of superficial peroneal fasciocutaneous flap pedicled with terminal perforating branches of the peroneal artery are as follows. First, the rotation point declined. Compared with sural neurovascular flap, the rotation point of this flap is more close to wound, increasing coverage area and decreasing the tension of flap pedicle with high survival rate of flaps. According to the conditions of wound, the rotation point may be moved under the external malleolus to repair soft tissue loss in the feet's anterior part. Second, the damage to donor area is relatively small because peroneal artery trunk does not require separation. Third, the flap color and texture are similar to that of the skin in the feet's anterior and middle parts. Fourth, selection of flap shape design may be relatively random because the donor area with double blood supply is large. The flap perforating branch is easily found preoperatively because its position is relatively constant. Fifth, surgical duration shortens because the flap is easily harvested. Sixth, for the less than 5 cm width flaps, the donor area may be directly sutured or undergoes small area skin grafting because subcutaneous muscles are abundant and skin is soft in the donor site.<sup>[18]</sup> Seventh, the flaps may be neatly designed because the peroneal artery and intermuscular septum long descending branch are in segmental distribution with extensive collateral anastomoses. Eighth, the repaired appearance is good and flap blood supply is not affected because the flap pedicle has axial pattern blood vessel and the pedicle is longer than the fascial pedicle.

#### 4.3. Main point noticed on operation

Although this surgical strategy is simple and convenient with small injury, a great deal of attention should be paid to the following several points. First, before operation, you must understand the distribution of perforating peroneal artery in the donor area and determine the position of the donor area using Doppler ultrasound in order to reduce operation duration and risk.<sup>[19]</sup> Second, in flap design, you should select the reliable perforating branch closest to the wound surface as a pedicle to reduce the damage to the donor area. In 2 children of this study, we found a reliable perforating branch at 1 cm under the distal end of perforating branch of preoperative positioning during operation, so the flap rotation point was moved down 1 cm and wound margin was moved down 2 cm, greatly relieving the damage to the donor site. Third, different from the traditional flaps, the axial line of this flap is designed along the superficial peroneal nerve, this flap pedicle carries the perforating peroneal artery, and the flap width may reach 13 cm and distal end of this flap may extend to upper one-third lower leg because there are double blood supply and abundant communicating branches within this area.<sup>[10-12,18]</sup> Fourth, the retention of soft tissue around the perforating branch is very important. Excessive soft tissue may affect pedicle rotation or compression; if soft tissue is too small, the perforating branch easily has stretch injury and spasm. Therefore, we propose that all tenacious fascia fiber bundle be removed and only a little of loose connective tissue be retained. Fifth, the perforating branch is separated to 2 to 3 cm below the deep fascia in order to avoid perforating branch compression when the flap rotates 180°. Sixth, preoperative

Doppler detection of position of perforating branch still has certain uncertainty (9% in this study), so you should pay attention to other branches during operation, flap design may be timely adjusted if more reliable perforating branch is found.

#### 4.4. Limitation

This method may affect the anterolateral muscles of the lower leg. If the donor area is too large to be directly sutured, skin graft is needed. In addition, we will collect more cases to sum up experience in the future because the sample in this study was relatively small.

In summary, different from adults, for children, operation time should be short as much as possible, and surgical procedures should be simple due to their poor tolerance. It is a feasible method to repair soft tissue loss in the anterior and middle parts of children's feet using superficial peroneal fasciocutaneous flap pedicled with terminal perforating branches of peroneal artery. It is worth the clinical promotion and application.

#### Author contributions

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**Investigation:** Wen-liang Cao.

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