An Anatomical Study of the Superficial Peroneal Nerve Accessory Artery and Its Perforators, and Clinical Application of Superficial Peroneal Nerve Accessory Artery Perforator Flaps

Running Head: Superficial Peroneal Nerve Accessory Artery Perforator Flaps

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ABSTRACT

In the 1990s, skin island flaps supplied by the vascular axis of sensitive superficial nerves, like the sural and saphenous nerves, were introduced. Flaps supplied by the superficial peroneal nerve accessory artery (SPNAA), however, are still not commonly used. The aim of this study is to understand the anatomical structure of the SPNAA and its perforators in the anterior intermuscular septum, and to utilize SPNAA perforator flaps in the clinic.

We dissected sixteen cadavers and assessed the location and number of the SPNAA, its perforators, and the septocutaneous perforators originating from the anterior tibial artery. A SPNAA perforator flap was applied to twelve patients, the free flap was applied to eleven patients, and the pedicled flap was applied to one patient.

SPNAA varied from 7 to 16 cm in length with an average of 4.5 perforators to supply lateral aspect. An average of 3.13 septocutaneous perforators originated from the anterior tibial artery. The mean size of the SPNAA perforator flaps was 65.5 cm^2. The

complete follow-up period was 3-20 months. Although one flap was lost as a result of arterial thrombosis, the procedure was successful in the remaining eleven patients. In addition, reduced flap thickness made them more aesthetically appealing.

SPNAA perforator flaps could be an excellent alternative to perforator flaps that use the lower leg as a donor site.

Key Words: Neurocutaneous flap; Superficial peroneal nerve accessory artery; Perforator flap; Anterior intermuscular septum.

INTRODUCTION

A variety of flaps using the lower leg as a donor site have been developed and applied for reconstructive surgery. In the 1960s and 70s, local muscle and musculocutaneous flaps were introduced and widely applied, however morbidity of the donor site and failure rates were relatively high.[1] In the early 1980s, the fasciocutaneous flap was introduced by Ponten, and soft tissue defects on the lower legs were reconstructed without damaging the muscle.[2]

In the 1990s, Nakajima et al. and Masquelet et al. showed that vessels

accompanying the sensitive superficial nerves enable skin flaps to survive introducing the novel concept of neurocutaneous flaps.[3,4] Subsequently, flaps that use the artery accompanying the sural or saphenous nerves were designed and applied in clinics.[5,6] Studies on flaps using the artery accompanying the superficial peroneal nerve are still rare, however.[7] To utilize the neurocutaneous flap supplied by the artery accompanying the superficial peroneal nerve, we began by studying the superficial peroneal nerve accessory arteries of dissected cadavers. We showed that perforator flaps originating from the superficial peroneal nerve accessory artery were accessible for application in the clinic.

PATIENTS AND METHODS

Anatomical Study

Sixteen cadavers were dissected, and the study was performed using the larger and best preserved one lower leg. Ten cadavers were male, six were female, and all sixteen appeared older than 60 years.

Surgical magnifiers were worn, the cadaver was placed in a supine position with the knee slightly flexed, and a line representing the anterior intermuscular septum

was drawn from the anterior fibular head to the anterior lateral malleolus. Dissection was performed at the subfascial level from an area 2 cm in front of this line to the anterior intermuscular septum. Using the same method, dissection was performed to the anterior intermuscular septum from an area 2 cm to the posterior side of this line. The musculocutaneous perforator was carefully dissected. The superficial peroneal nerve, superficial peroneal nerve accessory artery, superior lateral peroneal artery, inferior lateral peroneal artery, septocutaneous perforator, musculocutaneous perforator originating from the superficial peroneal nerve accessory artery, and septocutaneous perforator originating from the anterior tibial artery, were all assessed (Fig. 1). All vessels with a diameter smaller than 0.4 mm were excluded. Musculocutaneous perforators originating from the anterior tibial artery were also excluded. In each cadaver, the distance from the fibular head to the lateral malleolus was measured, the origin and the disappearing point of each artery was assessed, location was shown using the fibular head as a standard, and the number was recorded. The largest diameter of the superficial peroneal nerve accessory artery was also measured.

Clinical Study

From April 2005 to January 2007, twelve patients (eight males and four females) underwent the procedure to repair trauma (nine patients), a Marjolin's ulcer (one patient), a diabetic foot ulcer (one patient) and a skin ulcer due to gout tophi (one patient). The mean age of patients included in this study was 46.3 years. The free flap was applied in eleven cases and the pedicled flap was applied in one case.

Surgical Technique

With the patients under general anesthesia, necrotic tissue in the recipient area was completely debrided, and the required flap size was measured. For the free flaps, recipient vessels were prepared for anastomosis. In the supine position, the knee was slightly flexed, and a line was drawn from the anterior fibular head to the anterior lateral malleolus. Using this line, the septocutaneous perforator was sought from the proximal one-sixth point to the half point with a hand held Doppler. The dissection was initiated at the subfascial level beginning at the anterior side, in the shape of a fasciocutaneous flap, and continuing to the septocutaneous perforator. The dissection was performed in the same way on the posterior side. When the dissection had reached the septocutaneous perforator, the dissection was performed deeply along the anterior intermuscular septum. It was confirmed that the septocutaneous perforator is a branch

of the superficial peroneal nerve accessory artery. While harvesting the flap, the dissection was performed more proximally and the pedicle was dissected near the origin of the superficial peroneal nerve accessory artery in order to lengthen the pedicle or the arc of rotation. Dissection was performed cautiously so as not to injure the superficial peroneal nerve.

The length of the pedicle ranged from 4 to 7 cm in our patients, with a mean of 5 cm. The harvested flap was transferred to the recipient site, the vessels anastomosed, and the flap sutured without tension. Primary closure was possible in two of the donor sites where the width of the harvested flap was 4 cm. In ten cases, a skin graft was required.

RESULTS

Anatomical Study

The distance from the fibular head to the lateral malleolus ranged from 29 to 37 cm, with a mean of 32.38 cm. In fifteen cases, the superior lateral peroneal artery originated from the anterior tibial artery and formed the superficial peroneal nerve accessory artery. In remaining one case, the superior lateral peroneal artery and the superficial

peroneal nerve accessory artery were absent. The origin of the superior lateral peroneal artery was 4 to 8 cm (average 5.5 cm) away from the fibular head.

The superficial peroneal nerve accessory artery was 7 to 16 cm in length (average 12.33 cm), originating from the superior lateral peroneal artery and gradually disappearing between 15 and 22 cm (average 17.06 cm) from the fibular head. In other words, the superficial peroneal nerve accessory artery originated from the proximal 1/6 of the lower leg and gradually disappeared in the proximal half.

The number of perforators in superficial peroneal nerve accessory arteries examined ranged from zero to eight (average 4.50, total 72 in 16 cadavers). Of these, the number of septocutaneous perforators ranged from zero to six (average 3.19, total 51 in 16 cadavers), and the number of musculocutaneous perforators ranged from zero to three (average 1.31, total 21 in 16 cadavers) (Table 1). As shown in Fig. 2, the perforators were evenly distributed in the same location as the superficial peroneal nerve accessory artery. The largest diameter of the superficial peroneal nerve accessory artery was between 0.6 and 1.2 mm (average 0.85 mm).

In one case, the inferior lateral peroneal artery originated from the anterior tibial artery 18 cm from the fibular head and formed the superficial peroneal nerve accessory artery. This was absent in the other fifteen cadavers.

The number of septocutaneous perforators originating from the anterior tibial arteries examined ranged between one and six (average 3.13, total 50 in 16 cadavers). As shown in Fig. 3, these perforators were abundantly distributed in the distal half, where the superficial peroneal nerve accessory artery had disappeared. Fig. 4 summarizes the results described above. All septocutaneous perforators had one artery and one or two venae comitantes.

Clinical Study

The size of the flap ranged from 3.5 x 6 cm to 9 x 12 cm (mean 65.5 cm^2). The complete follow-up period ranged from three to 20 months (mean 7.6 months). By this time, thrombosis had developed in one case (patient 5), and the flap was completely lost. This defect was re-covered using a pedicled groin flap. The procedure proved successful in the remaining eleven cases, however, with no complications observed at the donor site. The flap was very thin, comparable in thickness to the recipient site (i.e. foot, ankle, pretibia, knee or hand), and thus, aesthetically appealing. One limitation was hair growth on the flap. Patient data are summarized in Table 2. Two representative cases are described in detail below.

Case Reports

Case 1 (patient 6)

A 50-year-old female was admitted with a soft tissue defect on the knee that was the result of trauma. Complete debridement was performed on the necrotic tissues in the knee. A superficial peroneal nerve accessory artery perforator flap (6.5 x 13.5 cm) was harvested from the right lower leg. The pedicles of the flap were anastomosed to the branch of anterior tibial artery and venae comitantes, and a split thickness skin graft was performed on the donor site. The flap and the donor site healed well with no major complications. Six months after surgery, the flap and the recipient site were well matched (Fig. 5).

Case 2 (patient 8)

A 36-year-old male was admitted with a soft tissue defect that left Achilles tendon and calcaneus exposed as a result of trauma. A superficial peroneal nerve accessory artery perforator flap (5.5 x 16 cm) was harvested from the right lower leg. The pedicles of the flap were anastomosed to the peroneal artery and the venae comitantes, and a split thickness skin graft was performed on the donor site. The flap and donor site healed well with no major complications. Four months after surgery, the

flap and the recipient site matched well (Fig. 6).

DISCUSSION

Anatomical Study

Numerous studies have investigated the vascular anatomy of the lower leg. Research on the vascular anatomy of the anterior intermuscular (peroneal) septum in the anterolateral surface can be divided into two groups. The first group describes the septocutaneous vessels of the anterior intermuscular septum, and the second group describes the septocutaneous vessels originating from the superficial peroneal nerve accessory artery.

Two studies are included in the first group, one based on work by Carriquiry et al., that divides the septocutaneous vessels into three sites: medial (from the posterior tibial vessels), anterolateral (from the anterior tibial vessels), and posterolateral (from the peroneal vessels).[8] Between six and 10 vessels are found in the anterolateral group (the average is eight). A second study by Cormack and Lamberty shows that most of the anterior tibial artery perforator passes along the anterior peroneal septum. Approximately six significantly sized fasciocutaneous perforators emerge between the

extensor digitorum longus and the peroneal compartment.[9]

Three studies are included in the second group. Rocha et al. report that the anterior tibial artery vascularizes the anterolateral surface of the leg through two main interseptal branches, the superior and inferior lateral peroneal arteries.[1] Yousif show that the superior lateral peroneal artery is located at the junction of the proximal and middle thirds of the distance between the fibula head and the lateral malleolus.[10] These two reports do not examine the number or the location of the perforators, however. According to Masquelet et al., the superficial peroneal nerve accessory artery supplies the lateral aspect by generating approximately five branches in the distal 1/3 of the lower leg.[4]

In our study, both groups of research were addressed. The superior lateral peroneal artery originating from the anterior tibial artery formed the superficial peroneal nerve accessory artery, and the superficial peroneal nerve accessory artery generated the septocutaneous (51 in 16 cadavers) and musculocutaneous perforators (21 in 16 cadavers) in the anterior intermuscular septum, and supplied the anterolateral side of the lower leg. The septocutaneous perforators (50 in 16 cadavers) originating from the anterior tibial artery were also present, and supplied the anterolateral side of the lower leg. One hundred one septocutaneous perforators within the anterior peroneal

septum (septocutaneous perforators from the superficial peroneal nerve accessory artery and the anterior tibial artery) were found in 16 cadavers (the average was 6.31). This was similar to a finding reported by Carriquiry et al. and Cormack et al.

In a study by Rocha et al., the inferior lateral peroneal artery was present in 70% of cadavers, type I was present in 30%, and type II was present in 30%.[1] In our study, the inferior lateral peroneal artery was present in one out of 16 cases, with type I being present in 15 cases, and type II in one case. Our finding clearly differed from Rocha et al.

In conclusion, septocutaneous perforators within the anterior intermuscular septum mainly originated from the superficial peroneal nerve accessory artery if the artery was present (proximal 1/6 to proximal half), and from the anterior tibial artery if the artery was absent (distal half). The primary shortcoming of this study is that it was performed using only 16 cadavers and will require a larger sample size to confirm the results.

Superficial Peroneal Nerve Accessory Artery Perforator Flap

Since Taylor and Ham introduced vascularized nerve grafts in 1976, vascularization of sensitive superficial nerves has been investigated in hope of finding a

donor vascularized nerve graft.[5] However, little attention has been paid to the blood supply provided by arteries accompanying the nerves to the skin, until 1992, when Masquelet et al. reported that these arteries have several cutaneous branches in the suprafascial course, and proposed the neuroskin island flap.

More recently, the neurocutaneous flap was improved and numerous studies applied the flap in clinics by using the arteries that accompany the sural or saphenous nerves. As far as we know, Rocha et al., Masquelet et al., and Coskunfirat et al. are the only groups that harvested a flap supplied by the artery that accompanies the superficial peroneal nerve and utilized it in a clinical setting. We are the first group to harvest and utilize a perforator flap supplied by the superficial peroneal nerve accessory artery.

Defects in foot, ankle, knee, hand, or elbow tissue are a challenging reconstructive problem because of the thin skin and soft tissue in these areas. Reparation of tissue defects in this area need to consider the functional and aesthetic aspects of reconstruction. The superficial peroneal nerve accessory artery perforator flaps were similar in thickness to this area, so the outcome of surgery was functionally and aesthetically satisfying. This perforator flap is also useful because it uses a septocutaneous perforator, and dissection is relatively easy compared to flaps that use

the musculocutaneous perforator. In cases in which a long pedicle is not required, it is not necessary to sacrifice the main artery. In addition, because the scar is on the lower leg it is not as noticeable as a radial forearm free flap. Since the anatomy of this area is relatively unfamiliar, however, sufficient time is required to learn how to harvest the superficial peroneal nerve accessory artery perforator flap. Another shortcoming is that hair growth is associated with the flap.

CONCLUSIONS

To assess the anatomical structure of the superficial peroneal nerve accessory artery and perforators within the anterior intermuscular septum of the lower leg, sixteen cadavers were dissected. The superficial peroneal nerve accessory artery had an average of 4.5 perforators to supply the lateral aspect of the lower leg. Based on this result, we harvested a superficial peroneal nerve accessory artery perforator flap, and applied it to soft tissue defects of the foot, ankle, pretibia, knee and hand. The flap was very thin, and both functionally and aesthetically suitable. Superficial peroneal nerve accessory artery perforator flaps could be excellent alternatives to perforator flaps that use the lower leg as a donor site.

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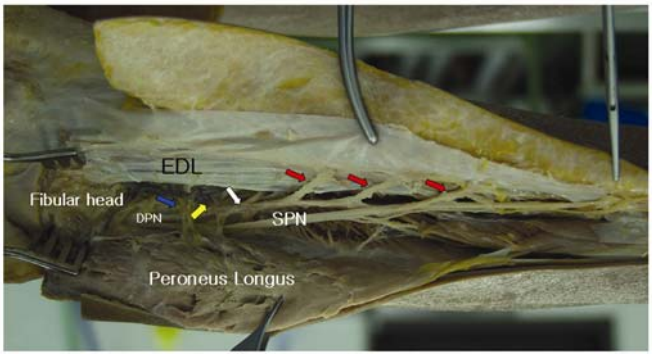
Legends



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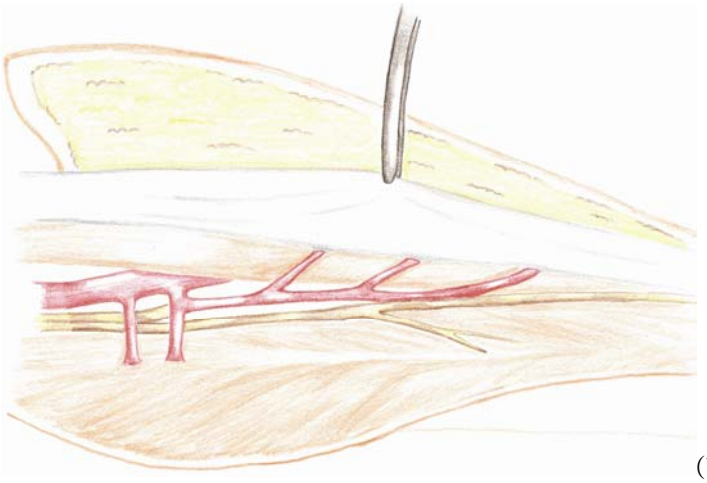
(below)

Fig. 1. (Above) Vessels within the anterior intermuscular septum. The superior lateral peroneal artery (yellow arrow) from the anterior tibial artery (ATA) contributes the superficial peroneal nerve accessory artery (SPNAA, white arrow). Red arrows represent septocutaneous perforators from the SPNAA, and the blue arrow represents the direct musculocutaneous perforator from the ATA. SPN: superficial peroneal nerve. DPN: deep peroneal nerve. EDL: extensor digitorum longus. The DPN disappears in the EDL. (Below) Schematic diagram.

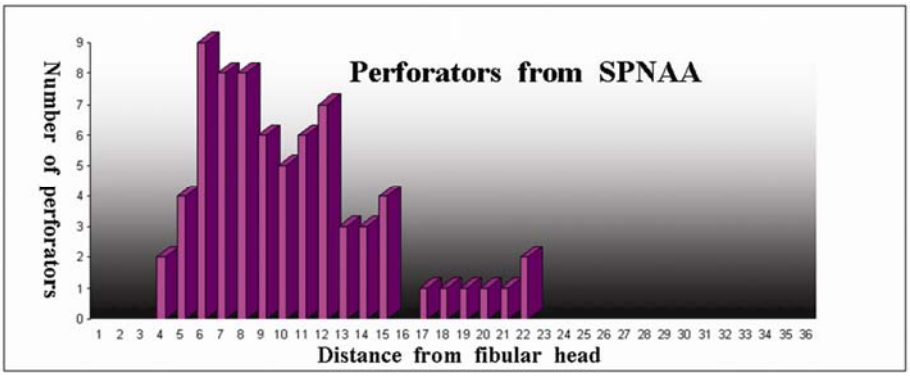

Fig. 2. Distribution of perforators from the SPNAA. Perforators are both septocutaneous and musculocutaneous.

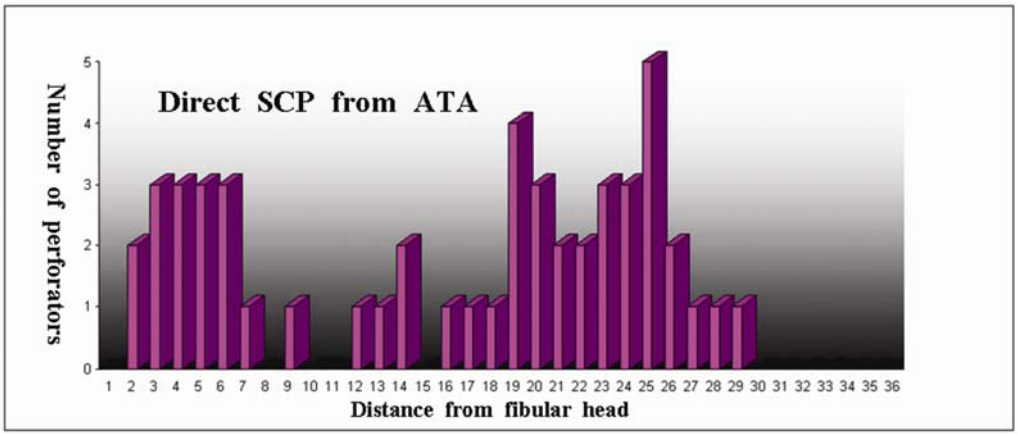

Fig. 3. Distribution of septocutaneous perforators (SCP) from the ATA.

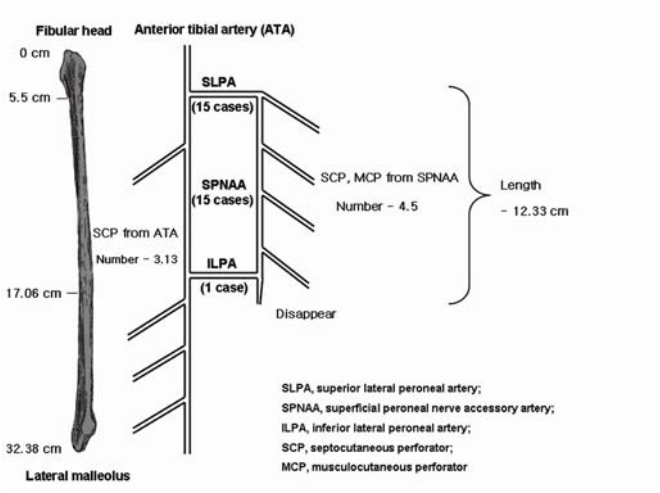

Fig. 4. Schematic diagram of vessels within the anterior intermuscular septum.

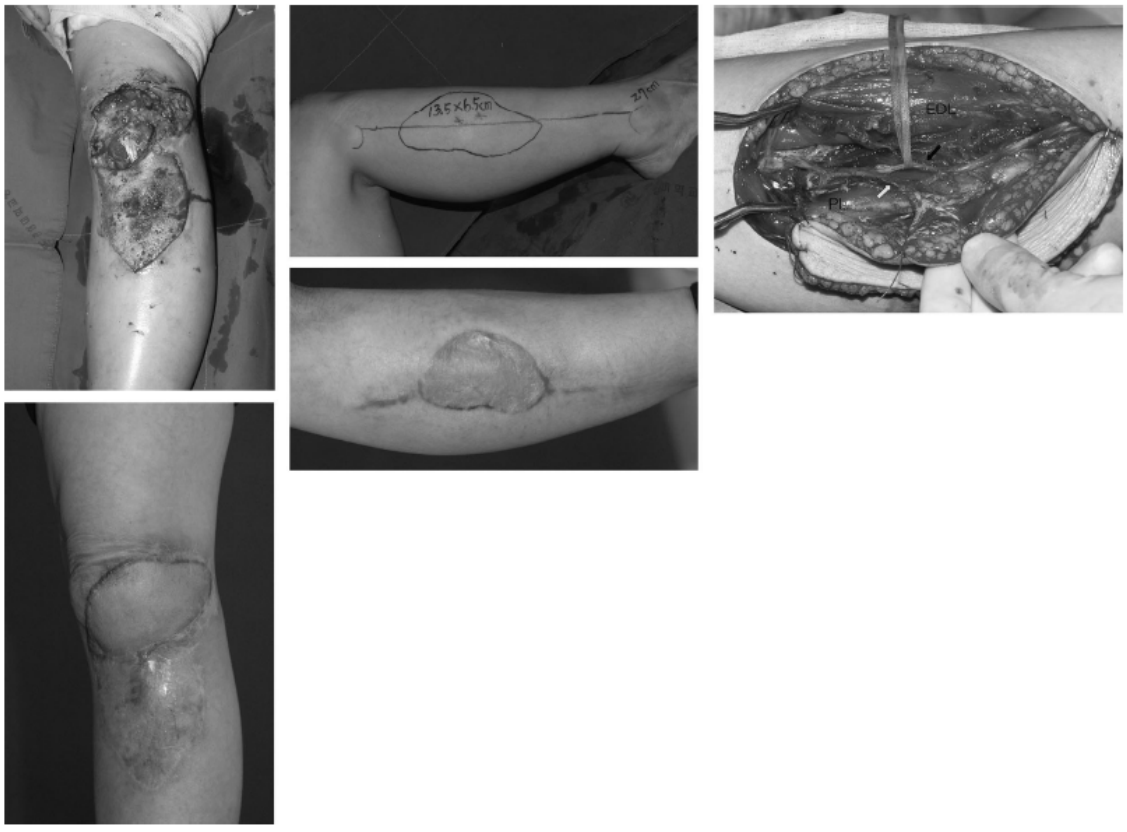

Fig. 5. (Patient 6) (Above, left) Preoperative view. (Above, center) Preoperative design of the SPNAA perforator flap. (Above, right) The septocutaneous perforator of the

SPNAA (yellow arrow) is the pedicle of this flap. Black arrow indicates the SPN. PL: Peroneus longus. (Below, left) Post-operative observation six months after surgery. (Below, right) Donor site of the flap six months after surgery.

Fig. 6. (Patient 8) (Above, left) Preoperative view. (Above, center) Preoperative design of the SPNAA perforator flap. (Above, right) Posterior view. The SPN (black arrow) and SPNAA (yellow arrow) were seen. (Below, left) Anterior view. After being divided from the SPN (black arrow), the SPNAA (yellow arrow) was seen. The septocutaneous perforator of the SPNAA is the pedicle of this flap. ATV: anterior tibial vein. (Below, right) Post-operative observation four months after surgery.