Journal of Plastic, Reconstructive & Aesthetic Surgery (2009) **62**, 1087—1093

JPRAS
An International Journal of Surgical Reconstruction
www.JPRASurg.com

Distally-based superficial sural neurocutaneous flap for reconstruction of the ankle and foot in children

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Received 16 November 2007; accepted 4 February 2008

KEYWORDS
Superficial sural flap;
Distally-based superficial sural flap;
Sural nerve;
Neurocutaneous flap

Summary *Introduction:* There are various options for covering soft tissue defects in the lower extremities, but the distal third of the leg continues to be a difficult area. The distally-based sural neurocutaneous flap which is based on the sural nerve and the superficial sural artery has been an important option since it was first proposed.
Methods and materials: 16 children, with an average age of 9 years had different local lesions on the distal third of the leg or foot which compromised the Achilles tendon, extensor tendons in the foot and toes or the osteoarticular system, were treated using the distally-based sural flap. One patient had an amputation at midfoot caused by a garden strimmer, seven had lesions caused by motorcycle accidents and eight were caused by car accidents.
Results: The minimum follow up was 8 months. In all cases, the lesions were successfully covered. Only one showed necrosis of the flap, but the adipofascial tissue was well irrigated and was resurfaced by a free skin graft.
Conclusion: The distally-based sural neurocutaneous flap is a good alternative for soft tissue defects in the distal area of the leg, a region where it is historically difficult to cover soft tissue defects.

Bone and soft tissue defects of the legs, especially those on the distal third of the leg and foot where vascular support for the tissue is critical, have been a challenge for the orthopaedic and plastic surgeon for years. Open fractures or exposed tendons, especially the Achilles tendon, must be covered immediately to avoid complications. This also reduces the rate of infection.[1—6] In addition, the patient can be rehabilitated more rapidly and with reduced hospital time.

There are various alternatives for covering soft tissue defects. Musculocutaneous flaps were the first solution that was developed.[7] After that muscle flaps, which continue to be very useful, were developed. Free flaps have also been a solution, but their greater complexity requires specially trained surgeons who are not always available at a hospital.

The concept of fasciocutaneous flaps appeared in Ponten's work in 1980[8] and, since then, a variety of anatomical

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1748-6815/$ - see front matter
doi:10.1016/j.bjps.2008.02.004

studies have been done that have contributed to our knowledge about them. These flaps have significantly helped solve the problems involved with the distal third of the leg. Fasciocutaneous flaps are irrigated by perforating arteries that come from main vessels such as the posterior tibial artery, anterior tibial artery and peroneal artery. Cormack and Lamberty classified flaps based on the anatomical disposition of the perforating arteries.[9]

Masquelet et al.[10] published anatomical and clinical studies of three nerves in the legs, including the sural nerve, and emphasised the importance of these superficial neurovascular axes in the design of neurocutaneous flaps to cover defects in the extremities. Other anatomical and clinical studies have corroborated the usefulness of these neurocutaneous flaps.[11–14] The objective of the current study is to show the results obtained from using the distally-based sural neurocutaneous flap to cover soft tissue defects on the legs and feet of children, as well as some technical details.

Patients and methods

The neurocutaneous flap, based on the sural distally-based nerve, was used to treat 16 children for a variety of lesions on the distal third of the leg. One patient had an amputation at midfoot caused by a garden strimmer, seven had lesions caused by a motorcycle accident and eight were caused by a car accident.

All of them had defects that compromised tendons, bones or joints. Their average age was 9 years (ranging from 7 to 12 years).

The surgery was performed during the 1st or 2nd week after the trauma. All of the parents agreed to the treatment and the publication of the results.

Anatomical bases and surgical techniques

The anatomical details for this flap were described by Masquelet et al. in 1992.[10] He developed a flap taken from the middle, back part of the leg that was centred over the sural nerve. This nerve arises from the tibial nerve or internal popliteal sciatic nerve in the popliteal fossa and passes between the two heads of the gastrocnemius muscle. It converges with the superficial sural artery and they descend together under the fascia in the upper third of the leg (Figure 1). Between the upper and middle third, the sural nerve, along with the superficial sural artery, pierces the fascia and becomes subcutaneous. Along its course, the artery irrigates the nerve.

During its subcutaneous trajectory in the two lower thirds, the artery sends branches to the skin. The sural nerve-artery complex descends obliquely towards the back of the lateral malleolus and always anastomoses with some branches of the peroneal artery in the distal third. The last one of them is found approximately 5 cm from the lateral malleolus and is relatively constant.[11,12,15–18]

In its trajectory, the superficial sural artery is a satellite of the nerve for which it provides branches directly. In a third of the cases, the nerve and artery may, especially in the distal third of the leg, form an interlacing network which justifies the dissection of the pedicle with sufficient fibroadipose tissue.[10,15]

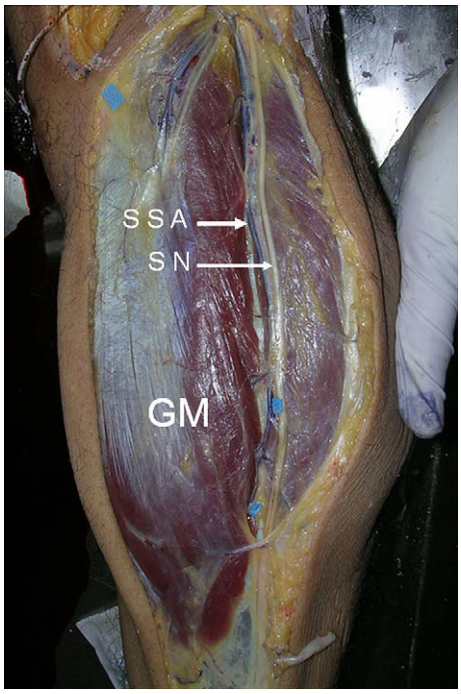

Figure 1 The sural nerve (SN) passes between the two heads of the gastrocnemius muscle (GM). It converges with the superficial sural artery (SSA) and they descend together.

Technique

This has been described in various articles. The dimensions of the flap depend on the size of the defect. The proximal edge of the flap does not extend beyond the popliteal fossa, and the lateral edges do not go beyond the lateral midlines. The flap is raised under tourniquet control. The incision is started on the lateral edge of the flap and continues until reaching the gastrocnemius. An incision is made in the fascia and the dissection is continued underneath it. At this point, care must be taken to include the sural nerve and the superficial sural artery in the flap. Sometimes a portion of the gastrocnemius muscle is included in the flap to ensure that the nerve-artery complex is in it. After that, the dissection is continued distally around the nerve and artery. The fibroadipose tissue around the nerve, including the superficial sural artery and the lesser saphenous vein, is preserved. The dissection continues to the last 3 to 4 cm proximal to the lateral malleolus, depending on the age of the child, where it is rotated to cover the defect. The base of this pedicule should be wide (Figure 2).

The flap is checked for viability after the tourniquet is released, after which a subcutaneous tunnel is created for the passage of the flap. The donor site is closed primarily when the defect is, in general, no greater than 4 cm. When this is not possible, it is resurfaced with free skin grafts.

The extremity was covered with a soft dressing postoperatively leaving the flap exposed in order to monitor the perfusion and the leg was placed on a pillow. Five days later the dressing was changed. The children did not have any problems with the dressing.

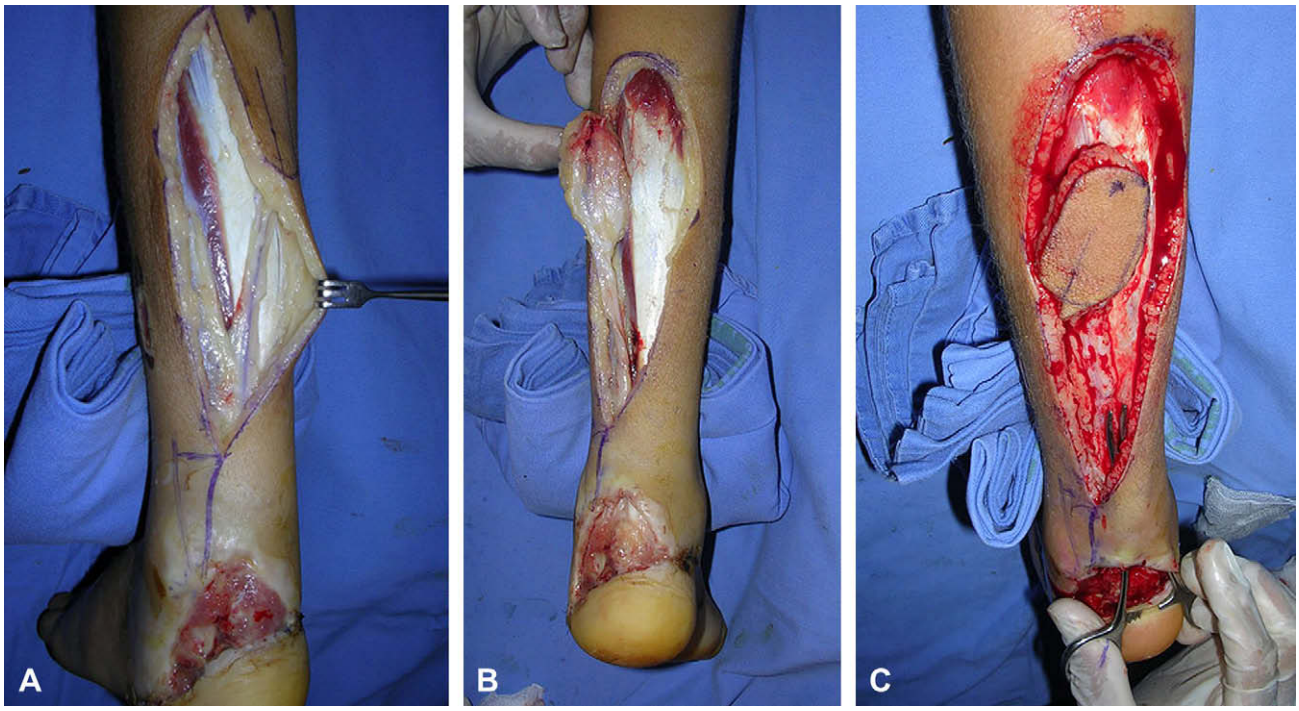

Figure 2 The dissection of the pedicle with fibroadipose tissue around the nerve including the superficial sural artery and the external saphenous vein can be seen. After the tourniquet is released, the flap is checked for viability and a subcutaneous tunnel is created for the passage of the flap.

Results

Follow up of the 16 patients ranged from 8 months to 2 years postoperatively. The soft tissue defects were completely and successfully covered for all 16 the children. All of the flaps were designed as island flaps. Three flaps presented venous congestion. Two of these also had partial necrosis distally and superficially that did not compromise the viability of the flap. Of these two, one was a long pedicle flap to cover the midfoot. The third presented total superficial necrosis. However, the adipofascial tissue was well irrigated which allowed free skin grafting to be done. There was no infection and all of the patients were able to leave the hospital within a very short period of time (an average of 3 days) after surgery.

The longest flap measured 10×5.5 cm. The arc of rotation varied between 100 and 180°. The time required to make the flap during surgery was approximately 1 h 30 min.

There was no significant donor site morbidity and there were no complaints related to the sacrifice of the sural nerve. Eight patients had a soft tissue defect on the heel with a lesion of the Achilles tendon. Three patients presented a fracture of the calcaneal with a lesion of the Achilles tendon. Two patients had a defect on the medial face of the ankle with nerve and posterior tibial artery lesions. Two patients had defects on the anterior face of the ankle plus a lesion of the extensor tendons and one patient had an amputation at midfoot.

One of the patients with a fracture of the calcaneal had to use a heel insert since prolonged walking caused pain in the heel. The patient with an amputation at midfoot did not require an orthosis in his shoe. He presented a minor limitation in running, but it did not hinder him from participating in sports such as soccer.

Case 1

An 8-year-old girl suffered a soft tissue lesion in the distal posterior of the leg with the exposure of the Achilles tendon and fractures of the calcaneal and metatarsus. This was successfully repaired with a 7×4 cm distally-based sural flap 8 days after the accident. The donor site was closed primarily. The flap did not present any type of complication. Eight months later she had a normal gait (Figures 3—5).

Case 2

A 9-year-old boy had a soft tissue lesion in the distal posterior of the leg with a lesion of the Achilles tendon and fractures of the calcaneal due to an automobile accident. There was a loss of osseous material from the calcaneal and infection. The defect was repaired and covered with a 10×6 cm distally-based sural flap 15 days after the trauma and free skin grafts were used for the donor site. There were no complications and the infection healed well (Figures 6—8).

Discussion

The reconstruction of the lower extremities that have exposed tendons, vascular elements and bone has been a constant challenge for the orthopaedic and plastic

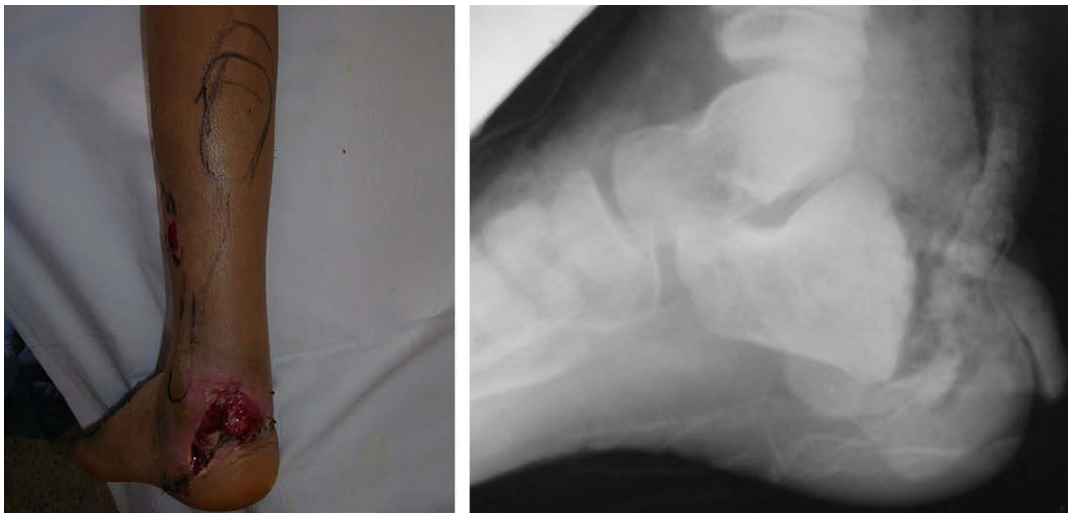

Figure 3 An 8-year-old girl with an exposed Achilles tendon and calcaneous fractures.

surgeon. Many studies confirm that immediately covering an open fracture, with or without osteosynthesis, dramatically reduces the possibility of infection and allows rapid functional restoration for the patient, especially when it is done during the first 72 h after the trauma.[1–6] Immediately covering it also prevents necrosis of the exposed tissue.

The wide adipofascial pedicle is very important since it enables us to safely raise the arterial-nerve complex and, moreover, it insures direct connections to the venae that accompany the sural nerve artery and the lesser saphenous vein. In our series all of the flaps were designed as island flaps. This gave us greater versatility in placing the flap and a much better aesthetic result. The key is the wide adipofascial pedicle that includes the sural nerve, superficial sural artery and lesser saphenous vein.

Congestion of the flap because of inadequate venous drainage is the most frequent complication described in the literature. Studies have been done of venous drainage for some flaps such as the distally-based peroneal flap and communicating channels and bypasses between the concomitant veins around the arteries have been demonstrated.[12,19] Venous drainage passes through these channels. Imanishi et al.[20] demonstrated that small veins run along the length of the lesser saphenous vein, accompanying the superficial sural artery, and these small veins interconnect the arterial system with the venous system.

We had three flaps with venous congestion, two of which had partial necrosis and one which had total and superficial necrosis. The cause is not yet clear. The great majority of

Figure 4 A 7×4 cm flap was harvested to cover the Achilles tendon and the calcaneous bone. The donor site was closed primarily.

Figure 5 A good result 8 months later.

authors emphasise the importance of including the lesser saphenous vein to ensure good venous drainage.[12–18]

Xu[21] has recently suggested that including the lesser saphenous vein in the pedicle is not sufficient to provide venous drainage for the flap and that this is the cause of venous congestion. He recommends ligating the lesser saphenous vein at the pivot point. After doing so, no serious venous congestion occurred in his series of patients.

Another cause of venous congestion is a lack of elasticity in the skin over the roof of the tunnel that has been created. This puts pressure on the vascular pedicule and it is necessary to insure that there is none. If there is, it is best to open the tunnel, dissect it well and close the tunnel again or, in some cases, leave the pedicle on the exterior.

The lesser saphenous vein was included in all cases in our series.

Impairment of sensitivity such as hyperaesthesia, anaesthesia and numbness of the lateral aspect of the foot due to the sacrifice of the sural nerve may cause problems for some patients, especially adults.[17,18] In our series there were no complaints related to the sacrifice of the sural nerve.

This flap is highly versatile. With it, it is possible to cover areas of the foot such as the midfoot or base of the metatarsal bones. In these cases, the flap is raised on the proximal third and directly over the gastrocnemius muscles and a large section of the muscle, fed by the same sural artery, is raised with the flap thus assuring that the nerve

Figure 6 A 9-year-old boy with an extensive soft tissue lesion in the heel with open calcaneous fractures that also compromised the Achilles tendon.

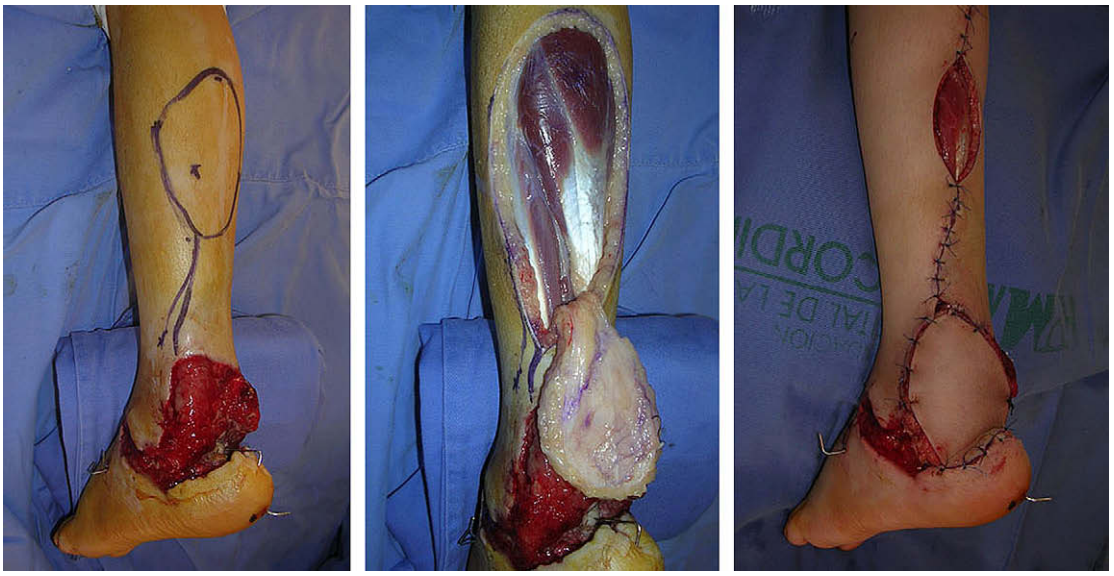

Figure 7 We harvested a 10 × 6 cm distally-based sural flap to cover the defect.

and sural artery, which at this point are subfascial, are included.[22] Remember that the point of rotation, depending on the length of the leg, could be between 3 and 5 cm. In addition, it is necessary to remember to leave a wide adipofascial base for the pedicle.

Extensive experience has been gathered that shows how good and secure this flap is as well as its safety.[10—13,15—18,21—23]

In this series of patients, 43% of the lesions were the result of being passengers on motorcycles. In our country, it is common for children to ride motorcycles as passengers without much protection and this vehicle is one of the major causes of accidents and lesions to the musculoskeletal system.

Repairing these lesions allowed a rapid solution to the problems and made a return home possible. Complications specific to the flap such as aesthetic defects of the leg were minimal. These were not very important to the patients considering the magnitude of the problem that had to be solved. The only flap that presented total, superficial necrosis still had viable adipofascial tissue fascia which made a free skin graft possible.

Figure 8 A good result 1 year later.

The flaps that were situated in areas that were partially weight bearing did not present complications and were thick enough to handle pressure without discomfort.

If the flap was not in a weight-bearing area, rehabilitation began 15 days after surgery, when all of the wounds had healed and ambulation was permitted at the same time. If the flap was in a weight-bearing area, rehabilitation was delayed another 15 days. A large majority of the children had difficulty receiving the necessary therapy due to the distance from where they lived or problems with their health plan, and they did not receive postoperative rehabilitation.

We did not observe any disturbance in normal growth during the follow up.

The distally-based sural flap is a relatively easy and reproducible flap, which solves many of the problems of covering difficult sites on the leg and foot. It also frequently avoids the use of free flaps which are much more complicated and carry greater risks. The surgical principles for children are the same as those for adults. It is a flap that can be done immediately by the attending surgeon, thus reducing complications and hospital time and saving money.

The author has no financial interest in any of the products, devices, or drugs mentioned in this manuscript.

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