

## Original Article

# The proximally based lateral superficial sural artery flap: a convenient and optimal technique for the reconstruction of soft-tissue defects around the knee

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**Abstract:** The proximally based lateral superficial sural artery flap offers prominent advantages in the reconstruction of soft-tissue defects around the knee. It is a thin, pliable and sensate flap; it has been shown to reduce donor-site morbidity and result in a good aesthetic outcome. However, there are few reports regarding this flap in literature. This study aims to present our experience on the use of this flap in 14 patients. This retrospective study was performed over a 6-year period (from February 2009 to February 2015) using the proximally based lateral superficial sural artery flap. The size of the flaps ranged from 6 × 5 cm to 12 × 11 cm for soft-tissue defects around the knee where there is defect sizes ranging from 5 to 10 cm in length and 4 to 9 cm in width. The donor site underwent direct suture or skin grafting. All flaps and skin grafts survived, and the wounds healed by first intention. Follow-up for all patients ranged from 3 to 18 months. All patients had achieved good final outcomes. Due to the flaps are soft, fine texture and having excellent appearance, the operated knee had good flexion and extension, and those patients could walk normally. Thus, we believe that the proximally based lateral superficial sural artery flap is an ideal pedicled flap that is suitable for regional reconstruction around the knee.

**Keywords:** Superficial sural artery, surgical flap, knee, reconstructive surgical procedures, wound healing

## Introduction

Soft-tissue skin defects around the knee are not uncommon and often caused by traffic accidents, burn, squeeze injury, or surgical infection. Reconstruction of defects is considered as a challenging operation due to thin and pliable skin appearance and restoration of knee function. There are various available methods for reconstruction of defects around the knee, such as local muscle flap, perforator flap, cross-leg flap or free flap etc. However, the outcome of these methods are always unsatisfactory, frequently compromising knee joint function and appearance. The proximally based sural artery flap from the posterior calf region is used for reconstruction of such defects because thin, reliable and sensate skin appearance can be provided, but the morbidity of the donor site is a drawback with this flap [1-3]. The proximally based lateral superficial sural artery

flap is not only providing thin, reliable and sensate skin appearance but also protecting the donor site, and is considered an excellent method for the reconstruction around the knee [4, 5]. However, there are few reports elaborating the anatomy and clinical application of this flap in the literature. Here, we shall firstly describe the anatomy of the proximally based lateral superficial sural artery flap by a series of figures and share our experience of this flap for the reconstruction of soft tissue defects around the knee.

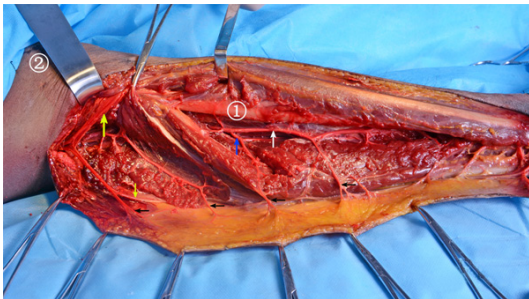
## Materials and methods

This is a retrospective study consisting of 14 patients operated between February 2009 and February 2015. The patients underwent reconstructions of soft tissue defects around the knee with the proximally based lateral superficial sural artery flap. All the patients who

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**Table 1.** Summary of patients

Patient	Sex	Age	Cause of injury	Defect site	Defect size (cm)	Flap size (cm)	Donor site closure	Complications	Follow-up (months)
1	F	76	Burns	Anterior aspect of patellar	10 × 9	12 × 11	Skin graft	No	8
2	M	27	Traffic injury	Anterior aspect of patellar	7 × 4	9 × 5	Primary suture	No	10
3	F	49	Traffic injury	Anterior aspect of patellar	8 × 6	10 × 8	Skin graft	No	12
4	M	12	Squeeze injury	Inferoanterior aspect of patellar	9 × 8	11 × 10	Skin graft	No	18
5	M	46	Infection	Inferoanterior aspect of patellar	5 × 3	6 × 4	Primary suture	No	12
6	M	14	Traffic injury	Inferoanterior aspect of patellar	8 × 5	9 × 7	Skin graft	No	3
7	F	68	Squeeze injury	medial aspect of patellar	7 × 5	9 × 7	Skin graft	No	10
8	M	72	Squeeze injury	Anterior aspect of patellar	8 × 5	10 × 7	Skin graft	No	9
9	M	59	Traffic injury	Inferoanterior aspect of patellar	4 × 3	6 × 4	Primary suture	No	7
10	F	50	Squeeze injury	lateral aspect of patellar	10 × 8	12 × 8	Skin graft	No	3
11	F	69	Burns	Inferoanterior aspect of patellar	7 × 5	10 × 7	Skin graft	No	10
12	M	70	Traffic injury	Anterior aspect of patellar	9 × 6	11 × 8	Skin graft	No	6
13	M	53	Infection	lateral aspect of patellar	10 × 3	12 × 4	Primary suture	No	5
14	F	51	Burns	medial aspect of patellar	9 × 7	10 × 9	Skin graft	No	4



**Figure 1.** A photo picture showing the sources of blood supply at posterolateral aspect of the right cadaver leg (injected with red latex): ① fibula; ② the lateral aspect of patella; the peroneal artery (white arrow); posterior tibial artery (blue arrow); the lateral superficial sural artery (the first black arrow from left); the lateral sural artery perforator (the second black arrow from left); the posterior tibial artery perforator (the third black arrow from left); the peroneal artery perforator (the fourth black arrow from left); the common peroneal nerve (the bigger yellow arrow); the lateral sural cutaneous nerve (the smaller yellow arrow).

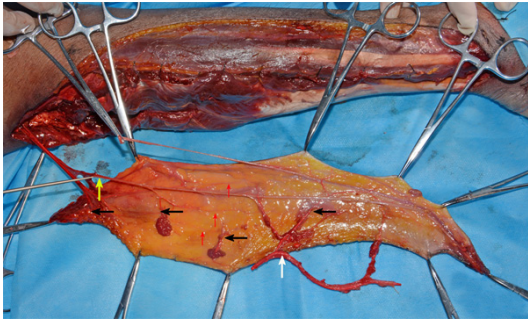
involved in this study provided written informed consent for participation. There were 6 male and 8 female patients, with a mean age of 51 years (12-76 years). The soft-tissue defects resulted from traffic injuries 5 patients, squeeze injuries 4 patients, burns 3 patients, surgical infection 2 patients and the mean time from injury to operation was 21 days, ranging from 10 to 35 days. The wound area ranged from 5 cm × 4 cm to 10 cm × 9 cm and located in prepatellar skin and/or peripatellar skin (Table 1). After surgery, patients were treated with antibiotics, anti-vasospasm and anticoagulant thera-

pies; capillary filling time, color and temperature of the skin flap were recorded; and arterial infusion and venous drainage in the skin flap were evaluated. Patients were reviewed for a mean follow-up of 8 months (range, 3-18 months).

### Flap anatomy

**Vascular:** As described by Taylor and Pan In 1997, sural angiosome is one of the 4 angiosomes of the leg. The source of blood supply of the angiosome is mainly by superficial sural arteries, various cutaneous perforators from sural arteries, posterior tibial artery and peroneal artery. There are three superficial sural arteries named the medial, median, and lateral superficial sural arteries (also called popliteal cutaneous arteries). Several studies have elaborated the anatomy of the superficial sural arteries [4-7]. Here, we have identified the sources of blood supply including lateral superficial sural arteries at posterolateral aspect of the leg from one adult cadaveric lower limbs injected with red latex with the approval of ethics board of affiliated hospital of zunyi medical college (Figures 1-3). The lateral superficial sural arteries is the first source of blood supply at posterolateral region of the legs, which has been reported to originate from a number of sources, including originate from the popliteal artery, the medial and the lateral sural artery [7]. After origin, lateral superficial sural arteries crosses the popliteal fossa and pierces the deep fascia somewhere at 1.8 cm lateral posterior median line below the fibular head and

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**Figure 2.** A photo picture for dissection of the skin paddle of posterolateral aspect of leg: the lateral sural cutaneous nerve (yellow arrow); the peroneal artery (white arrow); subfascial vascular chain (red arrows); black arrows as same as shown in **Figure 1**.



**Figure 3.** A photo picture for the lateral superficial sural artery origins from popliteal artery: popliteal artery (white arrow); the lateral superficial sural artery (black arrow); the lateral sural cutaneous nerve (yellow arrow).

travels lateral heads of the gastrocnemius muscle toward the lateral malleolus. The artery courses alongside the lateral sural cutaneous nerve to the distal one-third of the leg, anastomosing with the supramalleolar branch of the peroneal artery and forming a subfascial and suprafascial vascular chain. The proximally intermuscular septum perforators originated from the peroneal artery are the second source of blood supply which may provide greater blood flow to the skin and fascia of posterolateral region of the legs. One or two perforators are constantly present, running along the posterior intermuscular septum a distance of 3 to 10 cm below the fibular head. A fine anastomotic network could be seen between these perforators and the lateral superficial sural artery. The musculocutaneous perforators from the lateral sural artery and/or posterior tibial artery are the third source of blood supply in lateral sural angiosome. Previous studies declared gastrocnemius musculocutaneous perforators

arising from the lateral belly may not be present in relatively high number of individuals or their size is often inadequate. However, the average number of lateral sural artery perforators identified per lower leg was three is demonstrated by recently study [8]. These musculocutaneous perforators join continually in suprafascial arterial network of angiosome previously mentioned. The last source of blood supply in lateral sural angiosome is neurocutaneous perforators arising from the small arteries accompanying lateral sural cutaneous nerve. In addition to their intrinsic blood supply, lateral sural cutaneous nerve has an extrinsic vascular plexus that runs along its length. This extrinsic vascular supply provides perforators that supply the skin and fascia of the sural angiosome. Thus, there are at least four sources of blood supply forming a suprafascial arterial network of angiosome at posterolateral of the legs. The lateral superficial sural artery is accompanied by two venae comitantes and drains into the popliteal vein.

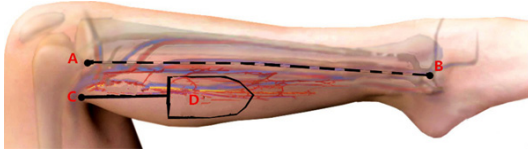
### *Lateral sural cutaneous nerve*

The lateral and medial sural cutaneous nerves originate from the common peroneal and tibial nerves respectively and in most of the cases the union of which form the sural nerve in the lower third of the leg. But, in some cases where they do not unite, the sural nerve is a direct continuation of the medial cutaneous nerve [9, 10]. After originating, the lateral cutaneous nerves travel along the surface of the lateral head of the gastrocnemius muscle, across the popliteal fascia, and pass through the subcutaneous layer and supply the middle of the sural area. The diameter of lateral cutaneous nerves at the middle of the lower leg was between 2.0 and 5.0 mm (mean 2.6) and the number of the branches from which on each leg was 1-2 (mean = 1.2) [9, 10].

### *Surgical technique*

The surgical procedures were performed when patients were under spinal or continuous epidural anesthesia. The patients were positioned in a lateral decubitus position or supine position with the knee joint bending to get optimal access to the posterolateral aspect of the calf. Then, according to the size and site of the recipient, we designed the outline of the flap on the posterolateral aspect of the leg. The principle of flap designed was that the lateral super-

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**Figure 4.** A schematic graph for preoperative design of the proximally based lateral superficial sural artery flap. (A) Fibular head, (B) Lateral malleolus, (C) Rotation point of flap, (D) The skin paddle of flap.

ficial sural artery was located in the shaft axis of the flap and the flap size was about 1-2 cm larger than the recipient and the pedicle length was added 2 cm to avoid tension. A transverse line was marked joining the lateral condyle of the femur and the posterior median line. This perpendicular line is marked, which pass through the midpoint of this transverse line and was parallel to the posterior median line. This vertical line represented the central axis of the flap (**Figure 4**). The pivotal point of the flap was located in the midpoint of this transverse line and the lower boundary did not exceed lower third of the leg. This flap marked can be performed at the posterolateral aspect of the leg.

After inflating the tourniquet, the wound was first debrided and irrigated. Then, the distal and lateral margin of the flap was incised including the deep fascia according to the outline. The lateral superficial sural artery, lateral sural cutaneous nerve, medial sural cutaneous nerve, sural nerve, lesser saphenous vein are exposed, identified and divided. After meticulously protecting the medial sural cutaneous nerve and sural nerve, the lateral superficial sural artery and lateral sural cutaneous nerve were cut and the vessels were ligated at the distal end of the flap. The deep fascia was elevated to make sure that the cutaneous nerves and accompanying vessel were included in the flap. Then, we incised the medial margin of flap and raised the flap from distal to proximal portion under the subfascial plane. When dissecting the proximal portion of flap, the common peroneal nerve and the pedicle of the flap should avoid injury. Skin was incised up to the pivot point and raised on both the sides retaining fascial tissue to protect the vascular pedicle. The pedicle of the flap only contains the lateral superficial sural artery and lateral sural cutaneous nerve, thus making the flap sensate. To assure success of surgery, pedicle skin of the flap is islanded keeping a cuff of subcuta-

neous soft tissue (around 5 cm) around the pedicle. Once the dissection of the flap was completed, we released the tourniquet and checked circulation of flap and transposed the flap to the recipient site through a tunnel or open tunnel and avoided twisting or kinking of the pedicle. Negative suction drains were placed under the flap and pedicle to prevent haematoma. The donor area was covered with a skin graft from the thigh or closed directly if less than 5 cm wide.

### *Ethics statement*

All clinical investigations were conducted according to the principles expressed in the Declaration of Helsinki. The patient who involved in this study provided written informed consent for participation. The individual in this manuscript has given written informed consent to publish these case details. The Ethical Committee of Affiliated Hospital of Zunyi Medical College has specially approved this study.

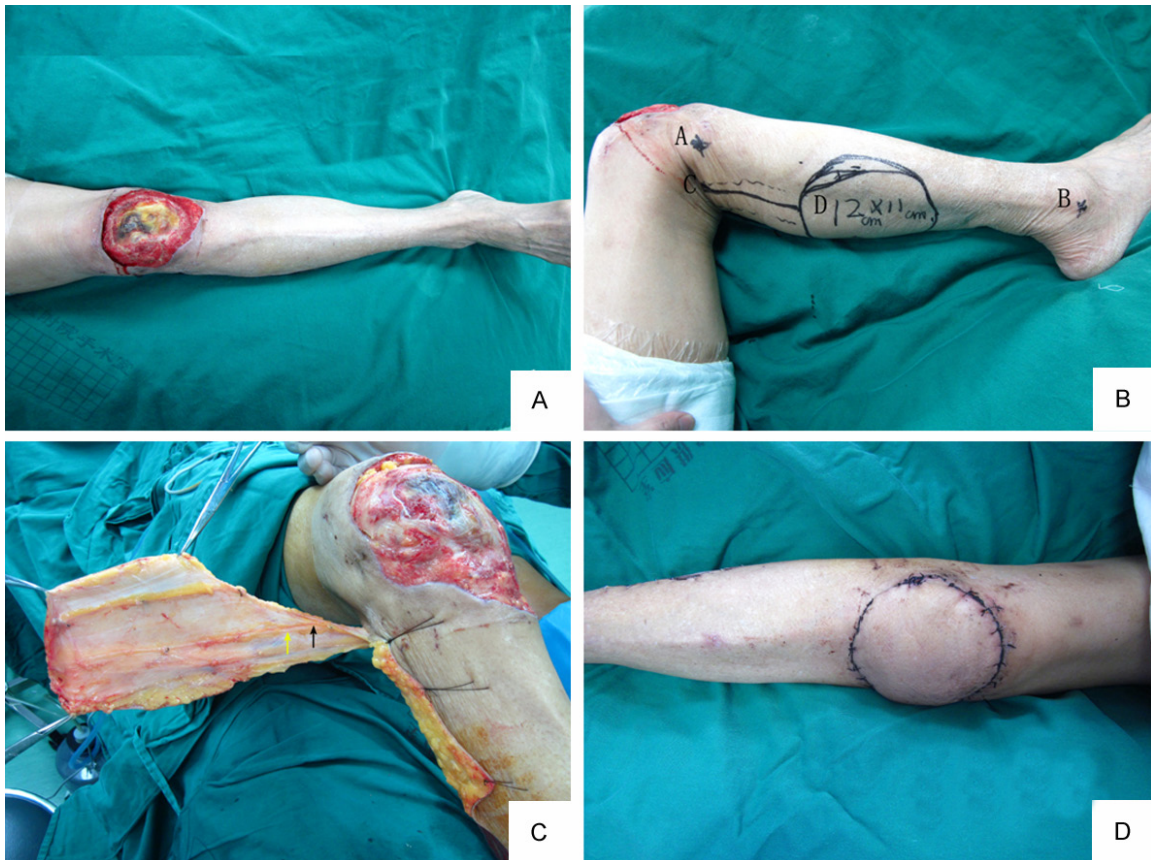
### **Results**

In this retrospective series, 14 patients underwent soft-tissue reconstruction around the knee by the proximally based lateral superficial sural artery flap after surgical debridement. All the flaps and the skin grafting survived and the wounds healed by first intention. Follow-up of all patients ranged from 3 to 18 months, all patients achieved a good final outcome that flaps possessed normal sensation and were thin, soft and elastic. The operated knee performed good flexion and extension, and patients could walk normally. Skin sensation of posterior aspect of leg, lateral malleolus and the lateral border of the dorsum of foot were remained.

### *Case 1*

A 76-year-old woman was referred to our department with skin necrosis for the past 7 days after a fire accident in her right knee. On admission, she underwent two surgical debridement because of necrosis tissue and the wound was covered with vacuum sealing drainage on Day 11 and Day 18 after injury. One week later, a flap surgery was performed under continuous epidural anesthesia. The wound with partial necrosis of patellar ligament and patella was located in prepatellar and measured 10 × 9 cm. The proximally based lateral superficial

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**Figure 5.** A photo picture for the proximally based lateral superficial sural artery flap for covering the defect of the anterior aspect of knee. (A) Preoperative wound, (B) Flap design, (C) Elevation of the flap: The flap contains The lateral superficial sural artery (black arrow) and the lateral sural cutaneous nerve (yellow arrow), (D) 7 days postoperation.

sural artery flap was designed to cover the defect, measuring  $12 \times 11$  cm, and the donor site was skin-grafted from the medial aspects of the left thigh. The flaps survived completely and the wounds healed by first intention. Follow-up of 8 months, the flaps possessed normal sensation and were thin, soft and elastic. The right knee worked with good flexion and extension and she could walk normally (the patient had already walked for two hours with three grandchildren when we followed-up examination). The donor site had no ulcer or graft contracture. Skin sensation of posterior aspect of leg, lateral malleolus and the lateral border of the dorsum of foot were remained (Figures 5, 6).

### Case 2

A 53-year-old woman was admitted to our department with skin necrosis for the past 5 months after total knee arthroplasty in her right knee. One day later, a flap surgery was per-

formed under continuous epidural anesthesia. The wound was located in peripatellar and measured  $10 \times 3$  cm. The proximally based lateral superficial sural artery flap was designed to cover the defect, measuring  $12 \times 4$  cm, and the donor site was closed directly. The flap survived completely and the wounds healed by first intention. Follow-up of 5 months, the flaps possessed normal sensation and were thin, pliable. The donor site had only linear scar and showed cosmetical appearance (Figures 7, 8).

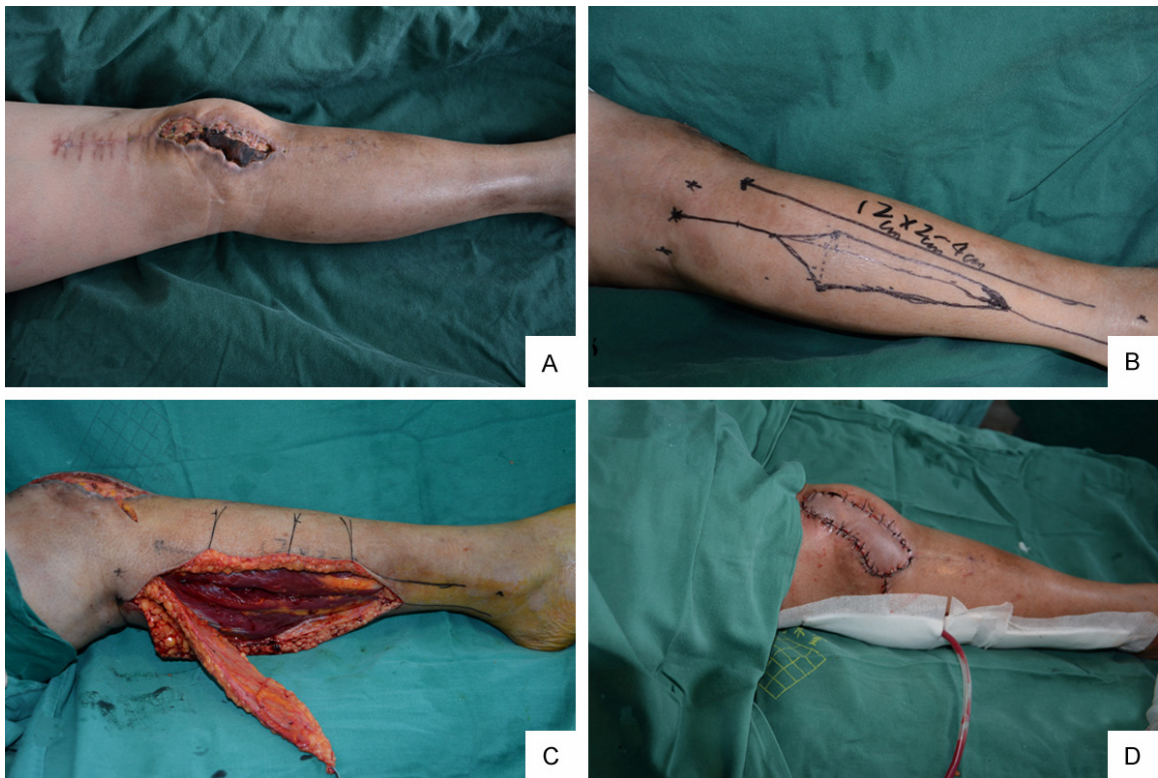
### Discussion

Improvement in the optimum reconstruction methods for recipient site and minimal donor site morbidity are perpetual exploration in reconstructive surgery. Reconstruction of soft-tissue defects around the knee is still considered as a challenging operation due to thin and pliable skin appearance and restoration of knee function. Various available methods for restoration of these defects of the knee area

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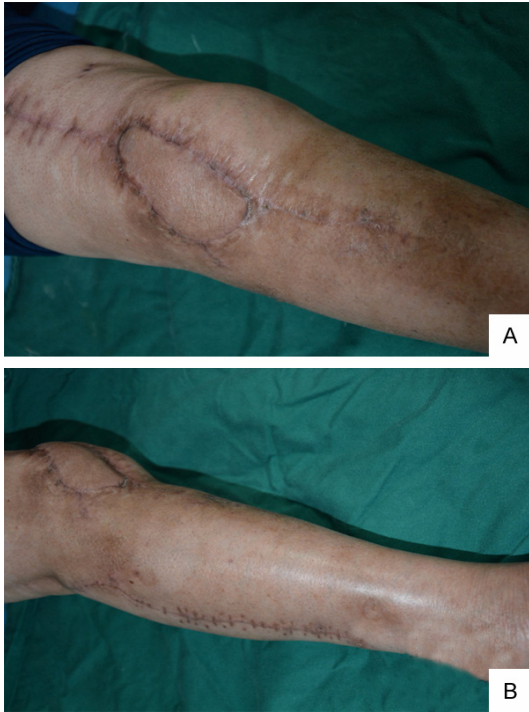


**Figure 6.** A photo picture taken from follow-up for 8 months after the surgery: A-C. The appearance of the flap and the donor site. D, E. The injured knee performed good flexion and extension.



**Figure 7.** A photo picture taken for the proximally based lateral superficial sural artery flap for covering the defect of the lateral aspect of knee. (A) Preoperative wound, (B) Flap design, (C) Elevation of the flap, (D) Immediate post-operative.

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**Figure 8.** A photo picture taken from follow-up for 5 months after the surgery: A. The appearance of the flap. B. Linear scar of the donor site.

include local muscle flap, perforator flap, cross-leg flap or free flap etc. The results of the above surgical flaps are not always satisfactory, frequently compromising function of knee joint and appearance or failing in the unfeasibility of flap operation [1-3]. Because of the providing of thin, pliable and abrasive skin, minimal donor site morbidity and functional and cosmetic advantage over other flaps, we utilize the proximally based lateral superficial sural artery flap for the reconstruction of soft tissue defects around the knee.

Since Taylor and Daniel [11] first reported that the posterior calf region can be used as a donor for free flap based on one of the superficial arteries of the sural angiosome, containing constant and thick vessels. Subsequently, Walton and Bunkis [12] reported free fasciocutaneous flap provided by superficial sural vessels from the posterior region of leg in 14 cases with 2 failures. It is initially clinical application of posterior region of leg as donor site of free flap. Although free fasciocutaneous flap from the posterior calf region is described in the literature, it still failed to be prevalent. Recently, Wolff and Bauer<sup>6</sup> reported that 20 patients with

primary oral cancer who underwent reconstructions through posterolateral calf free flaps based on the superficial lateral sural arteries or the peroneal perforator arteries and the outcome was satisfactory. In the report, they found that a suitable superficial lateral sural artery and vein was found in 12 patients, whereas in 8 patients no suitable vascular pedicle was present and a proximal peroneal perforator was used as the vascular pedicle as a back-up procedure. Thus, the main use of posterolateral calf flap is not as a free flap but as a local pedicled flap for reconstructions around the knee due to the variation of the diameter of the lateral superficial sural artery.

Li et al [4] described an island flap based on lateral sural cutaneous artery for covering defects around the knee in 17 cases, resulted from acute trauma soft tissue tumours, unstable scar or ulcer and chronic osteomyelitis or infected open fractures with tissue loss. Their anatomical study of 20 legs showed that the lateral sural cutaneous arteries were constant and the outer diameter ranged from 0.4 to 0.6 mm at its origin, which descended along the posterolateral aspect of the leg together with two venae comitantes and the lateral sural cutaneous nerve. These clinical results were satisfactory and the flaps possessed normal sensation and elasticity. Rajacic et al [5] had used lateral sural fasciocutaneous artery island flap in 6 patients to reconstruct defects around the knee. The causes of the defect include trauma, deep burns, chronic ulcers, and post-burn scar contractures and the maximum flap size was 12 cm × 15 cm. All the flaps survived and the flaps which can be raised easily were thin and reliable.

The perfect reconstruction for soft tissue defects around the knee should have thin, pliable, stretchable, and sensate skin without an adhesive undersurface which affected excursion of the extensor apparatus. The covering methods should be easy to perform and reproducible with minimal functional and aesthetic morbidity of the donor site [5]. The proximally based lateral superficial sural artery flap conforms to almost all of these criteria. As previously stated, this flap included at least four sources of blood supply forming a suprafascial arterial network of angiosome at posterolateral calf flap: such as lateral superficial sural artery, the proximally intermuscular septum perfora-

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tors from the peroneal artery, musculocutaneous perforators from the lateral sural artery, and neurocutaneous perforators from lateral sural cutaneous nerve. The supplying artery of the island flap was lateral superficial sural artery which accompanies the lateral sural cutaneous nerve and comitantes vessels, anastomosing with the supramalleolar branch of the peroneal artery and forming a subfascial and suprafascial vascular chain. Thus, the fascial island flap proximally based lateral superficial sural artery or distally based supramalleolar branch of the peroneal artery were respectively used for reconstruction for soft tissue defects around the knee or lateral malleolus, heel and foot [13].

In our study, we utilized the proximally based lateral superficial sural artery flap for the reconstruction of soft tissue defects around the knee in 14 patients, with patellar ligament necrosis in someone. The flaps all survived and all patients achieved a good final outcome that flaps possessed normal sensation and were thin, pliable and elastic. It is stimulant that all the operated knee performed good function and patients could walk normally though some cases showed necrosis of patellar ligament and patella. As the literature shows, the merits of the proximally based lateral superficial sural artery flap with thin, pliable, stretchable, and sensate skin were that incision of the flap was easy and change of patient position during elevation and inset of the flap was not required and the functional deficit of the donor area was minimal.

Another island fasciocutaneous flap for the reconstruction of soft tissue defects around the knee was the proximally based sural artery flap. Cheon et al [2] utilized the proximally-based sural artery flap for covering soft tissue defects around the knee and on the proximal third and middle third of the lower leg in 10 cases, with following-up for 1-2.5 years. The result showed that the flaps were thin and sensate, and did not restrict the excursion of the extensor apparatus, and no need microsurgical techniques, and had an excellent survival rate. However, they found that the disadvantages of the flap were sensory disability in the dorsolateral aspect of foot and inferior cosmetic results of the donor site. Suri et al [3] used proximally based sural artery flap for knee defects in 37

cases. They also found that the islanded sural artery flap provides thin pliable skin were a simple and reproducible technique and the flap is suitable in the regional reconstruction around the knee as a pedicled flap. As Cheon reported, the disadvantage of this flap included loss of sensation over the dorsolateral aspect of foot because the sural nerve was divided. However, the skin paddle of lateral superficial sural artery flap located at the proximal two thirds of posterolateral aspect of the leg, where the innervation was only provided by the lateral sural cutaneous nerve. The distal third of the leg, however, supplied by the lateral sural cutaneous nerve and the recurrent superficial peroneal nerve [14-16]. Thus, besides the advantages of the proximally based sural artery flap, cutting off the lateral sural cutaneous nerve had no effect on the sensation of the distal third of the leg, lateral malleolus, and the dorsolateral aspect of foot because the medial sural cutaneous nerve and sural nerve were meticulously protected when the proximally based lateral superficial sural artery flap was incised, which was another superiority of the flap.

There are several muscle flaps in the femoral and sural areas known available for reconstruction of the knee area, such as gastrocnemius muscle flap, sartorius muscle flap, vastus medial muscle flap and vastus lateral muscle flap, etc [17]. The gastrocnemius medial muscle flap was the most common for reconstructing defects around the knee due to the longer medial head of gastrocnemius, which was first reported by Barfed et al [18] in 1970. These muscle flaps without innervation, although very useful, were bulky and not a satisfactory match for the knee region due to contour defect and cosmetically disfiguring.

Perforator flaps, such as medial sural artery perforator flap, anterior tibialis artery perforator flap, anterolateral thigh perforator flap, the pedicled vastus medialis perforator flap, etc [19-22]. were the most popular reconstructing method for repairing skin defect around the knee with an excellent cosmetic outcome and minimal morbidity at the donor site in recent years. The perforator flaps were thin and pliable and so fulfills well the most of requirements of reconstruction in the knee area. However, the most disadvantage of perforator flap was non-sensate and time-consuming

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because a tedious dissection was required during dissecting the perforator vessel. In addition, the size of perforator flaps were much smaller and a need for familiarity with vascular anatomy and require perforator mapping using Doppler ultrasound due to the variation of perforator arteries.

Free flap was a good option to cover extensive defects around the knee joint. It offered the comfort of singlestage procedure but requires surgical expertise and infrastructure. What was more, finding a reliable recipient vessel for vascular anastomosis of free flap around the knee joint was challenging [23-25]. Cross-leg fasciocutaneous flap, which necessitates a staged procedure, may not be a suitable option for reconstructing defect around the knee when satisfactory single stage alternatives were available. Furthermore, the interim period of in-hospital limb immobilization could be uncomfortable and inconvenient for the patient and increase the incidence of complications, such as bedsore, deep venous thrombosis and joint stiffness, etc.

The other advantage of the proximally based lateral superficial sural artery flap was that the operational time required is relatively shorter because it does not require microsurgical skills and dissecting the perforators. Besides, it provided much greater arc of rotation and also provided much larger flap sufficient for reconstructing the defect area.

The disadvantage of this flap was inferior cosmetic result of the donor area due to skin graft in some patients. However, all patients were satisfactory with the functional improvement.

### Conclusions

The proximally based lateral superficial sural artery flap with constant blood supply provides a thin, pliable, stretchable, and sensate flap that has greater arc of rotation and is functionally and cosmetically acceptable. Skin sensation of posterior aspect of leg, lateral malleolus and the lateral border of the dorsum of foot are remained and changing of patient position during elevation and inset of the flap is not required. The surgical procedure is easy to perform and reproducible with minimal morbidity of the donor site. Thus, we believe that the proximally based lateral superficial sural artery

flap is an ideal pedicled flap that is suitable for regional reconstruction around the knee.

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### Disclosure of conflict of interest

None.

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