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Gastrocnaemius-propeller extended miocutaneous flap: A new chimaeric flap for soft tissue reconstruction of the knee

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Lower limb reconstruction;
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Summary Purpose: Soft tissue defects involving the anterior aspect of the knee are a frequent finding in a number of pathological conditions. The aim of this article is to describe a new pedicled flap consisting of a conventional medial gastrocnaemius muscle flap associated with a propeller flap based on a perforator of the medial sural artery.

Material and methods: Five males ranging in age between 26 and 72 years underwent a reconstruction of the soft tissue of the knee by means of the described procedure. Three patients sustained complex tissue loss subsequent to high-energy trauma; two losses were due to septic complications after elective knee surgery.

Results: Four flaps survived allowing adequate proximal tibial metaphysis and patella coverage. One patient underwent early above-the-knee amputation due to life-threatening septicaemia.

Discussion: The described chimaera flap consists of a medial gastrocnaemius flap with a skin paddle that is elevated on a perforator of the medial sural artery and then rotated according to the propeller flaps' principles. It provides effective coverage of large soft tissue defects of the knee. In the authors' experience, the propeller flap portion proved to be particularly useful to cover the patella, while the muscle flap was used to cover the proximal metaphysis of the tibia and fill the dead space if present.

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Soft tissue defects in the knee area may result from trauma, oncologic resection and from complications due to knee replacement surgery. The knee is often involved in high-energy trauma subsequent to motor vehicle accidents,

and severe soft tissue injuries are frequently associated with fractures, increasing the rate of complications, particularly if internal fixation devices are used to stabilise the bone.^{1–3} Soft tissue sarcomas requiring a wide margin

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of resection are also frequently located in the knee area, and simultaneous reconstruction is mandatory.^{4,5} In the orthopaedic literature, skin infections post-total knee replacement are observed in 2% of the procedures.⁶ It has been proven that 58% of patients develop a deep wound infection after having a superficial surgical-site infection post-total knee or hip arthroplasty.⁷ In a recent study, a 0.33% complication rate of early wound healing requiring a return to the operating room was reported following total knee replacement. Although this rate is quite low, the long-term effect of these complications is important. A 6% rate of deep prosthetic infection and a 5.3% rate of major additional surgery requirement were reported, which was much higher than for the control group (1.4% and 0.9%).⁸

Particularly in case of infection, the medial gastrocnemius muscle flap is still the best option to cover the proximal tibia. However, its arc of rotation is limited and a muscle is not the ideal tissue to cover the patella, which requires thin and pliable skin coverage.

The saphenous flap and propeller flaps based on the perforators of the deep femoral artery may be good alternatives to cover the patella region. They provide supple and pliable skin but when the defect involves the proximal tibial metaphysis, these flaps are not able to reach the recipient site to fill the dead space.

The authors report a new chimaeric pedicled flap consisting of a musculocutaneous medial gastrocnemius flap where the skin paddle is raised, after the transfer of the muscle, according to the principles of propeller flaps, and is oriented in a different direction in order to increase the potential area of coverage and reach the patella and distal femur. This flap fulfils the requirement to cover the tibial tuberosity with a muscle flap and the patella with a skin flap.

Material and methods

From 2010 to 2012, five males ranging in age between 26 and 72 years were treated for soft tissue defects around the knee. Among these defects, three were due to trauma, one due to infection and one post-knee replacement surgery. In all these cases, due to poor general or local condition of the patient, the goal was to cover a large soft tissue defect by means of a local flap. A musculocutaneous medial gastrocnemius flap was raised. After carrying out the first part of the dissection, the fasciocutaneous component over the muscle was then harvested to obtain a propeller flap based on the major musculocutaneous perforator from the medial sural artery. Having done that, it was then possible to rotate and place the skin paddle in a different direction from its muscle component (Figure 1).

Four patients healed uneventfully. One patient underwent emergency above-the-knee amputation, 4 days after surgery, due to life-threatening septicæmia. At the time of amputation, the flap was still viable.

Surgical technique

In case of trauma, it is recommended to perform an angiography of the lower extremity to assess the patency of the sural arteries. Preoperatively, an ultrasound Doppler is used to map the location of the musculocutaneous perforator

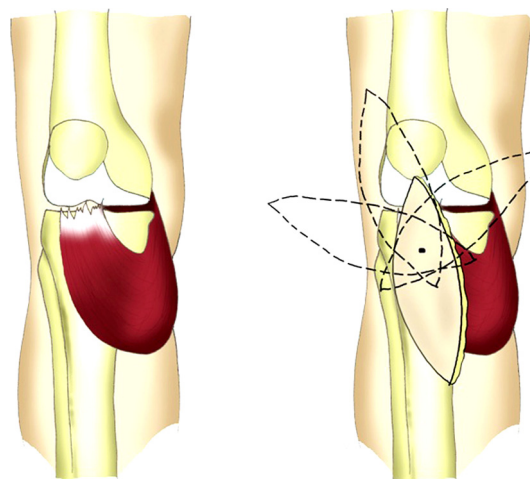


Figure 1 a) Conventional medial gastrocnemius is ideal for coverage of tibial tuberosity but it is not adequate in case of larger defects involving the patella. b) A propeller fasciocutaneous flap may be designed based on a single perforator raising from the medial sural artery and rotated in any direction. Patella is the ideal recipient site but the flap can reach also the tibial diaphysis if needed.

from the medial sural artery. One skin perforator from the medial sural artery can supply almost the whole skin above the medial gastrocnemius muscle.¹⁸ The skin perforator is ideally located in the centre of the skin paddle but, according to the principles of propeller flaps,⁹ it is more conveniently located in the proximity of either the distal or the proximal pole in order to increase the arc of rotation (Figure 2). A preliminary explorative incision is made on the cutaneous projection of the medial border of the medial gastrocnemius. The skin is elevated in a subfascial plane until the perforators are identified (Figure 3). All perforators identified during the dissection are spared until the dominant one is precisely located. Once the main perforator is identified and chosen, the flap design and skin incision are completed. Adequate vascularisation of the skin paddle is then assessed. Intramuscular dissection of the perforator is performed for 1 cm in order to obtain the desired arc of rotation of the skin paddle without any pedicle kinking. The skin paddle is secured to the underlying muscle to avoid shearing before raising the conventional medial gastrocnemius muscle flap. When the muscle flap is completely raised and the muscle belly securely sutured into the recipient site, the sutures of the skin paddle can then be removed and the skin oriented in the desired direction (Figure 4). A 90° rotation of the skin flap is often sufficient as the muscle flap covers the tibial tuberosity on a transverse axis while the skin paddle covers the residual defect on a longitudinal axis. With this technique, the authors were easily able to cover defects extending to the patella and distal femur. Primary closure at the donor site is possible for a skin defect <6 cm; a skin graft can be used otherwise.

Case presentation

A 32-year-old male, involved in a motorcycle accident, sustained a high-energy trauma to the left lower extremity.



Figure 2 Preoperative Doppler investigation identifies the best perforator that is marked on the skin. The flap design includes the perforator in the proximity of the proximal pole.

He reported a severe compound open fracture involving the distal femur and proximal tibia. The Mangled Extremity Severity Score (MESS) score was 7.¹⁰ He was initially referred to another institution where he was treated in the Emergency Department with bone stabilisation by means of a compression plate. No attempt at soft tissue coverage was done at the initial referring hospital. When referred to our Unit, 2 months after the injury, the patient presented a wide infected exposure of the knee joint, exposure of the hardware and bone necrosis (Figure 5). Radical resection of the knee joint, temporary replacement with a cement

spacer (Figure 6) and soft tissue coverage were planned. A chimaeric flap composed of a medial gastrocnemius flap augmented with a propeller flap, based on a perforator of the medial sural artery, was used to reconstruct the soft tissue. The muscular belly was rotated to cover the proximal tibia and a skin flap, 18 cm long and 12 cm wide, was then elevated and rotated 90° to cover the knee joint and the distal femur (Figure 7). Both flaps survived and healed in 15 days achieving a reliable coverage of the cement spacer and the exposed bone (Figure 8). A skin graft was needed to close the donor site (Figure 9).

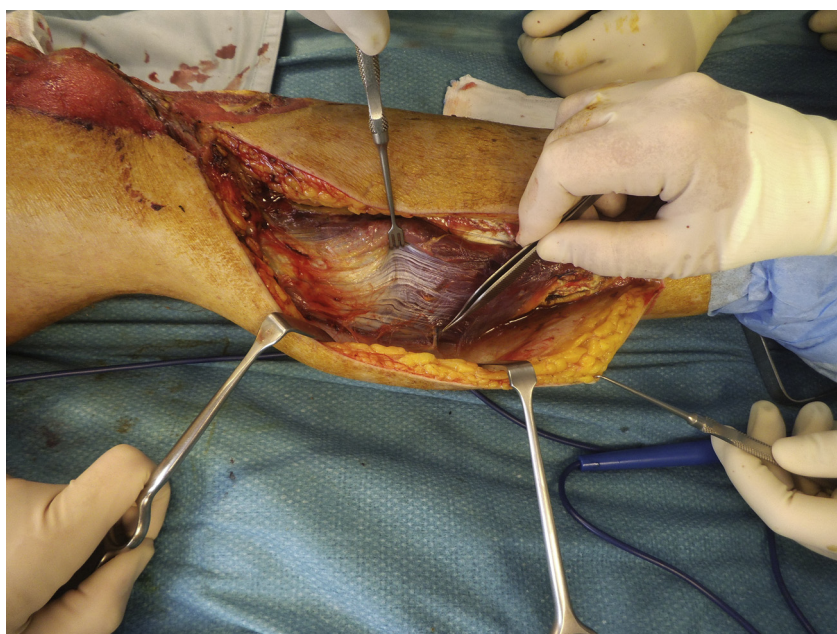


Figure 3 A straightforward dissection in the sub-fascial plane allows for direct visualization of the best perforator.



Figure 4 The muscle is secured to the tibial metaphysis and the skin paddle may be rotated on a single perforator according to the propeller flaps principles.

At 3 months' follow-up, both the donor and recipient sites are healed ([Figure 10](#)).

Discussion

Adequate coverage of the knee is often a challenge for the reconstructive surgeon. Local options are quite limited in terms of size and are often restrained by their arc of rotation. However, free flaps may increase the length and complexity of surgery. Whenever possible, salvage of the knee joint is highly advocated, as above-the-knee amputation is associated with a high complication rate and increase in energy expenditure for the patient. It is well established that muscle flaps are best indicated to fill the dead space when present; besides, the high vascular volume of these flaps serves as a carrier for antibiotics locally. Fasciocutaneous flaps, though, provide thin and pliable skin offering a good, deep gliding surface over the patella and are, therefore, preferred to cover the anterior aspect of the knee joint. The workhorse flap to cover defects following infection, trauma and tumour excision in the anterior aspect of the knee is still the medial gastrocnemius muscle flap. It provides good vascularised tissue that helps sterilise the recipient site, it is wide and bulky enough to cover a prosthesis and fill the dead space if needed, and it can be transferred as a musculocutaneous flap to provide skin coverage. Unfortunately, the medial gastrocnemius flap cannot easily reach the upper portion of the knee. In addition, the conventional musculocutaneous flap, raised along with the skin extension over the medial gastrocnemius, is quite bulky and the cutaneous portion being attached to the underlying muscle cannot be freely and independently placed to increase the surface of the flap.

To increase the length of the flap, different techniques have been reported. These techniques mainly entail scoring

the underlying muscle fascia and/or dissecting the muscle up to its origin. Whitney et al. reported on an angiographic study performed to identify the origin of the sural arteries in relation to the joint space. According to this article, the origins of the arteries were located above the joint line in all the cases (mean of 32 ± 14.5 mm above the lower femur). The medial gastrocnemius muscle was mobilised up to 21 and 26 cm, respectively, above the joint line to



Figure 5 Clinical and Radiographic appearance at the time of referral. The lateral condyle of the femur has been avulsed by the trauma. Large soft tissue defect, infected exposure of the knee joint, exposure of the hardware and bone necrosis.



Figure 6 Radical debridement of the distal femur and the joint. Custom made cement spacer.



Figure 7 The mio-cutaneous flap is elevated and transferred into the recipient site. The skin paddle is then rotated upward to cover the cement spacer, which replaces the distal femur.

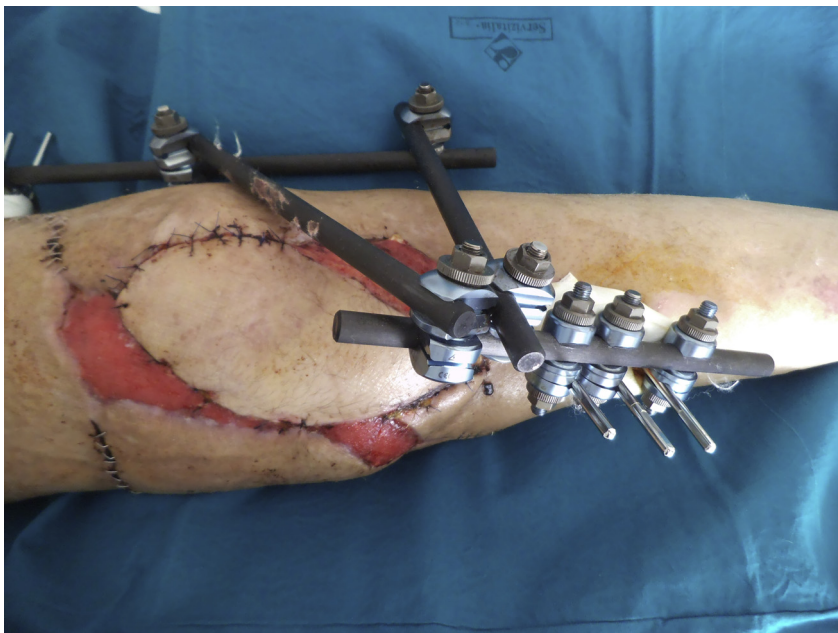


Figure 8 Clinical outcomes four weeks after surgery.



Figure 9 Donor site.

cover two defects.¹¹ In our experience, nonetheless, proximal dissection of the pedicle may be tricky and time consuming and it is often difficult to achieve a good coverage for the upper knee area. In addition, the muscle tends to adhere to the patella instead of providing a smooth gliding surface.

Propeller flaps have been extensively used for soft tissue reconstruction in almost all the anatomical districts.^{12,13} They can be raised virtually anywhere a suitable perforator is available and they follow simple principles. The eccentric location of the pedicle and the possibility to rotate the flap as much as 180° allow for a great coverage potential of small- to-medium-sized defects according to the principle of 'repair like with like'. The morbidity at the donor site is minimal. Any axial artery of an anatomical region (source artery) gives perforators able to supply skin flaps. In this case, the source artery is the medial sural artery and it is within the medial gastrocnemius muscle. In 1996, Montegut¹⁴ first described the clinical application of the medial sural artery perforator flap. The anatomical background, however, dates back to the 1970s when Taylor and Daniel investigated the surgical anatomy of the region considering possible donor sites for free flaps.¹⁵ More recently, Hallock pointed out the availability of this pedicled flap to reach, as far as the medial gastrocnemius muscle flap itself was concerned, the knee and upper third of the leg defects.¹⁷ Lately, several anatomical studies have been carried out to define the number, size and location of these perforators.^{16–19} According to Wong et al., in 2012, the medial sural artery gives off two branches, a medial one and a lateral one (the lateral being the one towards the midline of the muscle). Two to six perforators are identified, from 10 to 16 cm from the popliteal crease, with a mean of 10 cm from the popliteal crease for the larger one. The perforators from the lateral row are larger and located, in average, 2 cm from the midline.¹⁹ Perforators from the lateral row are also more

frequent, being present in 66% of the dissections versus 34% from the medial row.¹⁸ The lateral sural artery system and its perforators, which supply the medial gastrocnemius muscle and the overlying skin, are much less reliable, being present in only 20% of the dissections.¹⁶ The skin perforator from the medial sural artery is able to supply almost the whole skin overlying the muscle, with an average area of 13 × 8 cm.¹⁸ Although the above-mentioned anatomical studies attempt to provide surgical landmarks for the identification and dissection of perforators, it is our opinion that any single patient should be preoperatively investigated by a Doppler ultrasound. The best perforator should then be identified and marked on the skin before surgery.

Conclusions

The authors present a single reconstructive solution for soft tissue loss around the knee, which combines the workhorse gastrocnemius muscle flap with its skin perforator component, both based in the medial sural artery. The described technique allowed a substantial increase of the flap surface and therefore the coverage potential (especially in the lower femur area), avoiding the use of a second local thigh perforator flap or a free flap.

Previous articles have described the medial gastrocnemius muscle flap and also the medial sural perforator flap, but no studies have combined the two techniques to provide a chimaeric flap. The presented flap has proven to be extremely useful for knee reconstruction where the defect is too large for a single medial gastrocnemius muscle flap. In our preliminary experience, the best indication for this flap is in defects involving the tibial tuberosity and extending proximally up to the quadriceps tendon. In these cases, the muscle easily achieves a safe coverage of the proximal tibia, while the skin paddle,



Figure 10 Clinical outcomes at 3 months follow-up.

rotated upwardly of 90°, provides excellent, thin and pliable skin to cover the patella. In addition, in case of defects involving the tibial diaphysis, the skin flap may be rotated distally, achieving optimal reconstruction of the soft tissue overlying the tibial crest.

In conclusion, this flap has proven to be versatile and highly reliable, offering an alternative solution to reconstruct medium- to large-sized defects around the knee. Its anatomy is consistent and the dissection relatively straightforward.

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