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Popliteal Axis Flaps for Reconstruction of Extensive Defects of the Knee and Upper Two Third of the Leg

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ABSTRACT

Defects around the knee and proximal leg are very common. They usually result from road traffic accidents as well as resection of malignant tumors. Reconstructive modalities available in these regions include regional flaps, free flaps or cross leg flaps. Free flaps are not always feasible if recipient vessels are located in the zone of injury and well trained microsurgery team may not be available. Cross-leg is a very cumbersome two-stage procedure and positioning may not be tolerated by most of the patients. The popliteal axis supplies the gastrocnemius muscle through the medial and lateral sural vessels and the sural fasciocutaneous flap through the superficial median sural artery. Each these regional pedicled flaps can cover defects around the knee joint and the upper third of the leg. The sural artery flap has the virtue of reaching the middle third of the leg. In this study, we describe our clinical experience with popliteal axis flaps for reconstruction of knee and leg defects in 17 patients. The medial head of gastrocnemius was used in ten cases and the lateral head in two cases. The sural artery flap was applied solely in two cases. We report a new chimeric flap based on the popliteal vascular axis: A combination of two flaps, the medial head of gastrocnemius and sural fasciocutaneous, was used to cover more extensive defects extending from knee to the middle third of the leg in three cases. Our study showed the popliteal axis flaps are reliable in reconstruction of knee and leg defects with minimal complications and short operative time. They are good alternatives to the more sophisticated free flaps.

Key Words: *Popliteal – Flaps – Reconstruction – Knee – Leg.*

INTRODUCTION

Lower extremity soft tissue defects may result from high energy trauma, extensive osteomyelitis with osteonecrosis, tumor extirpation with or without radiation therapy, diabetic ulceration and peripheral vascular disease and failed joint replacement **[1]**. Free tissue transfer is indicated for some middle third and most distal third leg defects. However, gastrocnemius muscle flap is considered the workhorse flaps in knee and proximal leg reconstruction **[2]**. For more extensive defects, several modifications were described including scoring of the muscle fascia, the use of gastrocnemius fasciocutaneous flap, placing a skin paddle at the distal end of the medial head of gastrocnemius, transposition of the muscle as an island flap, and more recently the use of the muscle-sparing gastrocnemius perforator artery flap **[3-7]**. In this study, we describe our experience with traditional pedicled gastrocnemius muscle flaps, the sural artery flap and we report the concomitant use of the medial head of gastrocnemius muscle and sural fasciocutaneous flap based on the popliteal vascular axis for reconstruction of extensive defects over the knee and upper two thirds of the leg. (Fig. 1).

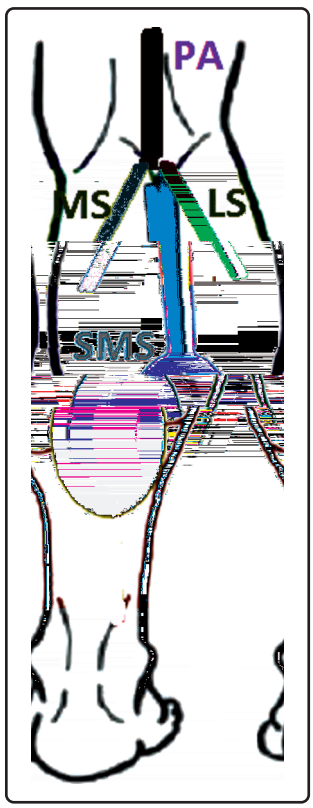


Fig. (1): The popliteal vascular axis: The medial sural artery (MS) supplying the medial head gastrocnemius muscle flap, the lateral sural artery (LS) supplying the lateral head gastrocnemius muscle flap and the superficial median sural artery (SMS) supplying the sural artery fasciocutaneous flap. Each muscle flap can be raised separately or in combination with sural artery flap as a "chimeric flap" based on the popliteal artery (PA).

PATIENTS AND METHODS

This study was performed on 17 patients from May 2011 till June 2015. Thirteen patients were male and four were females. Their ages ranged between 7 and 54 years (mean 27.5 years). Patients with defects in the knee region and the upper two thirds of tibia were included in the study. The causes of the defects were compound fractures of the tibia with exposed bone or hard ware (9 cases), gun-shot injury (2 cases), osteomyelitis in the tibia (2 cases), pressure ulcer by lower limb prosthesis (one case), unstable scar or ulcer in the knee region (2 cases) and septic arthritis of the knee with multiple sinuses in the leg (one case). The cases studied are summarized in Table (1).

Table (1): Summary of patients.

	Patient age (years)	Sex	Cause of the defect	Site of the defect	Size of the defect	Flap used for reconstruction
1	20	F	Road traffic accident	Upper 1/3 of the right tibia	5x8 cm	Medial head muscle flap
2	24	M	Gunshot injury	Lateral side of upper 1/3 of left leg	4x8 cm	Lateral head muscle flap
3	18	M	Road traffic accident	Upper 1/3 of right tibia	4x6 cm	Medial head muscle flap
4	28	M	Osteomyelitis	Upper 1/3 of left tibia	5x5 cm	Combined medial and distally based lateral head muscle flap
5	32	M	Septic arthritis of the knee	Right knee and upper 1/3 of right tibia	9x8 cm	Combined medial and half of lateral head muscle flap
6	54	M	Pressure ulcer	Lateral side of the left knee	4x4 cm	Lateral head muscle flap
7	42	M	Unstable scar	Anterior aspect of the left knee	6x6 cm	Medial head musculocutaneous flap
8	32	M	Road traffic accident	Lower aspect of right knee	4x4 cm	Medial head muscle flap
9	21	M	Road traffic accident	Upper 1/3 of left tibia	5x6 cm	Medial head muscle flap
10	37	M	Road traffic accident	Upper 1/3 of left tibia	5x5cm	Medial head muscle flap
11	30	M	Gunshot injury	Upper 1/3 of right tibia	6x8 cm	Medial head muscle flap
12	54	F	Post-inflammatory ulcer	Right knee	5x7 cm	Medial head muscle flap
13	7	M	Road traffic accident	Knee and upper 2/3 of right tibia	27x10 cm	Combined medial head muscle and sural fasciocutaneous flaps
14	26	M	Road traffic accident	Upper 2/3 of left tibia	22x9 cm	Combined medial head muscle and sural fasciocutaneous flaps
15	20	F	Infection over hardware	Upper 2/3 of right tibia	24x13 cm	Combined medial head muscle and sural fasciocutaneous flaps
16	23	M	Exposed hardware	Middle third of right tibia	10 x8cm	Sural artery flap
17	28	F	Post-inflammatory ulcer	Middle third of right tibia	7x6cm	Sural artery flap

N.B.: Size of the defect is measured after debridement.

A signed written consent is taken from each patient before surgery. Traumatic cases were done after resuscitation, debridement and bone stabilization by the orthopedic surgeon. Gun shot injury was done after repeated debridement and systemic & topical antimicrobial therapy till necrotic tissue is removed and infection is controlled. Septic arthritis was treated after control of infection by systemic antibiotics and joint irrigation.

Surgical technique:

Medial and lateral head gastrocnemius flaps:

Surgery is done under general endotracheal anesthesia in the prone position. Muscle harvesting is done through an anterior approach. The medial head of gastrocnemius muscle is dissected through a longitudinal incision in the leg 2cm posterior to the tibia as described by Mathes and Vasconez, **[8]**. In short, the plane between the gastrocnemius and soleus is identified and the muscles are bluntly separated in the upper third of the leg preserving plantaris tendon. Distally, sharp dissection is needed till the tendinous insertion is reached and divided. Superficially, the medial head is dissected from the overlying skin at subfascial plane taking care to avoid injury of the lesser saphenous vein and the sural nerve. The lateral head of gastrocnemius is exposed in a similar way through a vertical incision 2cm posterior to the fibula. Dissection is done in the upper third of the leg taking care to avoid injury of the peroneal nerve around the head of the fibula. Combined medial and part of the lateral head of gastrocnemius are exposed through the same approach of the medial head. Medial head of gastrocnemius musculocutaneous flap is elevated in the same way of the medial head without the subfascial separation. Additional posterior median and distal transverse incisions are made 5cm proximal to the flare of the medial malleolus.

Sural artery fasciocutaneous flap:

A posterior approach was used for elevation of sural artery flap or composite medial head of

gastrocnemius and sural flap. The limb is exsanguinated by elevation and a tourniquet is applied. It is important that the short saphenous vein retains some blood to facilitate the dissection and identification of the pedicle. Initially, a line was drawn on the posterior calf to indicate the course of the sural nerve and adjacent lesser saphenous vein, usually extending from the midpoint of the lateral malleolar tip and Achilles's tendon to the midpoint of the popliteal skin crease. The donor site was centered on this line, which also roughly marked the course of the pedicle. The flap pivot point is at 2cm below the popliteal crease. The territory of the sural artery flap extends vertically from just below the popliteal fossa to 7cm above the lateral malleolus. Horizontally, the safe flap width spans the whole of the posterior aspect of the gastrocnemius muscle ranging from 8-10cm. After using a template to design the flap the medial, lateral and inferior borders of the flap are incised to the deep fascia while it stops just above the fascia in the upper border. The vascular pedicle containing the short saphenous vein, the superficial median sural artery and the sural nerve are identified running within the deep fascia. They are ligated and cut along the inferior border of the flap. The dissection proceeds from distal to proximal and once reaching the upper border of the flap the incision is completed to include the deep fascia except 3cm around the pedicle where the fascia and subcutaneous fat are left intact. For further mobilization the rest of calf skin is undermined leaving just a cm of fat attached to the dermis and in a cephalad direction until just below the popliteal fossa and the fascia around the pedicle is divided both medially and laterally leaving a cuff of 3cm of fat and fascia around the vessels and nerves. Now the sural flap is free to rotate to reach from middle third of the leg up to the knee joint.

After sural artery flap elevation, the two heads of the gastrocnemius muscle are totally exposed and the elevation of any of its heads is straightforward depending on the defect proximity to each one of them. The combination of the sural artery flap with any of the gastrocnemius heads allow for coverage of extensive defects extending from knee joint to the middle third of leg.

The position of the patient is changed as necessary to transpose and suture the flap onto the primary defect. A drain is left under the flap at the end of the operation and removed after one week. Skin grafting of the donor site in case of sural artery flap was performed immediately with a mesh graft while muscle flap grafting was postponed one week after flap transfer. Gentle mobilization of the knee is encouraged after 2 weeks till full range of motion is gained in 6-8 weeks.

RESULTS

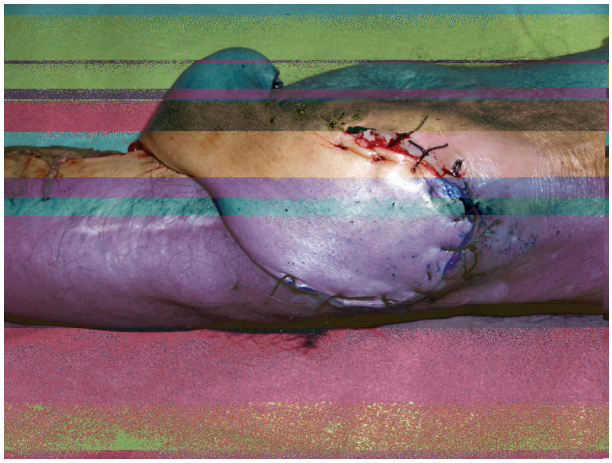
Medial head gastrocnemius flap was used to treat defects in the knee region and the upper third of tibia as a muscle flap in 9 patients and as a musculocutaneous flap in one patient (Fig. 2). The lateral head was used to reconstruct a pressure ulcer in the lateral side of the knee joint or the upper third of the leg in 2 cases (Fig. 3). The medial head was combined with antegrade sural fasciocutaneous flap in 3 cases when the defect was extensive reaching the middle third of the tibia (Fig. 4). The sural artery flap was used solely for exposed middle third of the leg in 2 cases.

All the gastrocnemius muscle flaps were viable except in one case of gun shot injury where partial loss occurred because of partial damage of the internal vasculature by small shots. Marginal loss occurred in the fasciocutaneous sural flap that eventually healed by debridement and local wound care. Prolonged edema was observed in the 2 cases, one of them was a patient with combined medial head of gastrocnemius muscle and sural fasciocutaneous flap and the other with medial gastrocnemius musculocutaneous flap. Regular daily activities were not affected after ambulation but we have no feedback about any deleterious effect on exercise. Sensory deficit was detected in the foot of the 5 patients for whom sural flap was used because division of the sural nerve was obligatory for flap dissection and vascular safety. The complications are summarized in Table (2).

Table (2): Complications.

Complication	Number of cases	Percent	Comment N = 17
Partial muscle necrosis	1	5.8%	Partial injury of internal vasculature
Marginal skin necrosis	1	5.8%	Oversized sural artery flap
Total necrosis	0	0%	–
Leg edema	2	11.7%	Use of musculocutaneous or sural flap
Delayed healing	2	11.7%	Partial or marginal flap necrosis
Gait & everyday activity disturbance	2	11.7%	Knee joint stiffness
Sensory deficit	5	29.4%	Transection of the sural nerve

(A)



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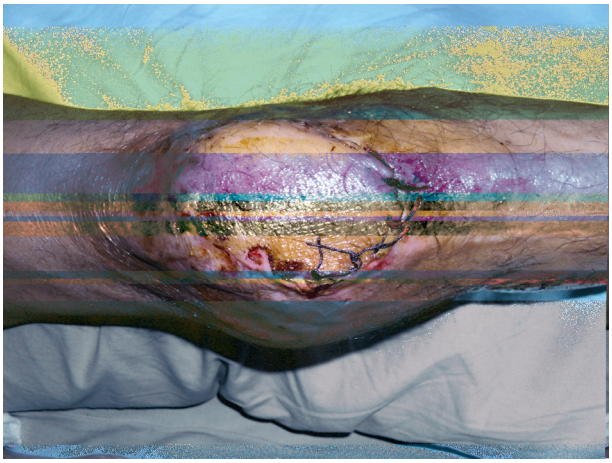

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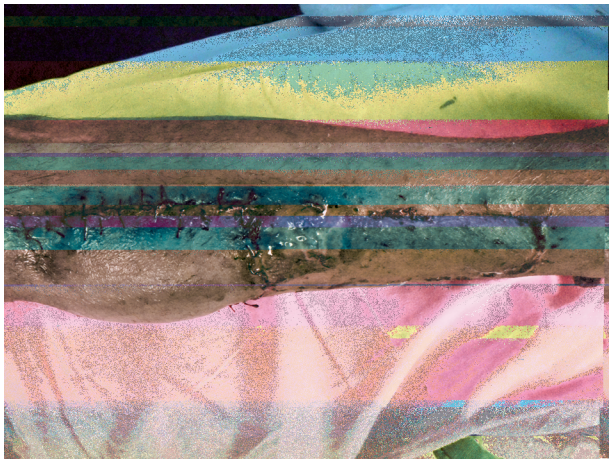

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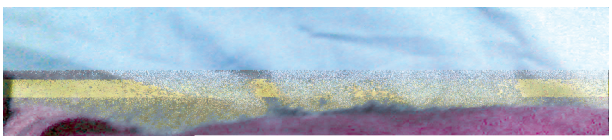
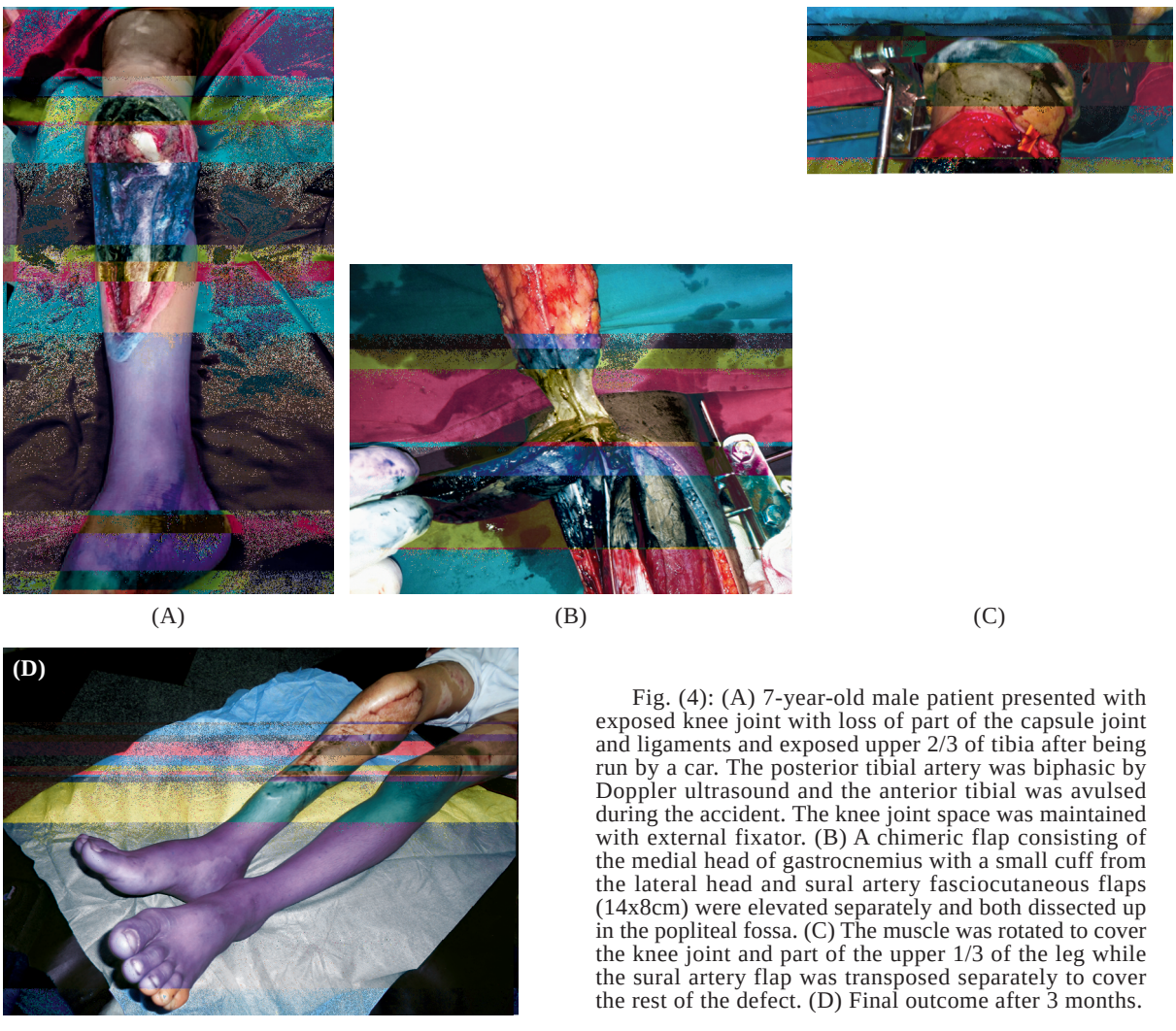


(E)

Fig. (2): (A) A 42-year-old male patient presented with unstable scar over the left knee. (B) After debridement the medial head gastrocnemius musculocutaneous flap was raise with a skin paddle extending just a 3 cm above the ankle joint. The defect was covered with the kin paddle and donor site closed by STSG. (C&D) 2 weeks later the skin flap was divided and the muscle flap with overlying skin returned to its place. (E) Result after 35 days.

(A) (B) (C)

Fig. (3): (A): A 24-year-old Male patient presented with gunshot injury of the lateral aspect of the left leg. After debridement of the soft tissue and peronei muscles a part of fibula and lateral aspect of tibia was exposed. (B) The lateral head of the gastrocnemius muscle was elevated and turned into the defect. (C) Final result after grafting the muscle flap.



(A) (B) (C)

Fig. (4): (A) 7-year-old male patient presented with exposed knee joint with loss of part of the capsule joint and ligaments and exposed upper 2/3 of tibia after being run by a car. The posterior tibial artery was biphasic by Doppler ultrasound and the anterior tibial was avulsed during the accident. The knee joint space was maintained with external fixator. (B) A chimeric flap consisting of the medial head of gastrocnemius with a small cuff from the lateral head and sural artery fasciocutaneous flaps (14x8cm) were elevated separately and both dissected up in the popliteal fossa. (C) The muscle was rotated to cover the knee joint and part of the upper 1/3 of the leg while the sural artery flap was transposed separately to cover the rest of the defect. (D) Final outcome after 3 months.

DISCUSSION

Since it was described in 1970 by Ger and Efron, gastrocnemius muscle flap remains the workhorse for reconstruction of knee and upper tibial defects [9]. According to the vascular supply each head of gastrocnemius muscle can be mobilized as type I muscle flap [8]. The medial and lateral sural arteries arise from the popliteal artery separately or from a common trunk above the articular line of the knee joint.

The average muscle flap dimensions are 15x7cm for the medial head and 12x5cm for the lateral head [2]. To enlarge the surface area of the muscle, Arnold and Mixter recommended the vertical or transverse cuts along the perimysium on the deep surface of the muscle, like the galea in the scalp, to allow the muscle to cover wider and distal defects [3]. Anatomical studies documented the presence of venous and arterial communications between the medial and lateral heads of gastrocnemius muscle [10]. According to Masquelet and Sassu, one muscle head can survive totally based on the vascular communications between the two bellies, the dominant vessel is the medial sural artery [2]. We used the medial head with the medial half of the lateral head to cover wide defects (case 4 and 13) or deep defects (case 5).

The gastrocnemius musculocutaneous flap has a wider arc or rotation as the skin territory extends beyond the muscle. The fasciocutaneous part can be used to cover extensive knee and middle third tibial defects without elevating the muscle [8]. The medial gastrocnemius musculocutaneous flap can be carried to a point 5cm proximal to the medial malleolus [4]. The skin distal to the muscle is supplied by musculocutaneous perforators that pierce the muscle in the proximal part of the calf 7-18cm from the knee crease [2]. We used the musculocutaneous version of gastrocnemius to cover anterior and lateral knee defect (case 7). The fasciocutaneous extension is thin in lean patients and allows free gliding of the skin over the patella. However, it is a two-stage procedure requiring division of the musculocutaneous pedicle after 3 weeks. Alternatively, a skin paddle may be placed at the distal end of the medial head with thinning of the muscle without endangering its blood supply [5].

The concept of muscle-sparing perforator flaps is gaining popularity because it allows transfer of the same skin territory without sacrificing the muscle. Cavadas et al., anatomically investigated and described the medial sural artery musculocutaneous perforating branches that nourish a cutaneous flap [7]. They also reported on 5 cases of free perforator flaps for distal leg and foot reconstruction and one case of pedicled perforator flap for covering a defect of total knee replacement arthroplasty. However, the dissection of the perforator vessel is both tedious and involves extensive manipulation of the vascular pedicle because it is totally intramuscular.

Free tissue transfer is indicated for some middle third and most distal third leg defects. Extensive avulsion and crushing produce a wide zone of injury beyond the margin of the wound where inflammatory changes and perivascular friability contribute to high failure rate of anastomosis for microsurgical free tissue reconstruction [1]. Moreover, free-tissue transfer is a prolonged procedure that necessitates dissection proximal to the zone of injury for exposure of recipient site vessels or the use of interpositional vein graft and is not without complications.

In 1985, Moscona et al., first described an islanded fasciocutaneous flap of the posterior calf for knee defect reconstruction as a random pattern flap deriving blood supply from the fascial plexus, and failed to recognize the contribution of the median superficial sural artery [11]. Later Suri et al and Cheon et al., used the proximally based sural fasciocutaneous or adipofascial flap to repair the soft tissue defects in 10 and 37 cases, respectively [12,13]. Recently Pan et al., performed sural flaps on 18 patients with no complication whatsoever [14]. In this study, we found that the sural artery flap is reliable with only one case (case 13) showing distal 1-2cm necrosis. This is partly due to an oversized flap and the injury of the vascular pedicle in the distal part of the flap.

Taylor and Pan, described the sural angiosome as one of the 4 angiosomes of the leg. Antegrade arterial supply of the skin and fascia of this angiosome comes from 1-3 superficial sural arteries, named medial, median and lateral based on their relation to the heads of gastrocnemius muscle [15]. The venous drainage of this angiosome is through the short saphenous vein and the smaller collateral veins [16]. To avoid the sophisticated, time-consuming perforator and free flap techniques, we report the use of combined medial head muscle and sural fasciocutaneous flaps to cover extensive knee and leg defects in 3 cases. Similar to the subscapular vascular axis and the lateral circumflex femoral vascular axis, the popliteal vessels supplies 3 different flaps which can be combined to reconstruct extensive defects around knee and upper

leg. The advantages of this procedure are numerous. First, the operative time is short (ranging between 60 and 90 minutes). Second, the posterior approach allows harvesting of both flaps which are closely-related in the calf region. Third advantage, like chimeric flaps, it allows independent coverage of knee defects and the upper 2/3 of the leg with gastrocnemius muscle covering the knee and part of the upper third of leg while the sural fasciocutaneous flap reconstructing the rest of the defect up to junction of the lower third. Moreover, this chimeric flap is safe and the results are reproducible. The muscular part enjoys the vascular reliability of type I muscle flaps and the sural fasciocutaneous flap enjoys vascular safety because it depends on antegrade arterial supply and normal direction of venous drainage. The fifth and last advantage, reconstruction of defects in the middle third of the tibia by the sural fasciocutaneous flap preserves the venous pump function of soleus muscle **[17]**.

Complications of the procedure are few. The use of the medial head of gastrocnemius as a muscle flap is associated with minimal disability because of compensation of its function by soleus, flexor digitorum longus, flexor hallucis longus and tibialis posterior **[18]**. Gait and muscle strength analysis in case of loss of both heads of gastrocnemius and soleus muscle revealed great loss in plantar flexion, early fatigue during exercise and inability to run although normal gait was not severely disturbed **[19]**. In our study, normal ambulation was achieved in all cases except in 2 cases (11.7%) because of knee stiffness and limitation of the range of motion (case 5 and 13). Five cases (29.4%) had insignificant loss of sensation in the lateral side of the foot. In these cases, the sural nerve is transected and elevated with the flap. We did not study the limb function during exercise.

In their retrospective study, Diageler et al., 2009 found that 7% of the cases required reoperation because of wound healing problems **[20]**. Partial muscle flap necrosis was reported to be 7-10% **[3,21]**. It was attributed to smoking, compression from wrong positioning, or lack of patient compliance in the postoperative period. Recurrent or residual infection occurred in 4-9.5% of cases and was attributed to inadequate debridement or recurrent osteomyelitis **[20,21]**. In our study, wound healing problems were encountered in 2 cases (11.7%) due to intramuscular injury and partial necrosis of the lateral head in one case and marginal necrosis of sural flap in another case. These complications required debridement and wound care till wound closure by grafting (case 2) or healing by secondary intention (case 13).

Edema is an uncommon complication in our series. 2 cases had leg and ankle edema that persisted after ambulation (11.7%). One of them was a patient with combined medial head of gastrocnemius muscle and sural fasciocutaneous flap and the other with medial gastrocnemius musculocutaneous flap. Pico et al., found leg edema in 100% of cases treated by gastrocnemius musculocutaneous flap **[21]**. The cause of edema is not clear in those 2 cases and may be attributed to the division of the lesser saphenous vein which is the main drainage port of the sural angiosome, together with extensive scarring and damage to the subcutaneous perivascular lymphatics **[16]**.

Conclusion:

The popliteal axis flaps, the gastrocnemius muscle with or without the sural flap, are very reliable reconstructive surgical procedures for problematic and extensive defects in the knee region and the upper two third of the tibia. The use of a chimeric flap based on the popliteal vascular axis consisting of gastrocnemius muscle and the overlying sural artery flap has been shown to be very useful in extensive upper 2/3 defects of the leg. Their application preserves soleus muscle with its venous pump and contribution to ankle flexion and normal gate. The technique of flap harvesting is not sophisticated or time-consuming like perforator flaps or microvascular free tissue transfer.

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