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Versatile Use of the Local Muscle Flaps Pedicled by Gastrocnemius and Hemisoleus Muscle with a Longer Reach for Coverage of Lower Extremity Defects

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Abstract

Purpose: *This study aims to highlight the clinical usefulness of multiple local muscle flaps pedicled on the gastrocnemius and hemisoleus muscles for managing soft-tissue defects of the lower extremity. The technique was applied to defects involving the distal femur and the distal one-third of the tibia, avoiding the need for free flap reconstruction.* ***Methods:*** *From January 2014 to January 2023, multiple local muscle flaps were planned and utilized for the reconstruction of lower-extremity defects in a total of 13 patients. These procedures were performed to achieve adequate soft-tissue coverage, restore limb function, and improve overall clinical outcomes following trauma or complex tissue loss.* ***Results:*** *All patients achieved complete wound healing, with only minimal and manageable complications observed during the postoperative period, indicating a favorable outcome of the reconstructive procedure. Conclusions: Local muscle flaps based on the gastrocnemius and hemisoleus muscles represent an effective alternative for the coverage of lower-extremity defects, providing extended reach and reliable soft-tissue coverage while eliminating the need for free flap reconstruction.*

Keywords: local muscle flap, gastrocnemius muscle, hemisoleus muscle, lower extremity defect

INTRODUCTION

Adequate reconstruction of both bony and soft-tissue defects is essential to minimize the risk of persistent infection and to preserve functional outcomes [1, 2].

Also adequate initial debridement of the involved area, so that the flap is placed in a healthy environment, helps to ensure the success of the procedure [3, 4].

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Soft-tissue reconstruction after extensive debridement aims to obliterate dead space and can involve procedures ranging from simple local muscle flaps based on a vascular pedicle to complex microvascular free-tissue transfers. In cases of chronic tibial osteomyelitis, local muscle flaps are most commonly employed, with reported success rates varying between 66% and 100%. Traditionally, the gastrocnemius muscle is used to address defects in the proximal third of the tibia, while the soleus muscle is preferred for defects in the middle third [5, 6].

Reconstruction of soft-tissue defects involving the heel, ankle, and distal third of the leg remains particularly challenging for plastic surgeons, as safer techniques with minimal donor-site morbidity

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are still being sought. Although microvascular free-muscle transfer is often considered necessary for distal-third tibial defects, such procedures may not be feasible in all clinical settings. Limited institutional resources, lack of microsurgical expertise, or patient-related factors – such as poor general health, inability to tolerate prolonged anesthesia, or poor postoperative compliance – can restrict the use of free flaps [7–9].

In response to these limitations, we developed a novel approach using multiple local muscle flaps based on the gastrocnemius and hemisoleus muscles for coverage of lower-extremity defects, including those involving the distal femur and distal one-third of the tibia. This technique is reliable, versatile, and associated with minimal donor-site morbidity and a low complication rate. Depending on the defect location, the flaps can be raised proximally as a continuous gastrocnemius–soleus flap or distally as an individual hemisoleus flap based on the posterior tibial artery, providing greater reach and flexibility in reconstruction [10–12].

MATERIALS AND METHODS

The procedures in this report were conducted in the Department of Plastic and Microsurgery, the General Hospital of the Ryanggang Province.

From January 2014 to January 2023, 13 consecutive patients (10 men and 3 women from 25 to 46 years old, with an average age of 37 years) underwent thirteen multiple local muscle flap reconstructions.

Nine wounds were located in the heel, three in the tibia, one in the distal femur.

The wounds' characteristics were dead space combined with skin defects in chronic wounds.

The skin defect size ranged from 2 × 3 cm2 to 30 × 8 cm2, and volume of the bony cavity ranged from 2 × 3 × 0.5 cm3 to 20 × 3 × 2 cm3.

In eleven patients, the lower extremity wound also involved bony cavities, and in two of these patients with superficial bony defects.

The age of the defect was from 4 days to 3years (Table 1).

Table 1. Patient's data.

Case	Age/ sex	Location of defect	Mechanism of wound	Age of defect (Day)	Skin defects (cm^2)	Volume of the bony cavity (cm^3)	Type of flap	The time of laying drainpipe (Day)	First weight bearing (Week)	Follow -up (Week)	Reappearance of the osteomyelitis	Other complication
1	31M	Femur	Electrical burn	37	240	6.8	1	3	6	52	-	-
2	25M	Tibia	Trauma	1075	175	120	1	18	8	260	-	-
3	29F	Tibia	Trauma	4	60	8	1	17	24	104	-	-
4	31M	Heel	Trauma	27	7	3	2	21	17	52	-	-
5	43F	Hell	Trauma	26	7	2.8	2	17	23	104	-	-
6	37M	Heel	Trauma	40	9	3.5	2	19	26	72	-	-
7	35M	Heel	Trauma	32	6.5	2.8	2	15	24	208	-	-
8	46M	Heel	Decubitus	27	8	3.1	2	22	27	46	-	-
9	42M	Heel	Trauma	53	9	4	2	7	19	156	-	-
10	38M	Heel	Trauma	41	8	8.7	2	9	22	24	-	-
11	43M	Heel	Trauma	27	7	6.8	2	13	20	120	-	-
12	39M	Heel	Trauma	45	6	3.5	2	31	21	156	-	-
13	42F	Hell	Decubitus	32	6	6.2	2	5	24	52	-	foot drop

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All 13 cases underwent complete debridement prior to the procedure.

In preoperative test, the anterior tibial artery and posterior tibial artery were identified by means of the Doppler ultrasound.

Intravenous Antibiotics Were Used in All Patients.

Following the procedure, the dimensions of the bone cavity and the extent of the associated soft-tissue defect were carefully documented. Scar tissue along the wound margins, as well as all necrotic soft tissue, was thoroughly excised. Sclerotic bone and loose necrotic bone fragments were removed, and in cases of severe bone sclerosis, an orthopedic grinding drill was used to flatten the hardened bone until healthy tissue was reached and pus drainage was achieved.

The wound bed was then irrigated three times using hydrogen peroxide followed by copious amounts of normal saline, and all dressings were replaced under sterile conditions. Excised bone and soft-tissue specimens were sent for histopathological analysis and bacterial culture.

Selection of the gastrocnemius or hemisoleus muscle flap was based on the anatomical location of the defect. All flaps were elevated under tourniquet control, with precise measurements taken using exposed bony landmarks as references. For preparation of the combined gastrocnemius–hemisoleus flap, the posterior midline incision was extended distally toward the Achilles tendon until the conjoint tendon of the soleus, along with the skin paddle and gastrocnemius muscle, was adequately exposed.

Individual muscles were first identified, after which the gastrocnemius and soleus were elevated together as a single, continuous flap. The more superficial gastrocnemius muscle was raised first, followed by the hemisoleus. During harvest of the medial gastrocnemius, the muscle was dissected from distal to proximal while carefully preserving its vascular pedicle from the sural artery. It was then separated from the lateral gastrocnemius along the midline raphe, with care taken to preserve the intermuscular perforators between the gastrocnemius and soleus.

The distal tendinous attachments at the Achilles tendon were identified and divided.

Subsequently, the medial hemisoleus was dissected in a similar distal-to-proximal manner, beginning at its Achilles insertion. Where required, the muscle fascia was scored to increase flap surface area, and the gastrocnemius insertion was divided to facilitate optimal coverage of the defect. The flap separated with longer diameter was transferred in to the distal femoral and tibial defects, respectively (Figure 1), the retrograde hemisoleus flap based on posterior tibial artery was prepared as follows.



Figure 1. Schematic diagram which shows overall design to create the contiguous gastrocnemius-hemisoleus flaps. (a) Gastrocnemius muscle; (b) Hemisoleus mucle; (c) Soleus muscle; (d) Lateral soleus muscle; (f) Skin paddle; (g) Cut insertion part of the gastrocnemius. Cadaver dissection which

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shows overall design to create the contiguous gastrocnemius-hemisoleus flaps. (a) Gastrocnemius muscle; (b) Hemisoleus muscle; (c) Sural artery; (d) Skin paddle.

The design of the skin paddle was based on the size of the wound and accommodation of the pedicle rotation.

The pivot point of the flap was determined by locating the branch of the posterior tibial artery proximal to the defect area by means of the Doppler ultrasound.

Dissection was proceeded in the proximal-to-distal direction.

The belly of the soleus was identified and the soleus was splitted medially as wide as width of bony cavity and incision was carried down to the intermuscular septum (IMS).

The nutrient branches to the marginal soleus from the posterior tibial arteries were carefully identified with loupe magnification.

Incision was made and carried down to the IMS and posterior tibial artery, vein, nerve, identified, and then the nerve carefully was separated away from posterior tibial vessels with preserved IMS.

When the upper border of the flap was elevated, the posterior tibial vessels was divided proximally and ligated respectively at the above level of the distal second to third nutrient branches to the marginal soleus from the posterior tibial artery.

When these smaller inferior nutrient branch are less predictable in location and size, the proximate main nutrient branch included.

Retrograde hemisoleus flap was applied to the defect with separated pedicle, including ligated distal posterior tibial artery.

Muscle flap was filled to the bony cavity and cutaneous flap was covered on the soft tissue defect.

Special attention was given to ensure that the vascular pedicle remained free from twisting, bending, compression, or excessive tension.

After flap was inserted, the donor site of skin was closed by a split thickness skin graft (Figure 2).

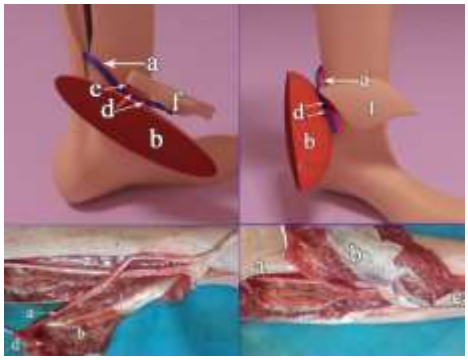


Figure 2. Schematic diagram and cadaver dissection which shows overall design to to create the retrograde hemisoleus flap based on posterior tibial artery. (a) Posterior tibial artery; (b) Hemisoleus muscle; (c) Tendo calcaneus; (d) Nutrient branch of the hemisoleus muscle; (e) Cutaneous perforating branch of the posterior tibial artery; (f) Skin paddle.

In all cases, we closed the wound loosely over drainage tube.

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All the patients in our study were given levofloxacin intravenously at the time of surgery and then orally for a perio d of 6 weeks postoperatively.

These patients were expected, if the patient was allergic to levofloxacin or microbiology culture and sensitivity testing of wound samples suggested a more appropriate antibiotic.

When culture results were negative, antibiotic therapy with cephalosporin or clindamycin continued. The drainage tube was removed once the output decreased to less than 5 mL and two consecutive drainage cultures showed no bacterial growth, with the removal time duly documented. Postoperative X-ray evaluations were performed periodically based on the progress of bone healing. All patients were followed up, and outcome measures included duration of drainage tube placement, effectiveness of infection control, recurrence of osteomyelitis, and the occurrence of any additional complications (Figure 3).



Figure 3. (a,b)Open tibial fracture with severe soft-tissue loss in the anterior tibial aspect and necrosis of the heel; (c,d)Postoperative outcome-30days; (e)Postoperative outcome-4months; (f,g)Postoperative outcome-1year.

Case1

Case 1: A 25-year-old man presented with a 3-year history of chronic right tibial osteomyelitis following a tibial fracture (Figure 4).



Figure 4. (a,b)Chronic right tibial osteomyelitis following a tibial fracture with a 3-years history; (c) Creation a final skin defect 25×7cm^2 and bony cavity 20×3×2cm^3 by radical debridement; (d)Operative finding of the contiguous gastrocnemius-hemisoleus flaps; (e,f)Postoperative outcome-5years.

The patient was diagnosed with osteomyelitis on the anterior aspect from the middle one third to the distal one third of the lower leg.

Radical debridement created a 25 × 7 cm2 final skin defect and bony cavity volume 20 × 3 × 2 cm3.

A contiguous gastrocnemius–soleus flap was then harvested with the skin paddle from the medial aspect of the lower extremity and muscle flap was filled to the bony cavity and cutaneous flap was covered on the soft tissue defect.

During the 5-year follow-up, right tibial osteomyelitis did not recur, and the flap remained viable in its entirety.

This repair provided reliable soft tissue coverage and at the most recent follow-up, the patient was able to ambulate without assistance.

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Case2

Case 2: This 31-year-old man suffered an electrical burn and presented with severe distal femoral soft tissue defect including dead space (Figure 5).



Figure 5. Electrical burn- induced dead space; (b) Operative finding of the contiguous gastrocnemius-hemisoleus flaps; (c)Postoperative outcome-15days.

Radical debridement was performed to remove necrotic skin and muscle, leaving a 30 × 8 cm2 soft tissue defect with an area of deeper dead space located at the edge of the wound.

A contiguous gastrocnemius–soleus flap was selected to optimally cover this patient's wound.

The patient experienced an uncomplicated postoperative recovery, and successful limb salvage was achieved.

Case 3

Case 3: A 29-year-old woman was transferred to our facility 4 days after being injured in a traffic accident (Figure 3).

There was open tibial fracture with severe soft-tissue loss and necrosis from the anterior tibial aspect to the heel in her left lower extremity.

External fixator was used and the wounds ware debrided, washed, and then performed later resurfacing by pedicled medial plantar flap to the heel defect.

The wounds were irrigated three times using hydrogen peroxide followed by copious amounts of normal saline.

For optimal repair of soft tissue defects in distal anterior tibial aspect, we initially chose the distally based saphenous neurocutaneous perforator flap.

However, intraoperatively, this flap could not be applied because saphenous vessel was previously damaged and identified free infectious bone in site fracture.

As a rescue strategy for this patient, we harvested a retrograde hemisoleus flap based on posterior tibial artery because was confirmed by means of the Doppler ultrasound that remained intact the anterior tibial artery and posterior tibial artery.

The retrograde hemisoleus with the skin paddle based on branch of the posterior tibial artery was used to cover the anterior tibial defect

During the 24 month follow-up, muscle segment with skin graft remained viable.

The patient was able to walk independently, and at the final follow-up assessment, ankle function remained well preserved.

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Case 4

A 38-year-old man presented with a crushing injury to the posterior part of his left foot.

After repeated debridement, cavity of the calcaneus was formed, needed coverage (Figure 6).



Figure 6. (a) Cavity of the calcaneus and separation of the retrograde hemisoleus flap; (b) filling the bony cavity with muscle flap; (c)Postoperative outcome-30days.

Retrograde hemisoleus flap was applied, muscle flap was filled to the cavity of the calcaneus and cutaneous flap was covered on the soft tissue defect.

At over six months of follow-up, the patient was walking independently without any assistance.

RESULTS

All patients were followed up for an average of 108 (24–260) weeks.

The time of laying drainpipe was from 3 days to 31 days (average 15 days).

There was no recurrence of osteomyelitis and no amputation was performed.

DISCUSSION

Adequate initial debridement of the involved area, so that the flap is placed in a healthy environment, helps to ensure the success of the procedure [2, 9].

In previous study, which retrospectively reviewed patients with chronic osteomyelitis of the tibia, it was found that those who had received free muscle flap transfers as part of their surgical treatment were more likely to be drainage-free after more than 7 years of follow-up than patients who had received debridement alone [13–15].

Although the primary purpose of local or free muscle transfer is to revascularize the debrided area, it also serves a purpose akin to bone grafting by simply filling in the dead space created by surgery [9, 15].

This notion is supported by studies that have found the recurrence of infection in patients with lower leg osteomyelitis to be significantly reduced when the muscle flaps completely pack the cavity left by surgical debridement [15].

Although local muscle flaps work well for the proximal two thirds of the tibia, the more distal one third requires the use of transplanted flaps to provide a sufficient soft tissue envelope for healing [2].

Stable, durable soft-tissue coverage and salvage of an extensive tibial wound can often be achieved with free-tissue transfer, one of the highlights in modern reconstructive surgery [2, 3, 4, 6, 14].

Nevertheless, it is still a standard of care that if a free-tissue transfer is not an option for patients with an extensive tibial soft-tissue defect, an amputation at the above knee level is often recommended to these patients without further reconstructive efforts [2].

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An another study has been reported that advantages of multiple local muscle flaps over microvascular free-tissue transfer for the coverage of extensive lower-extremity wounds can include[1]: shorter operative time[2], relatively straightforward surgical technique[3], less-intensive requirements for flap monitoring [4] shortened hospital stay[5], avoidance of peri-operative anticoagulation[6], less-vigorous postoperative care, and [7] often no additional soft-tissue debulking needed [2].

In Hyodo's original description, the gastrocnemius and hemisoleus muscles were elevated together as a single flap to cover an anterior tibial defect. In this approach, the soleus muscle acted as a distal extension of the gastrocnemius flap, receiving its blood supply through intramuscular perforators originating from the gastrocnemius muscle [7].

Another study reported the use of a combined pedicled gastrocnemius and hemisoleus double muscle flap to cover large leg defects that would typically require free-flap reconstruction. The authors also described modifications to the original technique to extend the reach of the flap, making it more versatile for covering extensive defects [5, 12].

The soleus muscle can be rotated inferiorly based on the two or three pedicles from the posterior tibial artery entering the inferior muscle [12].

However, this transposition is rarely indicated, since the dissection in the proximal soleus muscle is different and these smaller inferior pedicles are less predictable in location and size [12].

The distal two-thirds of the soleus muscle receive their blood supply from the posterior tibial and peroneal arteries. Specifically, the posterior tibial artery supplies the medial portion of the muscle and serves as the primary vascular source for the distal segment of the soleus [11, 12].

Therefore mobilization of deep medial surface of soleus muscle in its distal third requires identification of posterior tibial artery and veins with identification of inferior minor vascular pedicles to muscle [11].

Many procedures, especially various kinds of flaps based on the posterior tibial artery, have been published and the arterial anatomy of these flaps has been revealed [7, 8, 10, 13].

Reverse-flow posterior tibial artery island flaps or adipofascial flaps are also valuable options, as they can cover nearly the entire foot and close larger defects due to their long pedicle, although their use involves sacrificing a major artery of the lower leg [7].

Vascular anastomosis commonly was performed between the posterior tibial vessels and lateral circumflex femoral vessels (LCFV) of the anterolateral thigh musculocutaneous perforator (ALTP) flap [3, 6].

In our study, when the retrograde hemisoleus flap was elevated, the posterior tibial vessels was divided proximally and ligated respectively at the above level of the distal second to third nutrient branches to the marginal soleus from posterior tibial vessels.

When these smaller inferior nutrient branch are less predictable in location and size, the proximate main nutrient branch was included in hemisoleus muscle flap and at this level the posterior tibial vessels was divided and ligated respectively.

Then the muscle flap can reach to the heel.

Thus, we could repair the defect to the heel as well as to the distal third of the tibia that was not previously available by local muscle transplantation.

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In this report, limb salvage was achieved in 13 patients with multiple local muscle flaps.

This was easily managed with surgical debridement of the chronic cavity.

We support the previous studies that have found the recurrence of infection in patients with lower leg osteomyelitis to be significantly reduced when the muscle flaps completely pack the cavity left by surgical debridement.

In summary, the successful treatment of these 13 patients indicates that soft-tissue defects from the distal femur to the heel can be repaired with multiple local muscle flaps when free-tissue transfer is not an option.

CONCLUSIONS

To reconstruct soft-tissue defects from the distal femur to the heel, local muscle flaps pedicled by gastrocnemius and hemi-soleus muscle provide advantages such as successful repair, minimal donor site complication, a long pedicle.

Thus, local muscle flaps pedicled by gastrocnemius and hemisoleus muscle may be an alternative for single-stage reconstruction of soft-tissue defects of the lower extremity, and is a worthwhile salvage procedure to be considered by reconstructive surgeons.

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