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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: *To report the usefulness of the multiple local muscle flaps pedicled by gastrocnemius and hemisoleus muscle for the treatment of the soft-tissue defects in the lower extremity, including the distal femur and more distal one third of the tibia without resorting to a free flap.* ***Methods:*** *From January 2014 to January 2023, the multiple local muscle flaps were designed to reconstruct the lower extremity in 13 patients.* ***Results:*** *All the patients had complete healing of their wounds with only minimal complications.* ***Conclusions:*** *The local muscle flaps pedicled by gastrocnemius and hemisoleus muscle are a useful alternative for coverage of lower extremity defects with a longer reach without resorting to a free flap.*

Keywords: Local Muscle Flap, Gastrocnemius Muscle, Hemisoleus Muscle, Lower Extremity Defect.

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INTRODUCTION

Bony and soft-tissue defects must be filled to reduce the chance of continued infection and loss of function [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 [2,14]. Soft tissue transfers to fill dead space left behind after extensive debridement may range from a localized muscle flap on a vascular pedicle to microvascular free tissue transfer [2].

Most commonly, a local muscle flap is used in the treatment of chronic osteomyelitis of the tibia [14,15].

The success rates for this technique reported in the literature have ranged from 66% to 100% [14]. The gastrocnemius muscle is used for defects around the proximal third of the tibia, and the soleus muscle is used for defects around the middle third [2,15]. Reconstruction of soft tissue defects of heel, ankle, and distal third of the leg is one of the most difficult assignments for plastic surgeons and it remains a challenge to seek safer options with less morbidity [3,7].

A microvascular free muscle transfer is required for defects around the distal third of the tibia [2,4]. However, not all surgeons or hospitals may be equipped to undertake micro-vascular surgery and postoperative flap monitoring, and very often patients may not be candidates for free-tissue transfer because of their overall medical conditions, i.e., unable to tolerate prolonged general anesthesia or not in

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compliance with proper postoperative follow-up after free-tissue transfer [2]. Therefore, we developed a new concept of the multiple local muscle flaps pedicled by gastrocnemius and hemisoleus muscle for coverage of lower extremity, including more distal one third of the tibia and distal femur. It is reliable, without significant donor morbidity and has low complication rate. It is also versatile and can be raised proximally as a contiguous gastrocnemius-soleus flap, or distally as individual hemisoleus flap based on posterior tibial artery with a longer reach.

MATERIALS AND METHODS

The procedures in this report were conducted in the Department of Plastic and Microsurgery, General Hospital of Ryang Gang Provinc. From January 2014 to January 2023, 13 consecutive patients (10 men and3 women from 25 years old to 46 years old, with an average age of 37 years old.) underwent 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 2×3cm^2 to 30×8cm^2, and volume of the bony cavity ranged from 2×3×0.5cm^3 to 20×3×2cm^3. 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.

Ccase	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	-	-

Ccase	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
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

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. Afterward, the size of the bone cavity and the area of the soft tissue defect were recorded.

The scar tissues around the wound edge and the necrotic tissues were then excised.

The sclerotic bones and free necrotic bones were also removed. As for the patients with severe bone sclerosis, the sclerotic bone was flattened with an orthopedic grinding drill until the bone surface and the soft tissue release the pus. The wound surface was then washed thrice with hydrogen peroxide and a large amount of normal saline.

Finally, the bed-dings were also replaced. After the operation, the dead bone and necrotic soft tissue were sent for pathological examination and bacterial culture. The kind of gastrocnemius and hemisoleus muscle flap selected to cover the wound depended on the location of the wound. The flaps were raised under tourniquet control and the measurements were taken from exposed bony landmarks. The contiguous gastrocnemius-hemisoleus flaps was prepared as follows.

The incision was extended distally towards the tendon archilles in the posterior midline until the conjoint tendon of the soleus, including skin paddle and gastrocnemius muscles was identified at the length as distal necessary.

The individual muscles for harvest were first identified in the area. The gastrocnemius and soleus muscles were identified and raised together with this muscles as a contiguous gastrocnemius-hemisoleus flaps. The more superficial gastrocnemius head was raised first before the hemisoleus.

When the medial gastrocnemius was harvested, it was dissected free in a distal to proximal manner, while preserving the pedicle arising from the sural artery, and then split from the lateral gastrocnemius muscle along the midline raphae. The inter-muscular perforators between the gastrocnemius and soleus were preserved. The distal tendinous insertion of the muscles at the tendon archilles was traced and divided. Next, the medial hemisoleus was dissected free in a similar fashion from distal to proximal, starting at the tendo archilles insertion.

The muscle fascia was scored to increase the surface area of the muscle flaps where necessary, and cut the insertion of the gastrocnemius. 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.

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. Care was taken to avoid torsion, kinking, compression, or tension on the pedicle. After flap was inserted, the donor site of skin was closed by a split thickness skin graft (Figure 2).

In all cases, we closed the wound loosely over drainage tube. All the patients in our study were given levofloxacin intravenously at the time of surgery and then orally for a period 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. If the culture result was negative, then the use of cephalosporin or clindamycin was continued.If the drainage volume was less than 5 mL and the bacterial culture in the drainage fluid was negative for two consecutive times, the drainage tube was pulled out and the time of removing the drainage tube was recorded.

X-ray examination was performed regularly after operation, depending on the progress of the bone healing.

All cases were followed up.

The follow-up indicators included the drainage tube placement time, infection control rate, and the reappearance of the osteomyelitis and other complications.

Case 1

A 25-year-old man presented with a 3-years history of chronic right tibial osteomyelitis following a tibial fracture (Figure 4). 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 25×7cm^2 final skin defect and bony cavity volume 20×3×2cm^3. 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-years 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.

Case 2

A 31-year-old man suffered an electrical burn and presented with a severe distal femoral soft tissue defect including dead space (Figure 5). Radical debridement was performed to remove necrotic skin and muscle, leaving a 30×8cm2 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's postoperative course was uneventful and limb salvage achieved.

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 ware washed thrice with hydrogen peroxide and a large amount 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 ambulate without assistance, and at the last follow-up, ankle function was preserved.

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). 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 more than 6 months of follow-up, the patient was able to ambulate without assistance.

RESULTS

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

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

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 the original description by Hyodo, the combined gastrocnemius and hemisoleus was raised as a single unit to cover an anterior tibial wound, with the soleus muscle component raised as a distal extension of the gastrocnemius flap, being vascularised by feeding intramuscular perforators from the gastrocnemius muscle [7].

An another study has been reported the use of the combined pedicled gastrocnemius and hemisoleus double muscle flap to cover large defects of the leg, which would otherwise be reconstructed with free flaps and also described they technique with modifications to the original description to increase the reach of the flap [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 are supplied by the posterior tibial and peroneal arteries [12]. The posterior tibial artery supplies the medial segment of the muscle and is the main blood supply to the distal soleus muscle [11]. 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].The reverse flow posterior tibial artery island or adipofascial flaps are also useful because they can reach almost all parts of the foot and close larger defects with a long pedicle, even though they sacrifice a main 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. 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.

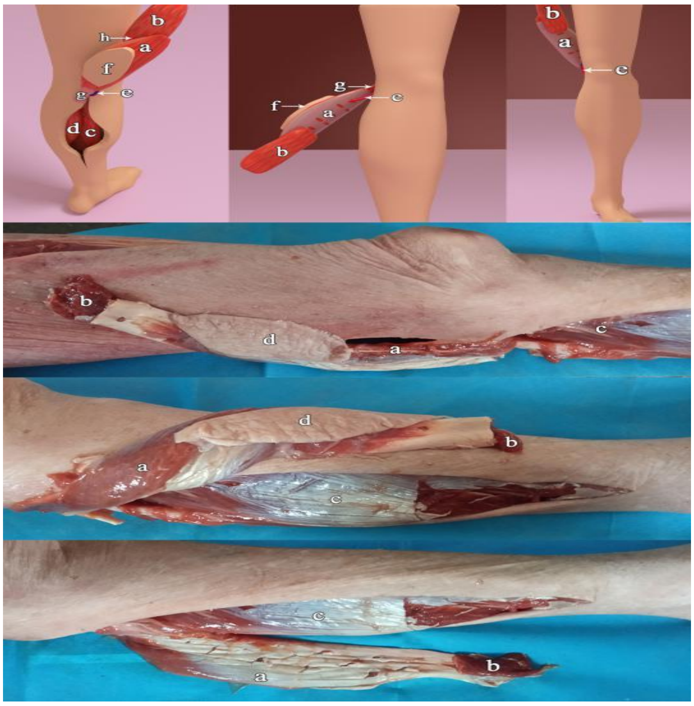

Figure 1. Schematic diagram which shows overall design to create the contiguous gastrocnemius-hemisoleus flaps.

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

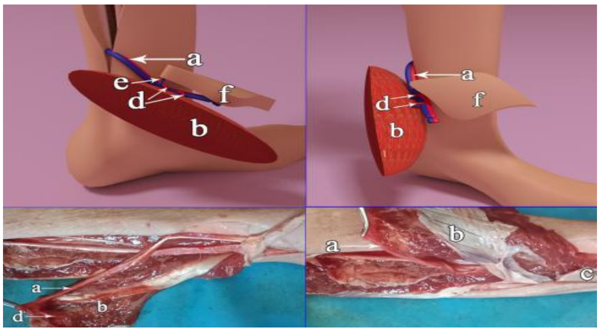

Figure 2. Schematic diagram and cadaver dissection which shows overall design to to create the retrograde hemisoleus flap based on posterior tibial artery.

(a)Posterior tibial artery; (b)Hemisoleus mucle; (c)Tendo calcaneus; (d)Nutrient branch of the hemisoleus muscle; (e)Cutaneous perforating branch of the posterior tibial artery; (f)Skin paddle

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.

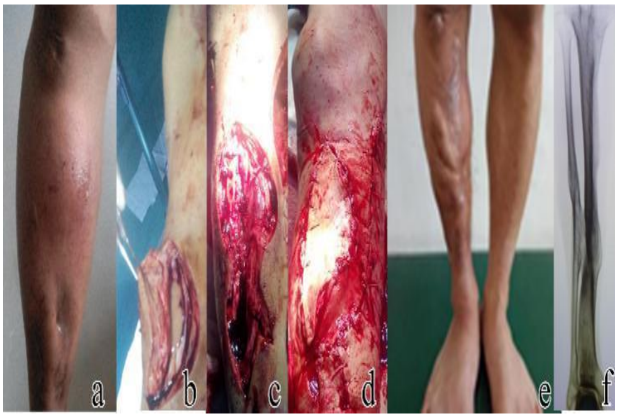

Figure 4. (a,b)Chronic right tibial osteomyelitis following a tibial fracture with a 3-years history; (c) Creation a final skin defect 25×7cm^2 and bony cavity 20×3×2cm^3 by radical debridement; (d)Operative finding of the contiguous gastrocnemius-hemisoleus flaps; (e,f)Postoperative outcome-5years.

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

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

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