

Analysis of Vascular Anatomy in Inferiorly Based Gastrocnemius Muscle Flaps in Japanese Individuals Using a Cadaver Study

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Background: Inferiorly based gastrocnemius muscle flaps have been successfully used to cover soft tissue defects of the middle third of the leg. This is done especially in older patients or patients with major complications where operative time should be limited. We aimed to determine the gastrocnemius muscle length that can be safely used for preparing inferiorly based muscle flaps.

Methods: We performed angiographies and dissection to investigate the numbers and distribution of the communicating arterial branches between the medial and lateral heads of the gastrocnemius muscle, and the perforating arterial branches of the medial sural artery from the soleus to the gastrocnemius muscles on 18 legs of preserved cadavers.

Results: The lengths of the gastrocnemius heads were approximately 10 cm, and the communicating arterial branches of the gastrocnemius muscle also were located at approximately 10 cm from the gastrocnemius head. The perforating arterial branches from the soleus muscle to the gastrocnemius muscle were also located at approximately 10 cm from the gastrocnemius head.

Conclusions: Communicating arterial branches of the gastrocnemius muscle were found in all cadavers. To the best of our knowledge, no other study has focused on investigating the perforating arterial branches that supply the gastrocnemius from the soleus muscle. Our study indicates that the entire gastrocnemius muscle can be safely used in reconstruction surgeries. (*Plast Reconstr Surg Glob Open* 2020;8:e3201; doi: 10.1097/GOX.0000000000003201; Published online 30 November 2020.)

INTRODUCTION

Treatment of soft tissue defects of the anterior lower leg secondary to trauma, tibial osteomyelitis, or defected surgical site following resection of a malignant tumor may be difficult. This is due to the lack of reconstruction materials for covering these abnormalities. In 1966, Ger reported a reconstruction that utilized the soleus muscle and medial head of the gastrocnemius muscle (GM), which was particularly useful for tissue defects of the lower leg.¹ With recent advances in microsurgery, free tissue transplantation has markedly developed and the use of muscle flaps has decreased. However, this option is not readily applicable to the elderly and patients with severe complications. Hence, it is hard to ignore the usefulness of muscle flaps.

Reconstruction of tissue defects of the middle lower leg with a soleus muscle flap is an excellent method. However, the surgical procedure is considerably complicated, and the muscle is markedly sacrificed.

In 1983, Bashir reported an inferiorly based GM flap.² A conventional GM flap uses the sural artery branching from the popliteal artery as a pedicle. In addition, the pivot point of the muscle flap is present in the popliteal region (Fig. 1A).^{3,4} However, in an inferiorly based GM flap, the pivot point is present on the reverse side of the middle third of the lower leg because blood flows from the opposite GM head into this flap (Fig. 1B). This facilitates its application to tissue defects of the middle third of the leg, which a conventional GM flap cannot reach. Moreover, because only one head of the GM is used, muscle sacrifice is less. This makes inferiorly based GM flap useful especially for covering soft tissue defects of the middle third of the lower leg.⁵⁻⁷ Tsetsonis et al. reported on the vascular anatomy of the GM flap,⁸⁻¹⁰ and Agarwal et al. reported on the detailed vascularity of the connecting branch between the medial and lateral heads of the GM.^{11,12}

In this study, we investigated the lengths of the medial and lateral heads of the GM, size of the medial and lateral

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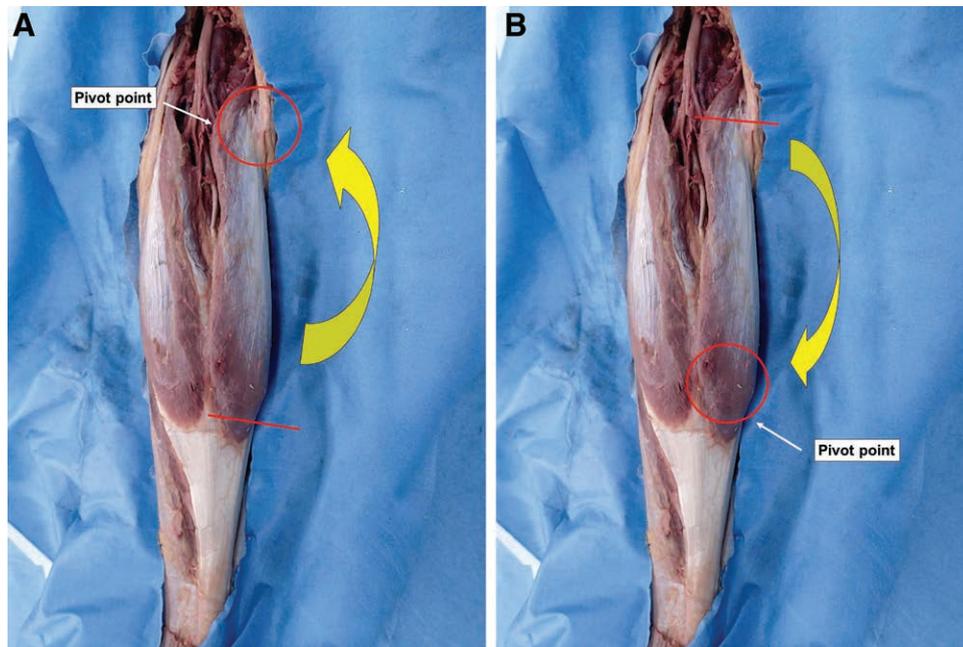


Fig. 1. A, Gastrocnemius muscle flap (GM flap). The red circle indicates the pivot point of the muscle flap, and the muscle flap is elevated upward. Thus, the muscle flap covers the upper one-third of the lower leg. B, Inferiorly based gastrocnemius muscle (GM) flap. The red circle indicates the pivot point of a muscle flap, and the muscle flap is elevated downward. Thus, the region up to the middle third of the lower leg can be covered by this muscle flap.

sural arteries, and the number and distribution of communicating arterial branches between the medial and lateral heads of the GM. In addition, the perforating branches of the sural artery from the soleus muscle to the GM were also examined, and blood circulation from the lower floor of the GM also was analyzed. We focused on the location of the perforating arterial branches from the soleus to the GM. This study aimed to determine the length of the GM, which can be safely used for preparing inferiorly based muscle flaps. To the best of our knowledge, no other study focused on investigating the perforating branch from the soleus to the GM.

MATERIAL AND METHODS

We examined 18 legs of preserved cadavers managed by the Department of Anatomy of Kawasaki Medical School. In total, the legs of 10 men and 8 women were used. The mean age of the cadavers was 80.6 ± 9.4 (mean \pm SD) years. Catheters were inserted from the bilateral femoral arteries, and contrast medium was manually injected under pressure. For a 5%–7%/w contrast medium, gelatin was dissolved in barium and used for gastrointestinal contrast imaging. This was used to solidify the contrast medium to prevent leakage during autopsy.^{13–17} After the gelatin had solidified, the gastrocnemius muscle was excised, and an angiogram was obtained (Fig. 2). At the same time, a macroscopic autopsy was performed.

The following items were investigated:

- 1) Distance between the base of the medial and lateral heads of the GM and Achilles tendon
- 2) Distance between the head of the fibula and the lateral malleolus of the ankle joint
- 3) Size of the medial and lateral sural arteries
- 4) Number of communicating arterial branches between the medial and lateral heads of the GM
- 5) Distance between the base of the medial head of the GM and communicating arterial branches
- 6) Number of the perforating arterial branches from the soleus to the GM, and the distance between the base of the medial head of the GM and the perforating arterial branches

This study protocol was approved by the Kawasaki Medical School Ethics Committee (1391-4; April 26, 2019).

RESULTS

Distance between the Base of the Medial and Lateral Heads of the GM and Achilles Tendon

The longest and shortest distances of the medial head of the GM were 14.0 cm and 7.5 cm, respectively, and the mean (SD) was 10.9 (1.8) cm ($n = 18$). The longest and shortest distances of the lateral head were 14.0 cm and 9.0 cm, respectively, and the mean (SD) was 10.9 (1.7) cm ($n = 18$).

Distance between the Head of the Fibula and the Lateral Malleolus of the Ankle Joint

The longest and shortest distances were 40.0 cm and 34.0 cm, respectively, and the mean (SD) was 37.7 (1.5) cm ($n = 18$).

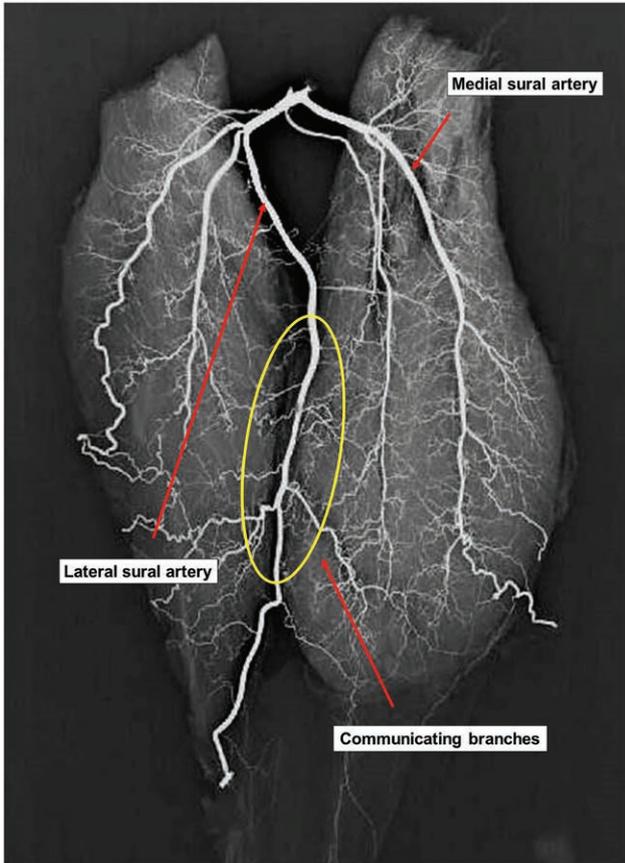


Fig. 2. Angiography of the gastrocnemius muscle (GM). The yellow circle indicates that there are many communicating arterial branches between the medial and lateral heads of the GM.

Size of the Medial and Lateral Sural Arteries

The size of the medial sural artery was measured at the bifurcation of the popliteal artery. The maximum and minimum size were 5.0 mm and 2.0 mm, respectively, and the mean (SD) was 3.3 (0.8) mm (n = 18). The maximum and minimum size of the lateral sural artery were 4.7 mm and 2.0 mm, respectively, and the mean (SD) was 2.6 (0.7) mm (n = 18).

The Number of Communicating Branches between the Medial and Lateral Heads of the GM

The number of communicating arterial branches between the medial and lateral heads of the GM was investigated by macroscopic autopsy and angiography. The communicating arterial branches were present in all cases. The maximum and minimum numbers were 7 and 2, respectively, and the mean (SD) number was 4.1 (1.7) (n = 18).

Distance between the Base of the Medial Head of the GM and Communicating Arterial Branches

The distance between the base of the medial head of the GM and communicating arterial branches was measured. The maximum and minimum distances were 16.0 cm and 1.5 cm, respectively, and the mean maximum and minimum distances (SD) were 10.9 (3.1) cm (n = 18) and 4.9 (1.6) cm (n = 18), respectively. To make a distribution diagram of each communicating arterial branch between the medial and lateral heads of the GM, the lower leg was divided into 20 sections, with the sections labeled as 5%, 10%, 15%, etc., beginning at the head of the fibula. (Fig. 3).

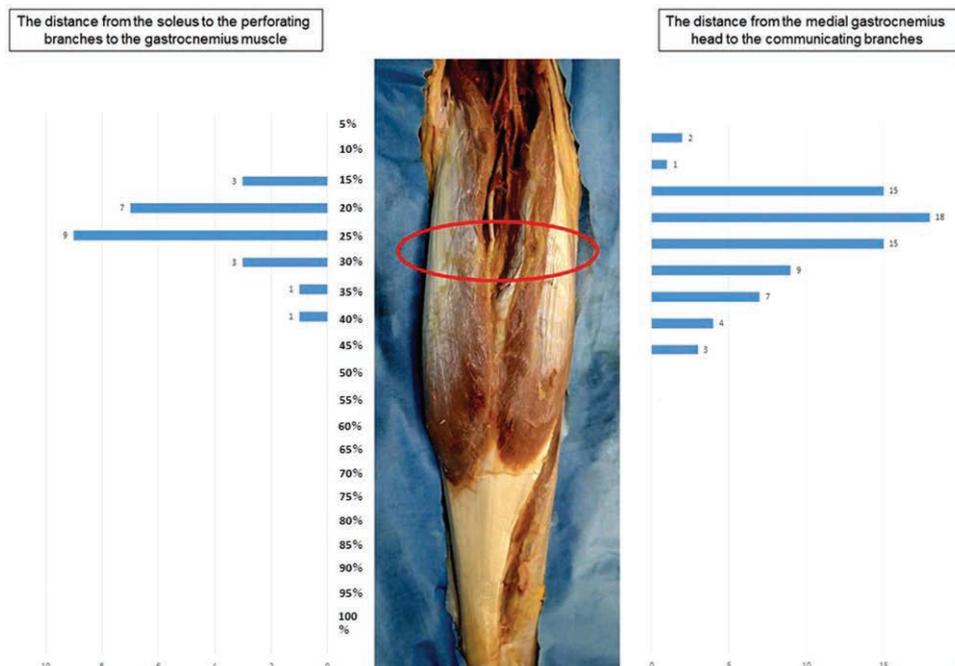


Fig. 3. Photograph displaying the positions of the gastrocnemius muscle communicating arterial branches, and those of the perforating arterial branches from the soleus muscle were almost the same.

The Number of Perforating Arterial Branches from the Soleus to GM and Distance between the Base of the Medial Head of the GM and Perforating Arterial Branches

The perforating arterial branches were present in all cases, and the maximum and minimum numbers were 3 and 1, respectively. The maximum and minimum distances between the base of the medial head of the GM and perforating arterial branches were 14.0 cm and 5.0 cm, respectively, and the mean maximum and minimum distances (SD) were 8.5 (2.4) cm ($n = 18$) and 7.5 (2.0) cm ($n = 18$), respectively (Fig. 4). To make a distribution diagram of each perforating arterial branch from the soleus to GM, the lower leg was divided into 20 sections, with the sections labeled as 5%, 10%, 15%, etc., beginning at the head of the fibula (Fig. 3).

DISCUSSION

In this study, there was no marked difference in the distance between the medial and lateral heads of the GM, and the mean distance was 10.9 cm. However, the mean distance of the lower leg was 37.7 cm, showing that the GM head accounted for about 30% of the lower leg. There were four communicating branches between the medial and lateral heads on average, and the most distal communicating arterial branch was present at 10.9 cm from the base, suggesting that it was feasible even if the whole medial head of the GM was used in the inferiorly based GM flap.

We measured the positions of the perforating arterial branches from the soleus to the GM, and the mean maximum distance from the base of the GM head was 8.5 cm. These perforating branches frequently anastomose with the communicating arterial branches of the GM, and

many of them were present around the bifurcation of the medial and lateral heads of the GM. The distances from the medial GM head to the communicating arterial branches, and from the soleus to the perforating arterial branches to the GM were investigated. The distances from the medial GM head to the communicating branches, and from the soleus to the perforating branches to the GM, were investigated, and found to be approximately equal (10 cm, Fig. 4). This suggested that it was possible to use the whole medial head of the GM for inferiorly based flap construction. In fact, we performed surgery using inferiorly based GM flap for soft tissue defect of the right lower leg (Fig. 5).¹⁸ It was possible to use the entire medial head of the GM in surgery and cover the middle part of the lower leg (Fig. 6).

There have been some reports of vascular anatomy of the GM using cadavers.^{8–12} All of these studies were conducted in western populations, and, to our knowledge, no studies have been conducted with the Japanese. Particularly, Agarwal et al. reported that the length of the GM was approximately 19.6 cm, and the distance between the base of the medial head of the GM and communicating arterial branches was 15.9 cm.¹² However, according to our results, the length of the GM was approximately 10 cm, which was approximately 30% of the total length of the lower leg. Typically, Japanese people have a small body size and short lower limbs. Therefore, there were some differences between our data and those of other previous reports. Our results are very different from those of Agarwal et al. It is essential to have a surgical plan that considers body size of patients before performing surgery.

Multiple cases in which the GM has been utilized as a free muscle flap have been reported.^{19–22} The mean

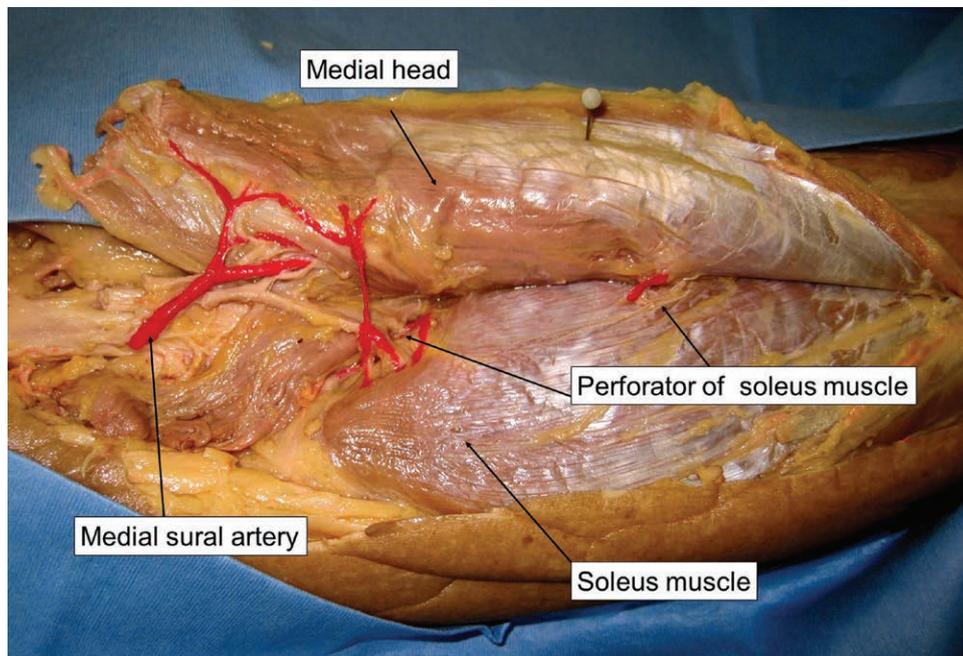


Fig. 4. Image showing the medial sural artery and perforators from the soleus to the gastrocnemius muscle.

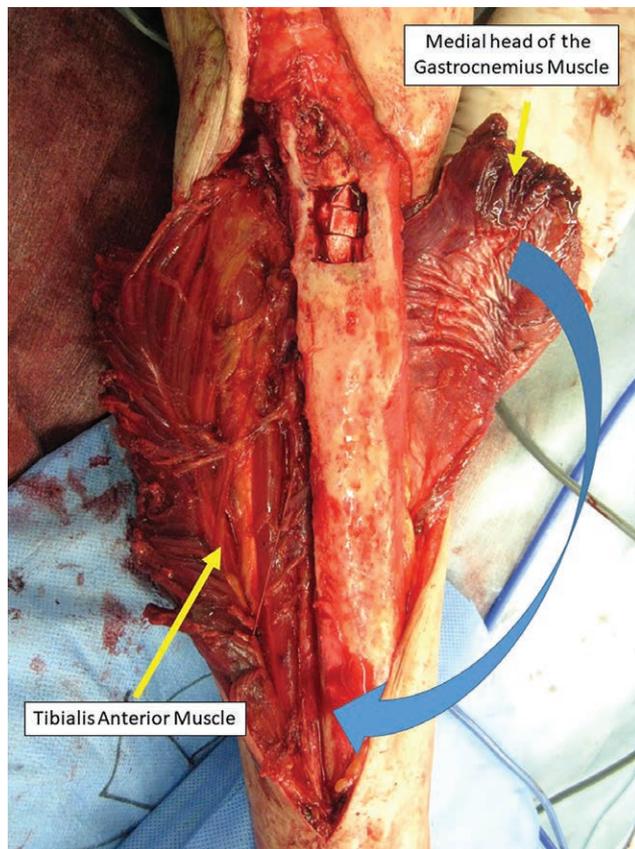


Fig. 5. Photograph showing a defect of the soft tissue of the lower leg that occurred as a result of osteomyelitis in the right leg. It was possible to use the entire medial head of the gastrocnemius muscle.

vascular diameter of the medial sural artery at the bifurcation of the popliteal artery was 3.3 mm, and that of the lateral sural artery was 2.6 mm. Agarwal et al. investigated the dissectible lengths of the medial and lateral sural arteries, and these were 2.1 cm and 2.3 cm, respectively.¹¹ When used as a free GM flap, these vascular pedicles were short. However, adequate vascular anastomosis was possible. The common peroneal nerve is present in the base of the lateral head of the GM in the popliteal fossa, and transection of the head may injure the nerve. Thus, it may be safer to use the medial head of the GM.

In recent years, with the development of microsurgery, opportunities to perform surgery using a free muscle flap for soft tissue defects of the lower leg have increased. However, microsurgery requires a prolonged operating time depending on cases. Pedicle muscle flaps may be useful in hemodynamically stable patients, and in cases where the operating time needs to be minimized. The procedure of preparing an inferiorly based GM flap is simple, and may be particularly useful for the reconstruction of the middle third of the lower leg.

CONCLUSIONS

Communicating arterial branches of the GM were found in all cadavers. Inferiorly based GM flap was possible to use the entire medial head of the GM in surgery,

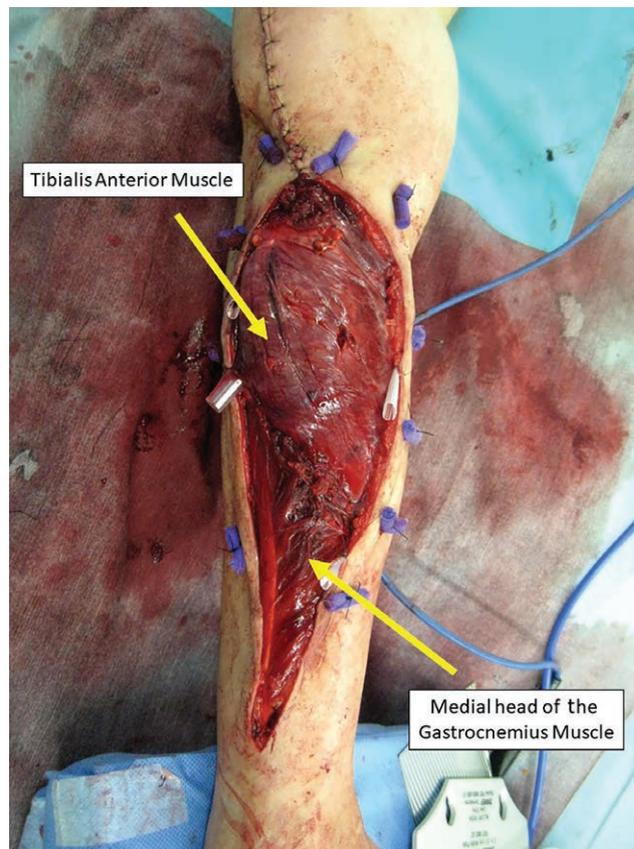


Fig. 6. Image displaying the coverage of soft tissue defect of the lower leg with the tibialis anterior muscle and inferiorly based gastrocnemius muscle. It was possible to cover the middle part of the lower leg.

and cover the middle part of the lower leg. To the best of our knowledge, there has been no study of vascular anatomy of the inferiorly based GM Flap in the Japanese. Our study reveals that the entire GM can safely be used in reconstruction surgeries.

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