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Original Article

Cadaveric study using radio-opaque contrast to determine arterial communication between the two bellies of gastrocnemius muscles

Pawan Agarwal, K. L. Gupta, P. Yadav, Dhananjaya Sharma
Department of Surgery, Plastic Surgery Unit, N.S.C.B. Government Medical College, Jabalpur, Madhya Pradesh, India

Address for correspondence: Dr. Pawan Agarwal, 292/293, Napier Town, Jabalpur - 482 001, Madhya Pradesh, India.
E-mail: drpawanagarwal@yahoo.com

ABSTRACT

Introduction: Gastrocnemius muscle is a workhorse flap to cover upper third tibial defects but has a limitation in covering middle one-third tibial defects. The inferiorly based hemi gastrocnemius muscle flap can be useful for reconstruction of the middle third of the leg. The arterial communication between the gastrocnemius muscle heads has been demonstrated, the consistent location, however, was not studied in large specimens. **Materials and Methods:** This study was conducted on sixty specimens of gastrocnemius muscles harvested from thirty fresh cadavers to determine arterial communication between two heads of gastrocnemius muscle using radio-opaque contrast with future application of taking one head of muscle distally based for coverage of middle third defect of tibia. A total of 60 specimens were obtained from thirty fresh cadavers. In thirty specimens, medial sural artery ligated and divided and 20 ml iohexol (350) given through popliteal artery. In remaining thirty specimens lateral sural artery ligated and divided and 20 ml iohexol (350) given through popliteal artery. Digital X-rays of gastrocnemius muscle specimens were taken, and collaterals between two bellies in lower half were noted and the distance of collaterals from the muscles top edge was also noted. **Results:** We found the communications between both bellies of the gastrocnemius muscle in all specimens in both legs. The mean distance of communications from the upper edge of the medial belly was 15.88 cm and from upper edge of the lateral belly was 14.72 cm in the right leg, respectively. The mean distance of communications from upper edge of the medial belly was 16.01 cm and from upper edge of the lateral belly was 13.78 cm in the left leg. The distal communications between gastrocnemius bellies were not constant in their location, but all the connections were present in distal 3.79 cm of raphe. **Conclusion:** This study supports the future application of inferior-based hemigastrocnemius muscles flap to cover defects of middle third leg. When distally based hemigastrocnemius flap is planned roughly 1/3rd of distal

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attachment or distal 3.79 cm of connection between raphe should be maintained to preserve the vascular communications between the two bellies.

KEY WORDS

Arterial communication; distally based; gastrocnemius

INTRODUCTION

Gastrocnemius muscle is commonly used as a local flap for coverage of soft tissue defect in the upper third of the leg. The arc of muscle flap extends from the lower thigh, entire knee joint, popliteal fossa and upper third tibia. Gastrocnemius muscle is a workhorse flap to cover upper third tibial defects because of its wide arc of rotation, easy dissection and a reliable vascular pedicle. The limiting factors in the case of gastrocnemius muscle are difficulties in covering middle one-third tibial defects. One of the most challenging areas in reconstructive surgery is the closure of soft tissue defects of the middle third leg because of a small quantity of local tissue available for reconstruction, poor vascularisation and subsequent poor healing encountered in this region.[1] Methods for coverage have evolved from the bipedical flap, local skin flaps; cross-leg flap, soleus flap and microvascular free flaps. However, all these techniques have its inherent limitations. The inferiorly based hemi gastrocnemius muscle flap can be useful for reconstruction of the middle third of the leg. The arterial communication between the gastrocnemius muscle heads has been demonstrated by some authors.[2-4] The majority of these arterial communications are arranged in bundles, although isolated, single ones are not infrequent. The bundles are consisted of arterioles and concomitant venules as well. All these studies were experimental and in 1983, Bashir first reported only three clinical cases of inferiorly based gastrocnemius muscle flap which was supplied from the lowermost vessel across the raphe. After that, some authors also proposed the use of inferiorly based flap, but not many clinical applications were reported.[4,5] Atchabahian and Masquelet[6] performed the anatomic study in thirty legs showing that it is not possible to raise this flap in almost 25% of patients due to small calibre of communicating branches. All these studies were performed in western population, and sample size was small. Till now, no Indian studies have been carried out, and the reliability of the pedicle of such a flap needs to be further investigated.[7] If this flap is feasible than it may be a reliable alternative for coverage of middle 1/3rd lower leg defects, especially when other flaps are not available and free flaps are not indicated.[8]

The objective of this study was to conduct a cadaveric study in the large specimen to determine the consistency of arterial communication between two heads of gastrocnemius muscle using radio-opaque contrast with future application of taking one head of muscle distally based for coverage of middle third defect of the tibia.

MATERIALS AND METHODS

This study was conducted over a period of 1 year in the Department of Surgery-Plastic Surgery Unit and Department of Forensic Medicine; in Government Medical College in Central India. Sixty specimens of gastrocnemius muscle were harvested from thirty fresh cadavers and studied. Before study Institutional Ethical Committee permission was obtained. Cadavers with any congenital anomaly, fractures or crush injury and previous surgeries around knee joint were excluded from the study. The cadavers were placed in prone position. A posterior longitudinal midline incision was given extending from 5 cm above the knee joint up to Achilles' tendon. The two skin flaps were reflected medially and laterally. Short saphenous vein and sural nerve were excised. Deep fascia was incised longitudinally and retracted exposing the superficial surface of the gastrocnemius muscle. Gastrocnemius muscle was carefully separated from soleus muscle and plantaris tendon posteriorly. Mobilisation of muscle started at lower muscle tendon junction in the loose areolar tissue between gastrocnemius muscle and soleus. Sharp dissection was required to separate the muscle from aponeurosis which develops on its anterior surface. A detachment of two heads of gastrocnemius muscle from femur was then done with careful dissection of the neurovascular pedicle. Popliteal artery ligated and divided just after it has given medial and lateral sural arteries and before bifurcation. The popliteal vessel also divided from proximal end with 5 cm stump. Iohexol (350) was used as a contrast agent. Totally sixty specimens were obtained from thirty fresh cadavers. In thirty specimens, medial sural artery ligated and divided and 20 ml contrast given through popliteal artery. In remaining thirty specimens lateral sural artery ligated and divided and 20 ml contrast given through popliteal artery. Digital X-rays of gastrocnemius muscle specimen were taken, and collaterals between two bellies in lower half were noted, and the distance of collaterals from the muscles top edge was also noted.

RESULTS

This study was conducted on thirty fresh cadavers. Twenty-eight were male and two were female. Sixty gastrocnemius specimens were obtained. After harvesting the muscle, the communications were studied using radio-opaque contrast injection using digital X-ray technique. We found the communications between both bellies of the gastrocnemius muscle in all specimens in both legs [Table 1 and Figures 1-4].

In the right leg, mean distance of communications from the upper edge of the medial belly was 15.88 cm (maximum 23.66 cm and minimum 12 cm) considering that mean length of the medial belly was 19.41 cm, communications were present in distal 3.53 cm. The mean distance of communications from the upper edge of the lateral belly was 14.72 cm (maximum 18.8 cm and minimum 10 cm) and mean length of the lateral belly was 17.41 cm, therefore, communications were present in distal 2.69 cm [Table 2].

In the left leg, mean distance of communications from the upper edge of the medial belly was 16.01 cm (maximum 19.91 cm and minimum 13 cm), the mean length of the medial belly was 19.80 cm. Therefore, communications were present in distal 3.79 cm. The mean distance of communications from the upper edge of the lateral belly was 13.78 cm (maximum 16.38 cm and minimum 8.2 cm) mean length of the lateral belly was 16.84 cm, therefore, communications were present in distal 3.06 cm.

Communications were consistently present between the two bellies of the gastrocnemius muscle in lower part across the raphe [Table 3].

DISCUSSION

Reconstruction of lower extremity defects can be a difficult task because of the lack of intervening muscle between the skeletal elements and the skin, and the limited mobility of the overlying skin.[9] Although microsurgical procedures provide excellent results in the head and neck region, the success rate is usually lower

Table 1: Presence of communication between bellies

Medial sural artery ligated and lateral sural injected		*Medial sural artery injected and lateral sural ligated*	
Right leg	***Left leg***	***Right leg***	***Left leg***
Communication	Communication	Communication	Communication
Present in all 15 bellies	Present in all 15 bellies	Present in all 15 bellies	Present in all 15 bellies

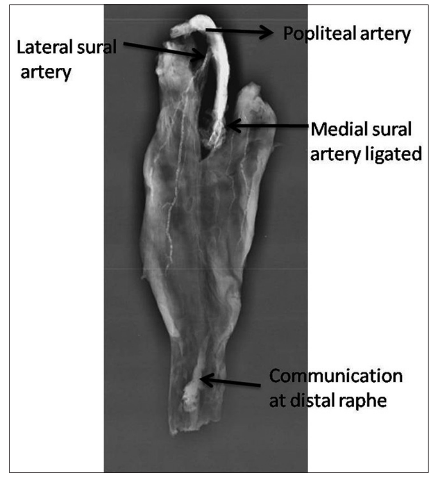

Figure 1: Right leg - medial sural artery ligated and lateral sural artery injected

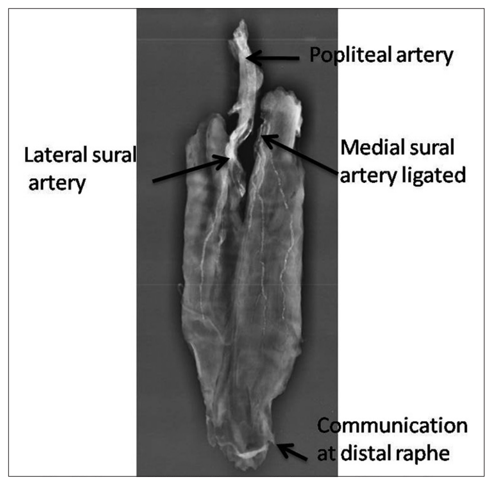

Figure 2: Left leg - medial sural artery ligated and lateral sural artery injected

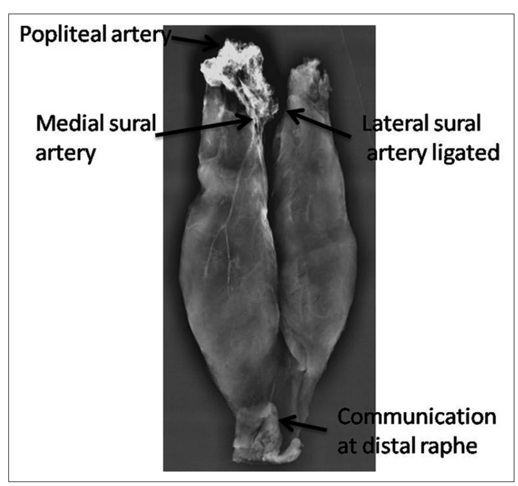

Figure 3: Right leg - medial sural artery injected and lateral sural artery ligated

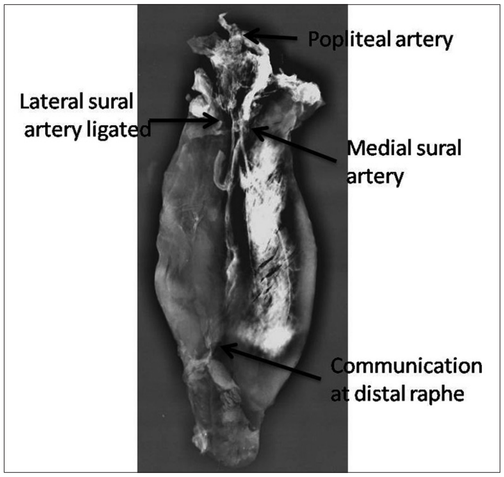

Figure 4: Left leg - medial sural artery injected and lateral sural artery ligated

in the lower limbs. It requires a long operative time; experienced skilful technique; and patent vascular status of the recipient site. Free flap transfer to the lower limb in chronic posttraumatic conditions is known to have a higher complication rate with flap loss in up to 10% of cases.[10-12]

Despite recent advances in microsurgical techniques, leading to major improvements in the quality of lower limb reconstruction, coverage of lower leg defects by loco-regional flaps remains indicated in selected cases. A local random-pattern skin flap has an indistinct perfusion pattern and is limited in size. Defects of the middle third of the tibia can be covered with the soleus flap.[13] However, the defect will be covered by the least vascularised part of the muscle; the volume of the flap is often too small to fill the defect. Local fascio-cutaneous flaps can provide an alternative for coverage of middle one-third tibial defects, but it may be in the zone of trauma hence not very safe. Gastrocnemius myocutaneous flap can also be used but lead to the unsightly donor site. The cross-leg flap has the disadvantage of long-term immobilization and two stage procedure.[14] The anterior tibialis flap is a useful option for providing soft tissue to cover open tibial injuries in the middle and distal thirds of the tibia. It is limited by the transition of the muscle to the tendon in the distal third of the tibia.[15]

In 1983, Bashir treated many severe lower injuries due to high-velocity missiles and he described the alternate method of covering a defect in the middle third of leg and the upper part of lower third using the medial head of the gastrocnemius muscle as an inferiorly based flap. He found three or four communicating vessels between the two heads. He used medial head gastrocnemius

Table 2: Right leg-distance of communication from upper edge of muscles

Serial number	*Medial belly (cm)*		*Lateral belly (cm)*	
	Distance from upper edge	*Length of belly*	*Distance from upper edge*	*Length of belly*
1	14	19	10.4	14
2	12.8	15	18.8	21
3	16	19.4	14.2	17
4	12.8	18	16	20
5	18.4	22.4	18.4	20.73
6	14	18	13	15
7	23.66	27.52	14	18
8	15.98	20.6	17.21	19.98
9	19.3	21.95	16.94	18.61
10	16.33	20.35	14.6	15.9
11	12	15.53	13.17	16.72
12	15.73	18.56	16	17.4
13	15	18	14.11	17.23
14	15.17	17.86	14	18
15	17	19	10	11.6
Mean	15.87	19.41	14.72	17.41

Table 3: Left leg-distance of communication from upper edge of muscles

Serial number	*Medial belly (cm)*		*Lateral belly (cm)*	
	Distance from upper edge	*Length of belly*	*Distance from upper edge*	*Length of belly*
1	16.4	19.6	12.2	15
2	17	19.8	16.2	19
3	13	15	11.6	14.4
4	19.91	26.69	11.8	14.8
5	19.29	23.35	16.2	20
6	18.6	22.47	16	20
7	18.75	23	13.8	16.8
8	13	16	15.74	19.85
9	13	17	16.38	19.66
10	12.33	16	15.13	18.47
11	14.64	18.6	13.2	14.88
12	18.4	24.5	11.3	17.61
13	15.26	18.6	12.85	14.98
14	13.61	18.4	16.2	19.2
15	17	18	8.2	8
Mean	16.01	19.80	13.78	16.84

muscle flaps as an inferiorly based in three cases with no failure rates. After that, there was isolated reports of using distally based gastrocnemius muscle for coverage of middle third tibial defects.[16]

Mathes and Nahai also proposed the use of an inferiorly based flap after having made a rough mention to anastomotic vessels. The vascular basis of this flap is the vessels across the distal half of the raphe between the muscle heads.[5]

Tsetsonis *et al*. studied the 14 fresh cadaveric gastrocnemius muscles to describe the anatomy of the communicating (anastomotic) vessels between the gastrocnemius muscle heads and record the extent of their supply potential. Communicating vessels were detected in all 14 specimens. A mean number of 5.8 vascular bundles and single vessels were found. The bundles consisted of arterioles and concomitant venules as well. Anastomotic veins were dissected along the raphe after perfusion of each muscle with 0.1% methylene blue solution. Communicating veins were dissected in all 14 muscles. He described mean distance 4.7 cm of lowest anastomotic vessels from the lower pole of the corresponding medial head. Regarding arterial cross-supply, it was clearly evident that each head could be vascularised solely from the contralateral one, mostly through these bundles. Nevertheless, the location of this vessel varies significantly and cannot be detected preoperatively. Measurements demonstrated that although this vessel is not found at a constant level, it is invariably detected in the lower third of the medial gastrocnemius head's length and in 93% of cases, in the lower fourth. Thus, rough preoperative planning becomes feasible. Given that the venous communication between the heads has been documented as well, the authors think that an inferiorly based flap of the medial gastrocnemius head for defects of the middle third of the tibia might be both reliable and applicable; however, for reasons of safety, the muscle heads should remain attached along their lower third.[17,18]

In 2008 Kishk[19] did a study by performing inferiorly based hemigastrocnemius flap in a reconstruction of middle third leg defect with exposed tibia in 19 patients and concluded that inferiorly based hemigastrocnemius muscle flap based on the vascular bundles between the two heads can be useful for reconstruction of the middle third of the leg. The follow-up period ranged from 6 months to 2 years. Partial flap loss occurred in two patients (10.5%). One flap (5.2%) was lost in the early postoperative period because of venous congestion related to inadequate tunnelling of the flap. There was no postoperative hematoma or infection.

This is the first study conducted on a larger number of cadavers (sixty specimens of gastrocnemius muscle were harvested from thirty fresh cadavers). We observed communications between the two bellies of gastrocnemius muscles in all specimens. In the right leg, the mean length of the medial belly was 19.41 cm and communications were present in distal 3.53 cm and mean length of the lateral belly was 17.41 cm and communications were present in distal 2.69 cm. In the left leg, the mean length of the medial belly was 19.80 cm and communications were present in distal 3.79 cm and mean length of the lateral belly was 16.84 cm and communications were present in distal 3.06 cm. The distal communications between gastrocnemius bellies are not constant in their location, but all the connections were present in distal 3.79 cm of raphe. Therefore, the precise pivot point for distal rotation of muscle cannot be ascertained but while taking distally based flap of gastrocnemius roughly 1/3rd of distal attachment or distal 3.79 cm of connection between raphe should be maintained to preserve the vascular communications between the bellies. A study by Tsetsonis *et al*. showed mean distance 4.7 cm of lowest anastomotic vessels from the lower pole of corresponding medial head, therefore, our study support more distal pivot point for muscle head rotation.

Our study supports the future application of inferior based gastrocnemius muscles flap to cover defects of the middle third leg. It is a simple technique allowing rapid, durable, and reliable coverage of these defects without sacrificing a major vessel to the foot. No donor site morbidity and functional deformity, with primary closure of donor site.

CONCLUSION

This is the large study on sixty specimens of thirty fresh cadavers and first reported from India. We found communications between both bellies of the gastrocnemius muscle in all sixty specimens in both legs in Indian population. Although communications between gastrocnemius bellies are not constant in their location, they were present in all specimens. Our study supports the future application of inferior-based hemigastrocnemius muscles flap to cover defects of middle third leg safely. When distally based hemigastrocnemius flap is planned, roughly 1/3rd of distal attachment or distal 3.79 cm of connection between raphe should be maintained to preserve the vascular communications between the bellies.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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