

## Split Gastrocnemius Muscle Flap

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### ABSTRACT

This work is composed of an anatomical study with its clinical applications. The anatomical study analyses the detailed anatomy of the blood vessels, nerve supply and the neuro-vascular relationship within each head of the gastrocnemius muscle. Radio-opaque material was injected into the arterial system of eight fresh muscles, also the nerve supply to the gastrocnemius muscle and its main branches were microscopically dissected and labeled with a fine wire, then all the specimens were x-rayed. The results of this study are presented and suggestions made regarding the clinical applications.

This study shows that the gastrocnemius muscle is able to be subdivided along its coronal plane into a two connected superficial and deep portions, each has its own independent neuro-vascular branches from the main pedicle. Also, the muscle sometimes, can be split into two independent neurovascular units, permitting segmental transfer in one quarter of cases. These anatomical features make possible increasing muscle surface area and add versatility to the gastrocnemius muscle reconstructive applications, also it minimizes donor site deformity and morbidity.

A clinical application was used successively by using the splitting technique of the muscle in ten cases with chronic leg ulcers.

### INTRODUCTION

Gastrocnemius muscle is frequently employed as a local flap for coverage of soft tissue defects in the upper two thirds of the leg [1-3]. The arc of the muscle flap extends from the lower thigh including the entire knee and popliteal fossa to the upper calf and proximal one third of the tibia. The reach of an island gastrocnemius muscle flap is limited by the length of its pedicle. Large defects might require a second flap such as the soleus muscle to fill the defect. This would necessitate further dissection of the leg with loss of another major ankle flexor, disruption of the lymphatico-venous pump

mechanism, and increase the deformity of the extremity [4]. Salibian et al., recommended transfer of the gastrocnemius muscle to the distal leg by using interposition saphenous vein graft between the transferred muscle and its sural artery [5]. Constantinos et al., discussed the venous communication between the two heads of the gastrocnemius muscle [6]. Basmocioglu et al., recommended endoscopic harvesting of the medial gastrocnemius muscle for reducing the donor site incision [7].

The lateral gastrocnemius belly is less useful than the medial one; however, injuries of the lateral side of the knee, the upper one third of the tibia, and the lateral side of the supra-patellar area are readily covered with the lateral gastrocnemius flap. Also, it has little use as a cross-leg flap and is very difficult to stretch into defects of the medial third of the tibia [8]. Harvesting of both gastrocnemius muscle bellies leads to partial loss of the plantar flexor which may, to a certain extent, decrease jumping and running ability. Myocutaneous or muscle transfer also causes substantial contour deformity, either in the form of depression in the donor calf or bulk in the recipient area. Also, microvascular transfer of the muscle is not widely applied clinically. While the vascular anatomy of the muscle is quite constant and the caliber of the pedicle is adequate for microvascular transfer [9], the average diameter of the sural artery is 2.48 mm, and the average vein diameter is 3.68 mm) and the pedicle length is somewhat short (length of 51.7 mm) [10].

The goal of this study was to investigate the neurovascular subdivisions within the gastrocnemius muscle in order to increase its surface

area for increasing its reconstructive applications. This may allow for more extensive use of the gastrocnemius muscle and reassess its donor site for functional muscle transfer and to diminish the donor site deformity and morbidity. The clinical application was used successively by using the splitting technique of the muscle in ten cases suffering from chronic leg ulcers.

## MATERIAL AND METHODS

The study involved microscopic neurovascular dissection then radiography of eight fresh cadaveric gastrocnemius muscles. The work was done in five phases:

### 1- Injection:

Through a small incision in the upper medial thigh, the common femoral artery was dissected and isolated for a five-centimeter distance, then the artery was cannulated and 60 cc of latex was injected gradually into each lower limb.

### 2- Dissection:

24 hours post injection, a posterior vertical midline incision in the leg was made and the two skin flaps were reflected medially and laterally exposing the entire gastrocnemius muscle. The two heads of the muscle were dissected carefully from the soleus muscle and sharply from the Achilles tendon, then detachment of the two heads of the gastrocnemius muscle from the femoral bone was done with careful dissection of the neurovascular pedicle (Fig. 1).

### 3- Splitting each muscle belly:

Each head of the gastrocnemius muscle underwent splitting in a coronal plane from outside to inside at the level of the neuro-vascular pedicle entrance into the muscle, essentially (bivalving) the muscle (Figs. 2,3).

### 4- Labeling:

Meticulous microscopic dissection of the nerve fibers was done and a computer link cable was used to label the nerve and its main branches. This labeling technique is preferred because the cable is malleable and multifilament, thereby making it easy to split at the appropriate branching points of the nerve.

### 5- Radiography:

Each muscle head was first x-rayed in the split position (Fig. 4) and then each head was closed in its normal configuration and frozen.

The frozen muscle was then sectioned transversely in 1-cm intervals along the entire length using a sharp, fast saw. The muscle sections were then arranged serially and x-rayed again to show the locations of the neuro-vascular pedicle in relation to the circumference along the entire muscle length (Fig. 5).

The clinical application was done for ten cases of upper third chronic leg ulcers. Two cases were complaining from large marjolin ulcers on the medial side of the limb extending medial to the thigh, the knee, and the upper third of tibia (Fig. 6). Six cases were suffering from deep burn and two cases were post traumatic ulcers.

After excision of the ulcers, the defects were large and the knee joint was exposed widely (Fig.7). The classic use of the gastrocnemius muscle to cover and protect the knee joint was not enough, as we needed a broader muscle for this wide defect. So, splitting the head of the gastrocnemius muscle to increase its surface was a good option to solve the problem. This can be done by either of two techniques:

\* The first technique: by starting from the upper pole of the muscle belly, just cephalad to the pedicle entrance. The dissection is carried on from that point along the whole length of the pedicle towards the outside of the muscle, splitting the muscle belly along its coronal plane into a superficial and deep portions (Fig. 8).

\* The second technique: this is more difficult than the first one. The dissection is starting at the outside border of the muscle. There are many perforators which exit the muscle belly in its coronal plane between the superficial and deep portions of the muscle belly. The surgeon can dissect along these perforators, through the muscle, until the main neurovascular pedicle is reached. The difficulty in this second technique lies in the determination of whether the perforators belong to the superficial or deep portions of the muscle belly (Fig. 9).

This new technique was used successively to cover the defect in our clinical cases and a split-thickness skin graft was used to cover the muscle flap and other parts of the defect.

## RESULTS

In all dissected muscles there was only one neurovascular pedicle for each muscle belly.

Only in one muscle (of eight), was there an additional smaller vascular pedicle entering the muscle formed of artery and vein without nerve. The neurovascular pedicle enters the upper pole of the lateral belly from its medial side and the medial belly from its lateral side at the level of the fibular head. There is an anastomosing network of arteries and veins (without nerves) between the two bellies of the gastrocnemius muscle. The entrance of the neurovascular pedicle divides each muscle belly into a superficial and a deep portions. The superficial portion was always the more bulky of the two. Also, The neurovascular elements always follow the intramuscular connective tissue framework to reach the muscle bundles. The main neurovascular pedicle in the upper half of the muscle runs at the side of the midline of the leg and gradually it courses toward the outside near the muscle's lower pole (Fig. 5).

The relationships of the structures within the neurovascular pedicle are as follows: Artery is usually the deepest structure (more towards the center of the muscle). The nerve is the most peripheral structure (away from the center of the muscle), while the veins are found in between the arteries and nerves. The nerves always course in a straight line, but the vessels usually assume a tortuous course and always follow the nerve.

The main neurovascular pedicle gives independent branches (artery, vein and nerve) to both the superficial and the deep compartments of each muscle belly, but some branches pass across from one half to the other. The direction of the main pedicle was always from the upper pole towards the lower pole, but the direction of the branches was always transversely oriented with a variable angle off the main pedicle (30-90 degrees) (Fig. 10).

The branching pattern of the main pedicle was different from one muscle belly to another. In most cases, the main pedicle gives off small and medium size branches (Fig. 10). In 25% of cases (2 muscles), there was a big branch which started near the pedicle entrance and ran through one half of the muscle while the main pedicle supplied the other half (Fig. 11). In all cases, each head of the gastrocnemius muscle was easily split in the coronal plane (like opening a book with the binding situated in the midline of the leg) (Fig. 2).

#### *The results of the clinical application:*

The medial head of muscle was used in 6 cases while the lateral head used in 4 cases. Sound healing and good function was observed in 70% of our patients (Fig. 12). There was partial necrosis of the flap in two cases (20%), while wound hematoma was detected in another one case (10%) (Table 1). Knee reconstructure was detected in two cases in which partial muscle necrosis was happened. The partial necrosis cases were trimmed and regrafted and the healing was completed nicely (Table 2). 6 months post-operatively 70% of our patients were satisfied of good cosmetic appearance and good knee functions. Deformed donor site recorded in two cases (20%) of our cases (Table 3).

Table (1): Local complication at the recipient site.

Results	Number	%
Partial necrosis	2	20
Total necrosis	0	0
Wound hematoma	1	10
Wound infection	2	20

Table (2): Late results and donor site morbidity.

Results	Numbers	%
Sound healing	7	70
Recurrent leg ulcer	1	10
Knee reconstructure	2	20

Table (3): Cosmetic results after 6 months follow up.

Cosmetic results	Numbers	%
Patient satisfied	7	70
Patient unsatisfied	1	10
Deformed donor site	2	20



Fig. (1): The two heads of the gastrocnemius muscle dissected out of the cadaveric leg.



Fig. (2): Starting splitting of the muscle belly from the site of pedicle entrance.

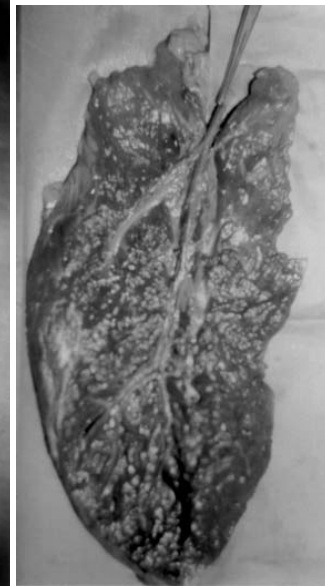


Fig. (3): The muscle belly is opened like a book.



Fig. (4): X-ray of the opened muscle belly showing its inside neurovascular distribution.



Fig. (5): X-ray of the sliced muscle belly showing the position of the main neurovascular pedicle along the belly length.





Fig. (6): A large marjolin ulcer at the medial side of leg.



Fig. (7): A defect after an ulcer excision.

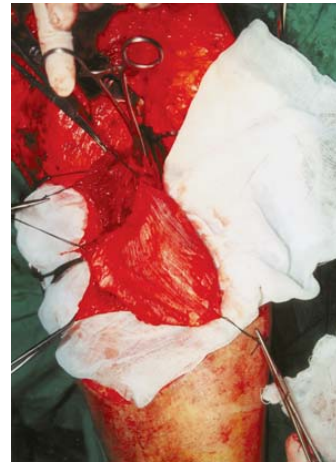


Fig. (8): Starting opening of the muscle belly in its coronal plain.

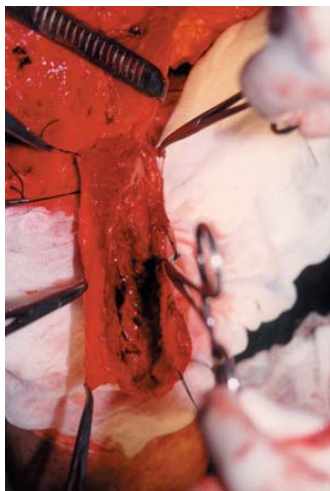


Fig. (9): The muscle belly is completely opened like a book.

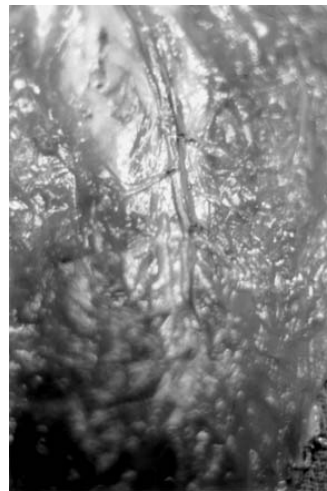


Fig. (10): The main pedicle sending side branches to the two muscle belly compartments.

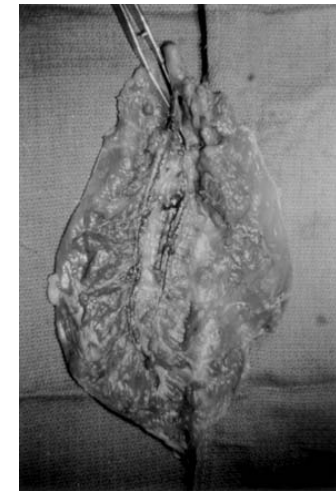


Fig. (11): A large branch of the main pedicle supplying one compartment while the main pedicle supply the other compartment.



Fig. (12): A skin graft over the splitted muscle belly after complete healing.

## DISCUSSION

Free muscle transfer as a functional unit has reached a high level of sophistication, but there are only few investigations that have tried to examine the subdivision of muscles according to their internal neurovascular anatomy. By knowing the intramuscular anatomy, the clinician could dissect and utilize only that portion of the muscle that was required and minimize the donor site morbidity.

For the gastrocnemius muscle, Dippell in 1980, tried to increase its surface area by describing longitudinal incisions of the thick deep muscle fascia allowing splaying out of the muscle and thereby increasing its ability of coverage. With detaching its origin, its arc of rotation will increase [8]. On the other hand, the neurovascular anatomy proximal to the hilum has been described in anatomy texts, but the detailed description of the vessels and the nerves within the muscle substances has not been sufficiently investigated. Taylor published an anatomical study analyzing the neurovascular relationship of the muscles according to their nerve supply. According to his classification, the gastrocnemius muscle is type 3 because it is supplied by two motor nerve branches derived from the same nerve trunk [11]. Potparic, also published a study that included recommendations for the use of the gastrocnemius muscle as a free flap and he suggested that the gastrocnemius muscle may be subdivided into functional neurovascular units for local or distant transfer [10].

The authors consider this study a continuation of the previously mentioned investigations. The previous studies are lacking in a description of the technique that should be used for gastrocnemius muscle subdivision as the authors showed in this study. The study gives the detailed description of the relationship of the vessels and nerves within the muscle substance and shows that in all conditions there was a single proximally located (complete) neurovascular hilum composed of a nerve, artery and vein supplying each muscle belly. The hilum in the upper pole of the muscle was always located near the midline of the leg. So, the neurovascular pedicle enters the medial head of the muscle from the lateral side and enters the lateral head from the medial side. The pedicle also divides the muscle into two distinct parts, a larger superficial portion and a smaller deep portion. This observation is

not recorded before in any previous study and it permits easy subdivision of the muscle into its functional neurovascular units.

The neurovascular pedicle follows the intramuscular connective tissue framework and its position is always eccentric at the side of the midline of the leg. This observation is in contradiction to the portion of Potparic's study, where he stated that the major intramuscular pedicle is located within the central portion of the muscle belly [10]. In all our cases, the main pedicle was always located eccentric at the side of the midline of the leg (Fig.4) and the branching of this main pedicle gave the superficial and the deep portions their own independent neurovascular supply which runs transversely at various angles off the main pedicle. Also, compared with the finding of the Potparic study, his incidence of double vascular supply was 15% [10], but he did not mention in his study if these cases also had a double nerve supply. The incidence of double vascular supply in our study was (12.5%) and there was no accompanying nerve with the additional vascular pedicle.

This pattern of intramuscular neurovascular distribution permits the clinician to take advantage of the branching of the neurovascular supply and split each belly of the muscle into superficial and deep portions attached longitudinally at the point of the main pedicle, and the surgeon can always do that either by starting from the point of the pedicle entrance going outside or from the outside border of the muscle to the inside as described above.

In our clinical cases, the knee joint was exposed in most of our cases and we needed a broad flap to be covered. The use of the classic broadness of the gastrocnemius muscle was not enough and splitting the medial or the lateral head of muscle increasing its surface area was ideal to the wide defects. The splitted head was covered with stable split-thickness graft, which healed completely within 10 days. During our follow up of the patients, the results were cosmetically and functionally good with a full flexion and extension. Only we noticed partial muscle necrosis in two cases, while recipient site hematoma was detected postoperatively in another case. Also, this technique helps minimizing donor site morbidity and deformity and gives a good cosmetic and function results.

In one fourth of our cases, there was a large branch originating from the main pedicle, composed of an artery, vein and nerve, starting its course early at the upper muscle pole. This large branch went on to supply one portion of the muscle, while the main pedicle supplied the remainder. This finding was recorded also by Zoran Potparic in his study. His incidence (of two intramuscular equal size vessels) was 48%, while that of single dominant vessel in his study was 52% of the cases [8]. Here, he also did not mention if these cases with double intramuscular equal vascularity also had double innervation nor did he describe the nerve pattern in those cases. In our study we recorded similarity between the behavior of both the nerves and the vessels in the cases of two intramuscular equal branches. In situations such as this, the muscle can be used as two independent vascularized, innervated motor units, using a portion of the donor muscle for transfer (pedicle or free), leaving a functioning remainder behind to minimize the donor morbidity. Also, the muscle can be transferred in its entirety and then split to provide greater surface area for coverage. Gastrocnemius muscle bellies when split in this fashion give the muscle a larger surface area for covering bigger defects, thereby adding versatility to its reconstructive applications.

#### *Conclusion:*

The anatomical features of the gastrocnemius muscle make increasing its surface area possible. Splitting the medial or the lateral head of the muscle in that fashion gives the muscle a larger surface area for covering bigger defects, thereby adding versatility to its reconstructive applications.

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