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SOME STUDIES ON THE IDENTIFICATION OF THE ARTERIAL PATTERN AND ANATOMICAL CATEGORIZATION OF SOME MUSCLES OF THE CRUS REGION IN BALADY GOATS

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SUMMARY

The present work was carried out on the pelvic limbs of ten adult clinically healthy balady goats of both sexes obtained from several farms at Ismailia Governorate.

Animals were bled to death, and the hind quarters were separated and in vitro injected via the abdominal aorta with a mixture of colored gum milk latex and Barium sulphate for angiography and gross dissection to outline the vasculature of the crural regions. Most of leg muscles (*M. extensor* digitalis longus, *M. extensor digitalis lateralis*, *M. peronaeus* (fibularis) longus, *M. peronaeus* (fibularis) tertius, *M. tibialis* cranialis, *M. gastrocnemius*, *M. soleus*, *M. flexor* digitalis superficialis, *M. flexor* digitalis profundus [Mm. flexor digiti I longus, tibialis caudalis & flexor digitalis longus] and *M. popliteus*) were resected and each was radiographed independently to clear the source, size, site of entrance and the pattern of the intramuscular distribution of its arterial pedicles.

The present study revealed that, the craniolateral group of the crus muscles gained their blood supply from variant arterial pedicles which arose from the cranial tibial artery. Meanwhile, the caudal group of muscles was supplied by many pedicles stemmed from the femoral, saphenous, distal caudal femoral, popliteal and caudal tibial arteries. From the clinical point of view, the investigated leg muscles were classified into five categories according to their observed nature of the arterial pedicles (dominant, major or minor). Moreover the obtained results recommended that, each of the *M. peronaeus* (fibularis) longus, *M. peronaeus* (fibularis) tertius and *M.tibialis* cranialis can be used for regional transposition or used as muscle flap in experimental and reconstructive surgery.

INTRODUCTION

Severe injuries associated with soft tissue damage are mostly complicated by reconstructive problems. Pedicled and micro-vascular free muscle flaps are used in both human and veterinary surgery for the repair of poorly vascularized defects of the lower limbs (Basher and Presnell, 1987 and Mclissinos and Park, 1989). Knowledge of the vascular anatomy to potential donor muscles is of paramount importance to assure that proposed flaps are based on consistently reliable vascular pedicles. Mathes and Nahai (1981) performed an exhaustive study of the vascular pedicles to human muscles with the characteristics of an ideal flap. Small animals can be used as experimental models to develop muscle transfer techniques for the treatment of osteomylitis and the reconstruction of esophagus and trachea in people (Chambers, Purinton, Allen and Moore, 1990 and Gregory and Gourley, 1991).

In ruminants, the intrinsic musculature of the pelvic limbs is simplified and specialized (Nickel, Schummer, Seiferle, Wilkens, Wille and Frewin, 1986) consequently such phenomena appear strongly in goats. The vasculature of the limbs of the goat attracted the attention of many investigators (Badawi and Schwarz, 1963; Ghoshal and Getty, 1967 and Garret, 1988). Moreover, Shehata (1998) as well as Mansour, Abd El-Mohdy, Youssef and Shehata (1999) recorded some anatomical informations on the vascular pattern of some muscles of the goat's thigh.

The present study was undertaken to identify the vascular pedicles of some muscles of the crus region of the balady goat in attempt to categorize the major muscles on the bases of their vascular pattern system. Consequently the current work was a trial to identify the muscles that could be used for local transposition or free-flap transfer in experimental and reconstructive surgical interferences.

MATERIALS AND METHODS

The present work was performed on ten adult clinically healthy balady goats (5males and 5 females) ranging from 25-35kg. body weight, obtained from several farms at Ismailia Governorate.

Goats were euthonized by intravenous injection of Thiopental sodium ® then exsanguinated from the common carotid artery. Hind quarters of the cadavers were separated and the arteries of the pelvic limbs were in vitro injected, via the caudal part of the abdominal aorta, with a mixture of colored gum milk latex and Barium sulphate (50:50) under hand presser till increased resistant was felt (Chambers et al., 1990).

The injected hind limbs were radiographed (60Kv, 200AMS, 1/10S exposure factor with FFD 50cm.) to visualize the arterial distribution in the crural regions. The specimens were then kept in refrigerator for 24 hours. Gross dissection was conducted on the injected limbs of four goats to outline the vascular anatomy of crus muscles. The major crural muscles of the other six animals were dissected carefully and each was radiographed independently (50Kv, 200AMS, 1/10S exposure factor with FFD 40-50cm.) to demonstrate the number, size, site of entrance, and the intramuscular distribution of its arterial supply.

Identification of the vascular pedicles (dominant, major or minor) and consequently categorization of the leg muscles, under investigation, was that adopted by Mathes and Nahai (1981) in man and Chambers et al., (1990) in dogs. Moreover, the nomenclature used in this work was in accordance with that of Schaller (1992) and Nomina Anatomica Veterinaria (1994) whenever possible.

RESULTS

Dissection of the crus region of balady goats had revealed that the craniolateral group of muscles (Figs.1A&1B and 2A&2B) gained their blood supply from vascular pedicles that arose from the cranial tibial artery. Meanwhile, the caudal group was supplied by many vascular pedicles detached from femoral, saphenous, distal caudal femoral, popliteal and caudal tibial arteries (Fig.3A&3B). The number, location and pattern of intramuscular distribution of the vascular pedicles varied from one muscle to another.

(I) Craniolateral group of muscles

1- *M. extensor* digitalis longus (Fig.4A):

The long digital extensor muscle, in the goat, was partially fused proximally with the fibularis tertius muscle. It appeared as having medial and lateral bellies receiving their vasculature mainly through proximal and distal major pedicles arising from the cranial tibial artery. These pedicles entered beneath the fleshy parts of the muscle bellies. Regarding the proximal pedicle (4A/1), it detached 2-3 small rami to the upper part of the lateral belly of the muscle, then it was bifurcated into upper and lower rami that entered the upper fourth of the medial belly (M.extensor digiti III). Meanwhile, the distal major pedicle (4A/2) was divided into lateral and medial descending branches. Each of these branches enters independently into the lower part of the homonymous belly of the muscle and consequently to ramify in its texture.

The vascular pattern of each medial and lateral bellies of the long digital extensor muscle resembled mostly Type III.

2- *M. extensor* digitalis lateralis (Fig.4B):

Two large dominant pedicles from the cranial tibial artery piercing the cranial border of the upper one-fourth and the mid-region of the lateral digital extensor muscle respectively (4B/1&2). The pedicles descend along the deep surface of the muscle parallel to its long axis. Along their courses on the surface of the muscle, the two pedicles gave off numerous collateral twigs which wrapped the muscle in a basket-net appearance. The vascular pattern of the lateral digital extensor muscle was mostly similar to Type III.

3- *M. peronaeus* (fibularis) longus (Fig.5A):

The major blood supply to fibularis longus muscle was represented by a large pedicle (5A/1) stemmed from the cranial tibial artery. The pedicle traversed the deep face of the upper third of the muscle and then coursed ventrally along with its fibers. The intramuscular branching pattern was in the form of simple secondary and tertiary subdivisions from the parent arterial pedicle. Additional 1-2 minor pedicles (5A/2&3), were also observed to arise from the cranial tibial artery and supplied the upper part of the muscle. The vascular pattern of the fibularis longus muscle appeared to be in accordance to Type II.

4- *M. peronaeus* (fibularis) tertius (Fig.5B):

A dominant pedicle arose from the cranial tibial artery entered the deep face of the upper fourth of the fibularis tertius muscle (5B/1). Within the texture of the muscle, the pedicle divided into a short ascending and a long descending ramus. The former ramus supplied the upper fourth of the muscle, while the latter one coursed cranio-ventrad and inturn gave off several minute subdivisions that supplied the rest of the muscle. The vascular pattern of the fibularis tertius muscle resembled mostly Type I.

5- *M. tibialis* cranialis (Fig.6):

The major source of the arterial supply to the cranial tibial muscle was represented by a stout pedicle from the cranial tibial artery (6/1). Immediately as it enter into the deep face of the muscle, the pedicle gave off two opposed short horizontal rami and a long vertical descending one. The former rami supplied the upper part of the muscle, while the latter one coursed ventrad parallel to the long axis of the muscle and gave rise to a series of short intramuscular subdivisions. Additional 1-2 small pedicles (6/2&3), were also observed to arise directly from the cranial tibial artery, and pierced the cranio-dorsal part of the muscle.The vascular pattern of the cranial tibial muscle was similar to Type II.

(II) Caudal group of muscles

1- *M.triceps* surae:

(A)- *M. gastrocnemius* (Fig.7A):

The two heads of the gastrocnemius muscle (Caput laterale & Caput mediale), gained their blood supply mainly from the distal caudal femoral artery. The latter vessel was represented, in the goats, by two long muscular branches which arose in a caudal direction either from the femoral artery, before its transition to popliteal artery, or occasionally from the popliteal artery (2/c&d). Regarding the proximal of the two muscular branches representing the distal caudal femoral artery (7A/1), it was demonstrated that during its course parallel to the caudal border of the fused part of the two heads of the muscle, detached side rami to supply the proximal two third of the two heads. On reaching the lower third of the muscle, it bifurcated into two stout branches, each coursed ventrad to ramify in the homonymous head of the muscle. The distal muscular branch of the distal caudal femoral artery (7A/2) curved more laterally and coursed along the deep face of the lateral head of the gastrocnemius muscle to share in its vascularization via several minute rami. It also detached two considerable sized rami to the medial head of the muscle (7A/A) as well as to the superficial digital flexor muscle (8A/1). Moreover, the dorsal part of each head of the gastrocnemius muscle was pierced by a minor pedicle from the popliteal artery (7A/B&3). Also, the fused lower tendentious part of the two heads usually received additional series of 4-6 minor pedicles from the saphenous branch of the femoral artery (7A/C&4). Multiple anastomoses can be seen in-between the variant intramural twigs inside the texture of the gastrocnemius muscle. The vascular pattern of both medial and lateral heads of the gastrocnemius muscle appeared to be in accordance to Type II.

(B)- *M. soleus* (Fig.7B):

The vascular supply to the soleus muscle was represented by 5-6 small pedicles of different origin. The distal one-fourth of the muscle was supplied by a minor pedicle (7B/1) detached from the saphenous branch of the femoral artery. A group of 2-3 small pedicles arose directly from the femoral artery itself pierced the caudal aspect of the upper three fourth of the muscle (7B/2&3), while the cranial aspect of that region was supplied by another group stemmed from the popliteal artery (7B/4&5). Weak anastomoses were observed in-between the intramuscular subdivisions of the different vascular pedicles. The vascular pattern of the soleus muscle resembled mostly Type IV.

2- *M. flexor* digitalis superficialis (Fig.8A):

Most of the arterial supply to the superficial digital flexor muscle came from a considerable sized pedicle that arose from the lower muscular branch of the distal caudal femoral artery (8A/1). It entered the caudal border of the muscle, near its middle third, and soon divided into 2-3 long intramuscular descending rami. The latter rami coursed ventrally parallel to the long axis of the muscle fibers with numerous anastomosis in-between their subdivisions. In addition to that, the popliteal artery gave off a small sized pedicle (8A/2) that ramified inside the upper third of the muscle. Usually, additional 1-2 minor pedicles (8A/3) originated from the saphenous and / or the medial planter arteries were seen to ramify in the lower part of the muscle. The vascular pattern of the superficial digital flexor muscle appeared to be classified as Type II.

3-*M. flexor* digitalis profundus (Figs.8B, 8 C&9A):

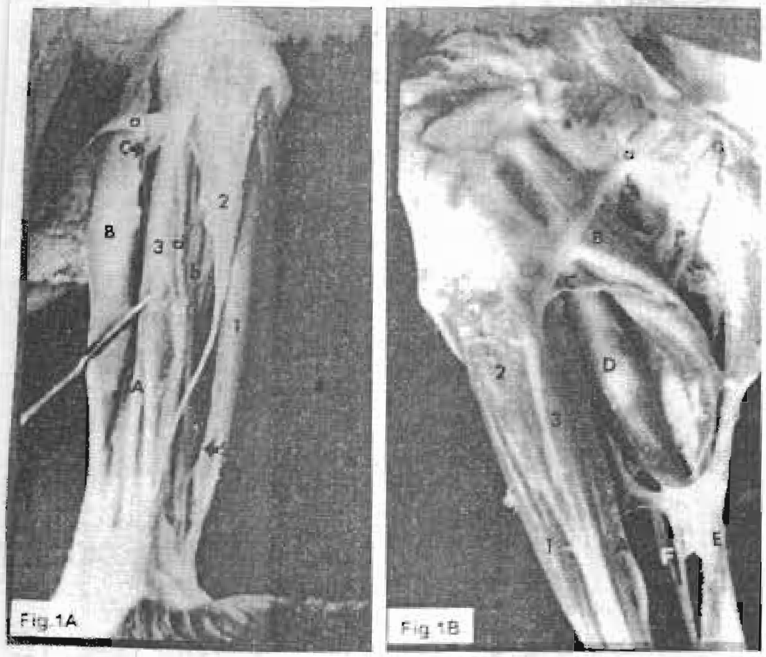
The dominant vessel supplying the three individual heads of the deep digital flexor muscle was achieved by the caudal tibial artery (8B&C/1). The vessel detached a group of variable sized pedicles before bifurcation just below the upper tip of the caudal surface of the *M. flexor* digiti I longus (deep head). These two terminal branches of the artery, ramified ventrally to supply the deep head together with the adjacent part of *M. tibialis* caudalis (superficial head). Additional 1-3 small pedicles arose directly from the popliteal artery (8C/2) pierced the most proximal part of the latter muscle.

The *M. flexor* digitalis longus (medial head) gained its blood supply via many pedicles that arose only from the caudal tibial artery (Fig.9A). The upper half of the muscle was pierced cranially by a considerable sized branch (9A/1), while caudally it was pierced by 3-5 minor pedicles (9A/2). The mid-region of the muscle was traversed by a major pedicle (9A/3), that usually detached a short ascending and long descending intramuscular rami. The long ramus proceeded ventrad and supplied the distal half of the muscle. Sometimes, an inconstant small pedicle was recorded enter the lower part of the muscle (9A/4). Weak anastomosis were seen in-between the fine subdivisions of the muscle pedicles.

The vascular pattern of the deep head of the deep digital flexor muscle mostly resembled Type I, while that of superficial and medial heads was similar to Type II.

4- *M. popliteus* (Figs.9B):

The popliteus muscle received its blood supply from two groups of small pedicles of different origin. The distal group of these pedicles (9B/1&2), arose from the caudal tibial artery and supplied the distal edge of the muscle. While the proximal group (9B/3&4), was detached from the popliteal artery and pierced the proximal edge of the muscle. Few anastomosis were observed in-between the branches of the pedicles inside the muscle. The vascular pattern of the popliteal muscle was mostly similar to Type IV.



Figs.1A&1B: Photographs showing dissected lateral aspect of right (1A) & left (1B) crus regions of balady goat.

1-M. peronaeus (fibularis) tertius.
2-M. peronaeus (fibularis) longus.
3-M. extensor digitalis lateralis.
4-M. tibialis cranialis.
5-M. extensor digitalis longus.
A-M. flexor digiti I longus.
B-M.gastrocnemius(caput laterale)
C-M. soleus.
D- M. flexor digitalis superficialis.
E-Tendo calcaneus communis.
F-A. saphena.
G-A. caudalis femoris distalis.
a-N. peronaeus communis.
a'-N. peronaeus profundus.
b-A. tibialis cranialis.

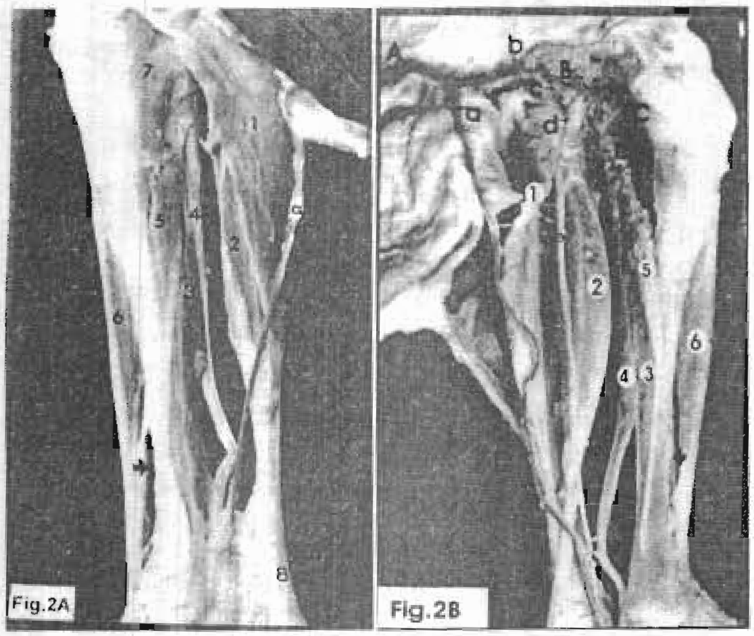
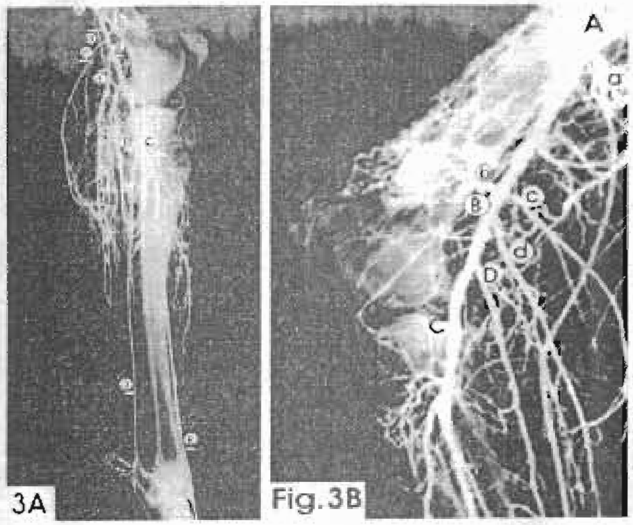


Fig.2: A photograph of a dissected medial aspect of the crus region of a balady goat.

(A) Superficial dissection (left crus).
(B) Deep dissection (right crus).
1-M.gastrocnemius(caput mediale)
2- M. flexor digitalis superficialis.
3- M. tibialis caudalis.
4- M. flexor digiti I longus.
5- M. flexor digitalis longus.
6- M. peronaeus (fibularis) tertius.
7- M. popliteus.
8- Tendo calcaneus communis.
A-A.femoralis.
B-A.poplitea.
C&arrow- A. tibialis cranialis.
D-A. tibialis caudalis.
a-A. saphena.
b- A. genus descendens.
c & d- A. caudalis femoris distalis (Proximal & distal rami).
e-N.tibialis.



Figs.3A&B:Angiography showing the generalized arterial supply to the right(3A) &left((3B)magnified) crus regions of balady goat.

(60Kv, 200AMS, 1/10S exposure factor with FFD 50cm).

A-A.femoralis.

B-A.poplitea.

C&E- A. tibialis cranialis.

D-A. tibialis caudalis.

a-A. saphena.

b-A. genus descendens.

c&d-A.caudalis femoris distalis

1. (Proximal & distal rami).

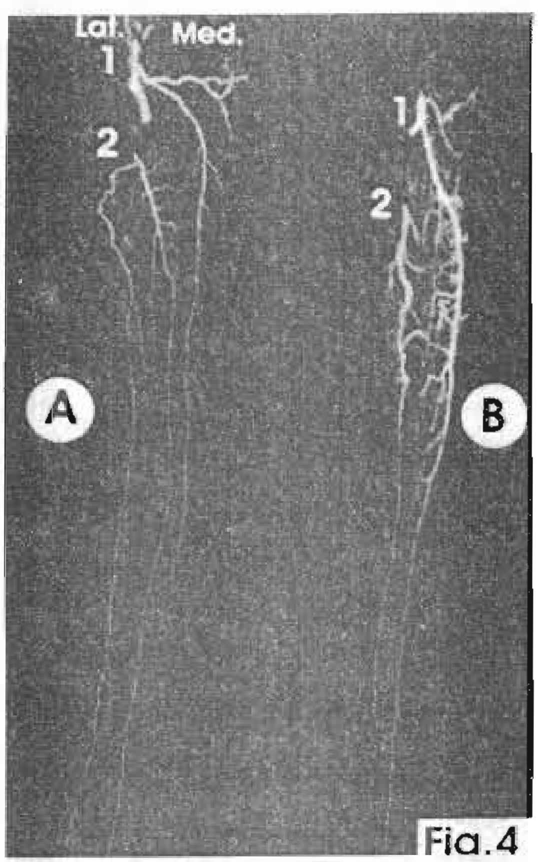


Fig.4A: Angiography showing the arterial vascular pattern for lateral (Lat.) and medial (Med.) bellies of M. extensor digitalis longus.

- Note proximal (1) and distal (2) large pedicles of the cranial tibial artery.
- Both bellies were of Type III.

(50Kv, 200AMS, 1/10S exposure factor with FFD 50cm).

Fig.4B: Angiography of the arterial pedicle system for the M. extensor digitalis lateralis, showing two large pedicles (1&2) of the cranial tibial artery pierced the cranial border of the muscle.

- Note intramuscular anastomosis between both pedicles.
- The muscle was of Type III.

(50Kv, 200AMS, 1/10S exposure factor with FFD 50cm).

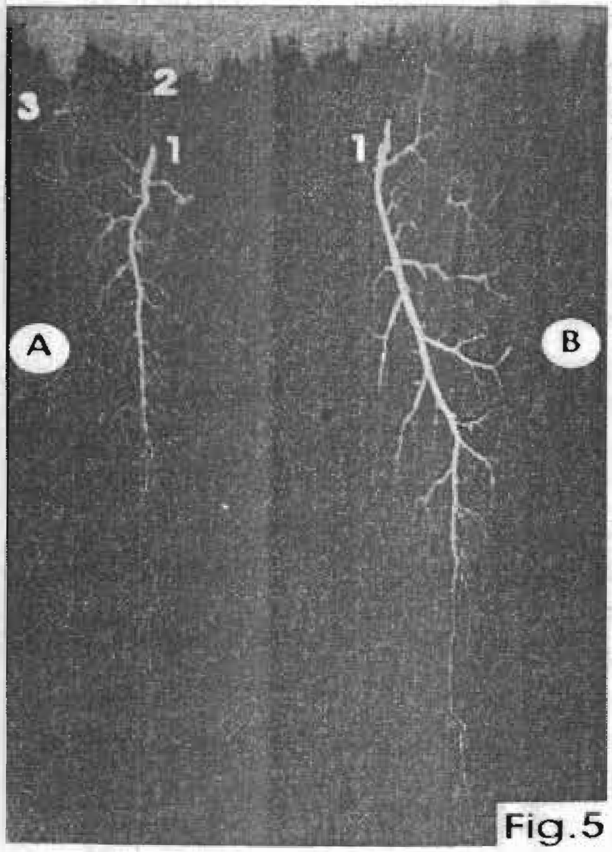


Fig.5

Fig.5A: Angiography showing the arterial supply to the M. peronaeus (fibularis) longus. Note one major (1) and two minor pedicles (2&3) of the cranial tibial artery.

- The muscle was of Type II.

(50Kv, 200AMS, 1/10S exposure factor with FFD 50cm).

Fig.5B; Angiography showing the vascular distribution of M. peronaeus (fibularis) tertius. Note a dominant pedicle (1), from the cranial tibial artery, supply the muscle.

- The muscle was of Type I.

(50Kv, 200AMS, 1/10S exposure factor with FFD 50cm)

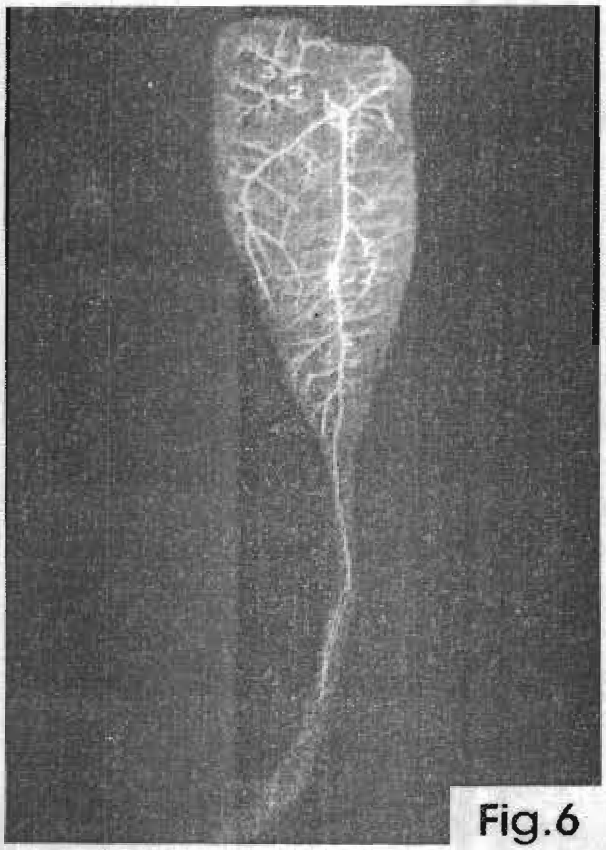


Fig.6

Fig.6: Angiography of the arterial vascular pattern of M. tibialis cranialis, showing that the majority of the muscle supplied by a large pedicle (1), from the cranial tibial artery.

- Note that the cranio-dorsal tip of the muscle pierced by additional two small pedicles (2&3) also from the cranial tibial artery.

-The muscle was of Type II.

(50Kv, 200AMS, 1/10S exposure factor with FFD 50cm).

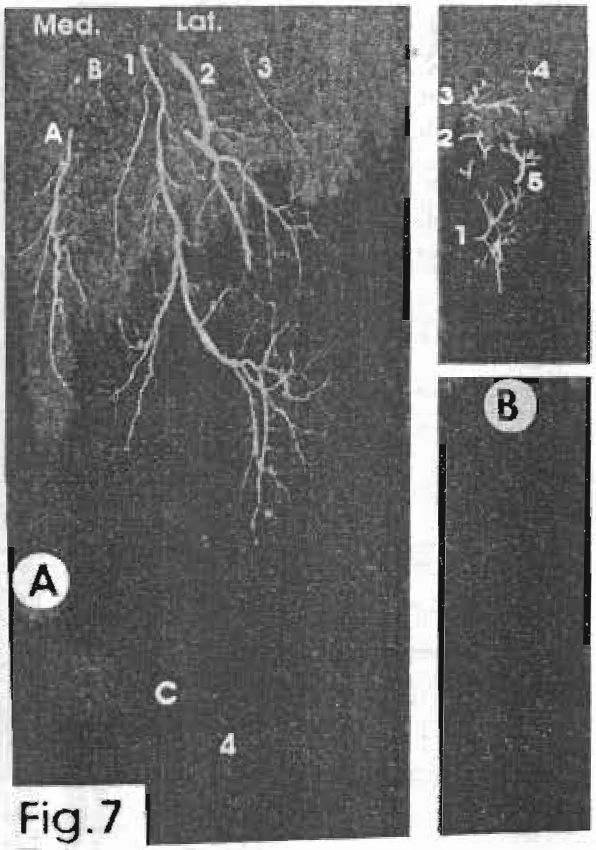


Fig7A: Angiography showing the arterial pedicle system for the M. gastrocnemius (Lat. =caput laterale& Med. = caput mediale). Both heads were of Type II.

1-A.caudalis femoris distalis (Proximal ramus).

2-A.caudalis femoris distalis (Distal ramus).

A-Large pedicle of A.caudalis femoris distalis (Distal ramus), to the medial belly.

B&3-Minor pedicles of A.poplitea.

C&4 Minor pedicles of A. saphena

(50Kv, 200AMS, 1/10S exposure factor with FFD 50cm).

Fig7B: Angiography showing the pattern of vascular anatomy of M. soleus.The muscle was of Type IV.

1- Small pedicle of A. saphena.

2&3-Small pedicles of A.femoralis

4&5- Small pedicles of A.poplitea.

-Notice the weak anastomoses between the different pedicle systems.

(50Kv, 200AMS, 1/10S exposure factor with FFD 40cm)

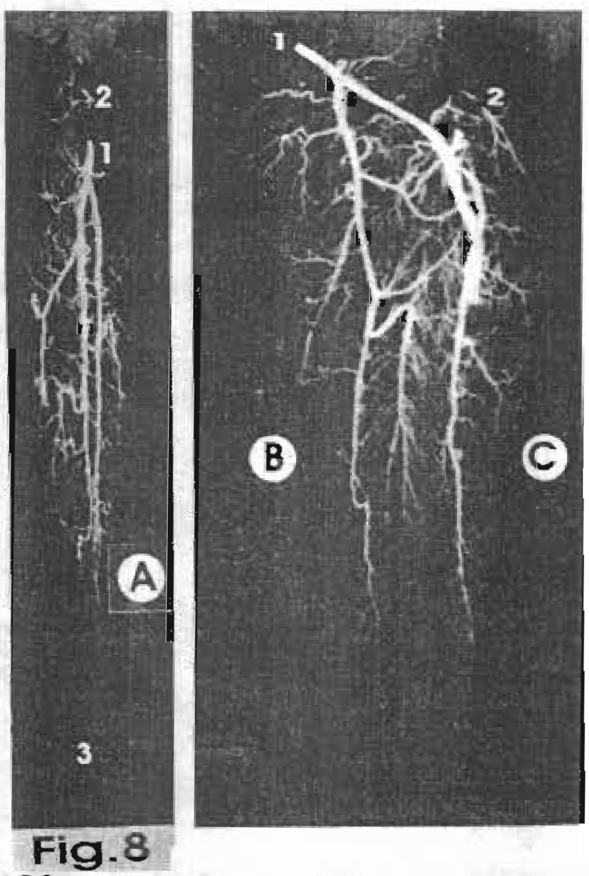


Fig.8A: Angiography showing the arterial supplies to the M. flexor digitalis superficialis.

The muscle was of Type II.

1-Considerable sized pedicle of A.caudalis femoris distalis (Distal ramus).

2- Minor pedicle of A.poplitea.

3- Minor pedicles of A. saphena

(50Kv, 200AMS, 1/10S exposure factor with FFD 50cm).

Figs.8B&C:Angiography showing the vascular distribution of M. flexor digiti I longus (8B= TypeI) and M. tibialis caudalis (8C= TypeII).

1- A. tibialis caudalis.

2- Minor pedicle of A.poplitea.

(50Kv, 200AMS, 1/10S exposure factor with FFD 50cm).

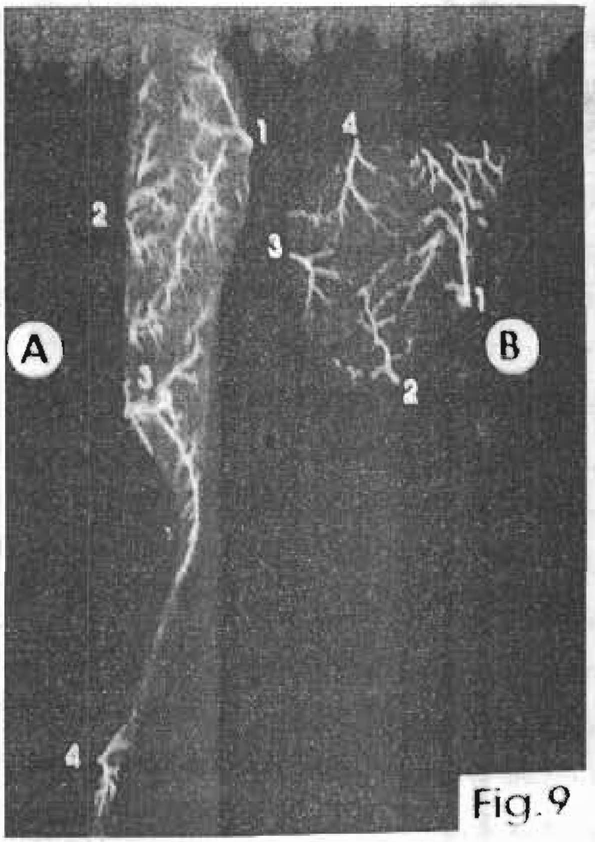


Fig.9A: A photograph showing the arterial pedicle system for M. flexor digitalis longus.

1-Proximal large cranial pedicle of A. tibialis caudalis.

2-Proximal small caudal pedicles of A. tibialis caudalis.

3- Middle large pedicle of A. tibialis caudalis.

4- Distal small pedicle of A. tibialis caudalis.

Note weak anastomoses between the different pedicle systems.

-The muscle was of Type II.

(50Kv, 200AMS, 1/10S exposure factor with FFD 50cm).

Fig.9B: A photograph showing the arterial pedicle system for M. popliteus.

1&2- Minor pedicles of A. tibialis caudalis.

3&4- Minor pedicles of A.poplitea.

-The muscle was of Type IV.

(50Kv, 200AMS, 1/10S exposure factor with FFD 40cm)

DISCUSSION

The vascular pedicle of a free muscle, musculocutaneous or musculoosseous flaps that can be used in reconstructive surgery must have an adequate size. In this respect, Mathes and Nahai (1981) in man and Chambers et al., (1990) in dogs described and classified the arterial vascular pedicles according to their size and the part of the muscle it supply into dominant, major or minor pedicles. They also classified the muscles according to the nature of their vascular pattern into five categories namely, type I (where the muscle is supplied by one vascular pedicle), type II (where dominant vascular pedicle(s) plus minor pedicle (s) contributed in the muscle vasculature), type III (where the muscle is supplied by two dominant pedicles), type IV (where a series of segmental pedicles supplied the muscle) and type V (in which one dominant pedicle and an opposing series of segmental pedicles vascularized the muscle). In this respect, the current study depended on angiography and gross dissection methods to apply that scheme of classification. Moreover, in agreement with Tobin, Netscher, Wiliams, Richardson, Flint, Sharp and Polk (1985) in cats and Chambers et al., (1990) in dogs, the exact identification of the vascular patterns must be established by additional physiological testing to various regions of the muscles after discriminating pedicle legation and flap elevation.

The present study revealed that, the crus muscles of the balady goats have a very rich blood supply, where the craniolateral group of muscles received numerous nutrient vessels that arose from the near-by cranial tibial artery, while the caudal group was supplied by many pedicles stemmed from the femoral, saphenous, distal caudal femoral, popliteal and caudal tibial arteries. Similar observations were recorded by Chambers et al., (1990) in dogs.

The current investigation revealed that the vascular pattern of each of the medial and lateral belly of the long digital extensor muscle belonged to type III, according to the classification made by Mathes and Nahai (1981). Both bellies were sharing in their vasculature by two major pedicles derived from the cranial tibial artery. The deep topographical position of the long digital extensor muscle in the crus region makes it relatively difficult to access and is thus not recommended to be used as a muscle flap. This conclusion was in a line with that recorded by Chambers et al., (1990) in dogs, however they described that muscle had relatively segmentalized vascular supplies which limit its rotation.

It was shown that the lateral digital extensor muscle received two dominant pedicles from the cranial tibial artery pierced the cranial border of both the upper fourth and the mid-region of the muscle respectively. Moreover; it was observed that the collateral twigs of these two pedicles wrapped the muscle in a basket-net appearance. In this respect, Mathes and Nahai (1981) in man classified the vascular pattern of such muscle resembled type III, where cutting off either pedicle may result in muscle necrosis. This fact rendered the muscle not useful as muscle flap.

According to the rules made by Mathes and Nahai (1981) for the classification of the muscles in man, the fibularis longus muscle in goat belonged to type II vascular pattern, where a single major pedicle plus 1-2 minor pedicles stemmed from the cranial tibial artery contributed in its vasculature. The superficial location of the fibularis longus muscle beside its vascular pattern; may facilitate its arc of rotation to adjacent areas of the crus. Moreover, Nahai and Mathes (1982) used the canine fibularis longus muscle as an experimental flap model.

The present work revealed that the fibularis tertius muscle in the goat appeared to be an excellent candidate for local transposition or free-flap transfer in spite of its partial fusion with the underlying long digital extensor muscle. Its vascular pattern mostly resembled type I, where the entire muscle was supplied by a dominant vessel from the cranial tibial artery. Moreover and on agreement with Nickel et al., (1986) in ruminants, the fibularis tertius muscle in goat lies quite superficially which facilitate the access.

The vascular pattern of the cranial tibial muscle, as revealed in the current investigation, appeared to be of type II as the cranial tibial artery supplied it via a stout dominant branch in addition to 1-2 inconstant small pedicles. Like that in dogs

Basher and Presnell, 1987) the superficial location of the cranial tibial muscle in the goat, may facilitate its local rotation. On the other hand, Chambers et al., (1990) in dogs, reported that the cranial tibial muscle had relatively segmentalized vascular supplies which would probably limit their arc of rotation to adjacent areas of the crus.

From the recorded observations, it was believed that the sharing of branches of the distal caudal femoral artery by the gastrocnemius and superficial digital flexor muscles in the goat would make individual flap difficult. This was in accordance with that mentioned by Chambers et al., (1990) in the dogs.

The current study recorded a group of 5-6 small pedicles which shared in the vasculature of the soleus muscle and constructing its vascular pattern resembled to type IV of classification as that reported by Chambers et al., (1990) in dogs. In this respect, Mathes and Nahai (1981) in man observed that division of more than 2-3 minor pedicles during flap elevation of the muscle will result in distal muscle necrosis.

The dominant vessel supplying the three heads of the deep digital flexor muscle, in the present study, was represented by the caudal tibial artery. In this respect, Yolo (2002), in small ruminants, recorded insufficient pumping power of the caudal tibial artery accompanied by accumulation of lactic acid inside the flexor muscles after any exercise. These observations together with our findings render the deep digital flexor muscle not popular as muscle flap, and may explain the common cramping syndrome (wooden leg) of goats described by Omer (2000).

The present investigation revealed that, the popliteus muscle received its blood supply from two groups of small pedicles stemmed from both caudal tibial and popliteal arteries. This segmentalized vascular pattern may limit the local rotation of the popliteal muscle in goat.

The carent work revealed that, the vascular pedicles to the major muscles of the crural regions in balady goats were generally consistent, that may be of great benefit in future laboratory and clinical studies. Similar observation was recorded by Mansour et al., (1999) on the muscles of the thigh region of the same animal.

However the venous drainage was not specifically studied in this work, as it is commonly accepted that the deep veins of the hind limb were largely satellites of the neighboring arteries. This opinion was on the same line with that recorded by El-Mahdy (1998) in red foxes, Chambers et al., (1990) in dogs and Mansour et al., (1999) in goats.

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