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Anatomical Study of the Blood Supply to the Peroneus Brevis Muscle and Its Relevance in Reconstructive Surgery

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Abstract: ***This anatomical study investigates the vascular supply to the peroneus brevis muscle, aiming to enhance its applicability in reconstructive surgeries. Dissections were performed on both legs of twelve preserved cadavers without congenital vascular anomalies. The study measured muscle dimensions and documented the origins and paths of arterial pedicles. It was found that the muscle receives multiple arterial inputs from the peroneal, anterior tibial, and posterior tibial arteries. These findings support the muscle's suitability for use in various flap techniques, including proximally or distally based flaps and free vascularized grafts.***

Keywords: Peroneus brevis, vascular anatomy, reconstructive surgery, peroneal artery, muscle flap

1. Introduction

The anatomical features have presented that the peroneal artery vascularizes peroneus brevis muscles. In 90% of leg, cutaneous artery is originated from peroneal artery within 2cm of the fibular midpoint. The vessel facilitates and acts as a monitor of vascularity for skin loss, and also allows transferring of skin along with bone. Skin defects, especially large defects with bone exposure, in the lower leg represent a major challenge for treatment. Local and free flaps could help reconstruction of such defects. The use of distally based peroneus brevis muscle flap can be effective with much less mortality and morbidity as compared to free muscle flaps especially for moderate and small defects (Eren et al., 2001; Bach et al., 2007). Many surgical procedures were described to cover defects in the lower third of the leg such as muscle trans - positional flaps, adipo - fascial flaps, and reverse - sural flaps. However, none proved ideal local - flaps (Hallock, 2000; Arnold, 1999; Hallock, 1991; Lai, 1992; Singh and Naasan, 2001; Price, 2002) due to the exposed bones and condensed lower leg tendons.

Mathes and Nahai (Mathes and Nahai, 1981) had classified the individual muscles according to their blood supply into five types. Type I muscle flaps are defined by a single vascular pedicle, while type II muscle flaps represent a dominant pedicle (s) and minor pedicle (s). Type III muscle flaps have 2 dominant pedicles, and the type IV muscle flap has segmented vascular pedicles. Finally, type V muscle flaps correspond to a single dominant pedicle and secondary segmental pedicles. It was also reported that most muscles in the lower leg are of type IV, which is considered to be the least mobile muscles. The peroneus brevis muscle was first classified as Type II then reclassified as Type IV (Mathes and Nahai, 1981; Yang, et al., 2005).

Reconstruction of defects in the distal third of the leg using local procedures is not always successful as relative deficiency of reliable local flaps, and their small radius of extension in distal direction (Benito - Ruiz et al., 2004). Consequently, free vascularized tissue grafts are usually considered as the treatment of choice to cover large lower leg defects. However, it needs experience in micro vascular anastomosis and also the healthy sizable vessels of the transferred tissue and the recipient sites (Gonzalez et al., 2002). The distally pedicle peroneus brevis muscle flap is proved to be more helpful to cover these defects and can reach areas distal to the lateral malleolus (Yang, et al., 2005; Eren, 2001; Eyssel and Dresing, 1989; Koski, 2005). Peroneus brevis was reported to be used as a functional component of osteomyo - cutaneous flap in the reconstruction of severe injury of the upper limb (Giessler and Schmidt, 2013). They utilized its segmental blood supply from the anterior tibial and peroneal arteries, and its single motor nerve that enters the muscle at its proximal end. Donor complication in this case was reported to be absent. The present study aims to identify and document the arterial pedicles of the peroneus brevis muscle to evaluate its suitability for reconstructive surgical applications. Understanding the vascular anatomy of this muscle can significantly enhance surgical outcomes in limb reconstruction, particularly in the lower extremity.

2. Method

The research was approved by the ethical committee, Faculty of Medicine, Umm Al - Qura University in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki).

3. Material

Both legs of twelve preserved cadavers including two stillborn, without obvious congenital vascular anomalies, were used in the current study. They were injected with lead oxide solution through the common carotid artery to visualize the arterial tree carotid. The calculated parameters were applied only on the adult cadavers.

4. Design

A vertical skin incision was done in the middle line of the posterior aspect of each leg. The skin was reflected on both sides of the incision. The Achilles tendon was identified and was transversely cut. The soleus and Gastrocnemius muscles were then reflected upwards to expose the posterior tibial artery. Branches of the posterior tibial artery were then identified specially the peroneal (fibular) artery. The latter was identified, and its relation to the flexor hallucis longus muscle was verified. The skin flap was reflected on more laterally to expose the peroneal compartment. Peroneus longus muscle was dissected to identify the arterial pedicles that supply the peroneus brevis muscle, then it was removed to expose the whole length of the peroneus brevis muscle. The muscle was then removed to measure the fleshy and tendinous portions together with the width of its fleshy part. The length of the leg was also measured from the middle of the knee joint cavity till the tip of the lateral malleolus. Swiss Vernier caliber (of 0.05 mm accuracy) was used to calculate the diameters of the major blood vessels especially the peroneal artery. Statistical analysis of the data obtained was calculated using the mean values and the standard deviation.

5. Results

Peroneus brevis dimensions

The total length of the peroneus brevis was at a mean of 28.6± 0.3 cm (ranging from 24 to 32 cm). The length of its tendon was at an average of 8 ±0.1 cm (ranged from 6.8 to 9.3 cm). The width of the middle third of it was at a mean of 3 ± 0.01 cm (ranging from 2.5 to 3.5 cm), while upper and lower thirds had an average width of 2.5± 0.02 cm (ranged from 2 to 4 cm). The total leg length was at a mean of 38 ± 0.7 cm (ranged from 31 to 44 cm). The average thickness of peroneus brevis was 2.22 ± 0.45 mm (ranged from 2 to 24 mm) and the average of cross - sectional area was 7.1 ± 1.55 mm^2 (ranged from 6.1 to 7.9 mm^2)

The blood supply to peroneus brevis

The upper portion of the medial part of peroneus brevis muscle got two arterial pedicles from the anterior tibial artery. The larger one penetrated the peroneus muscle at a mean distance of 18.1± 0.4 cm (ranging from 14.4 to 21.5) from the lateral malleolus. The other pedicle accompanied a nerve supply from the superficial peroneal nerve to the peroneus brevis muscle. The lateral portions of the middle and lower parts of the muscle got multiple arterial pedicles from the peroneal artery and a perforating branch of the posterior tibial artery (Figs.1, 2, 3).

The peroneal artery pierced the posterior inter - muscular septum (18.3 cm from lateral malleolus; ranged from 15 to 24), and passed between the peroneus longus and brevis. Its external diameter at its origin from the posterior tibial was at a mean of 2.2± 0.02 mm (ranging from 1.4 to 3.3 mm). It passed for a mean distance of 14±0.1 cm (ranged from 11 to 15 cm); it penetrated the peroneus brevis at a mean distance of 16± 0.3 cm (ranged from 11.5 to 18.3 cm) from the lateral malleolus. It ended by anastomosing of a perforating branch of the posterior tibial artery in nearly 90% (10 cases) of the studied cases. The perforating branch perforated the posterior inter - muscular septum at a mean distance of 4± 0.01 cm (ranged from 3 to 5 cm) from the lateral malleolus. Its external diameter was at a mean of 1.1± 0.03 mm (ranging from 0.8 to 1.6 mm). In 10% of the cases, the artery ended in peroneus brevis without visible macroscopic anastomosis with the perforating branch of the posterior tibial artery. The peroneal artery supplied the two peronei and the fibula; it gave branches to anastomose with the arterial pedicles of the anterior tibial artery (Fig.1, 3).

The middle portion of the muscle got arterial pedicle from the upper perforating branches of the posterior tibial artery that perforated the posterior inter - muscular septum. The lower portion of the muscle, together with its tendon, received vascular branches from the periosteal arteries of the fibula, branches from adjacent vessels and muscles. The total number of arterial pedicles to peroneus brevis was at a mean of 4 pedicles (ranged 4–5 pedicles), shared by the anterior tibial, peroneal and posterior tibial arteries in 90% of the studied legs.

The peroneus muscle was supplied by the peroneal artery that can be elevated with it to get a vascularized free muscle graft. Moreover, the muscle can be used as distally - based muscle flap depending on the perforating branch of the posterior tibial artery. Similarly, it can be used as proximally - based muscle graft depending on the peroneal artery. The muscle got arterial pedicles from the anterior tibial, peroneal and posterior tibial arteries in twenty of the studied cases (85%).

6. Discussion

The distally based peroneus brevis muscle flap is a reliable alternative for covering defects in the ankle region. Several studies on the clinical application of this muscle flap have shown appropriate outcomes (McHenry, 2001; Bach, 2007; Ng, 2010). Moreover, reported cases of its use as a composite distally pedicle osteo - muscular flap permitting individual placement of a middle fibula segment (Giessler and Schmidt, 2013). The study has illustrated that the peroneus brevis got its blood supply from three sources; the anterior tibial, posterior tibial, and peroneal arteries. The anterior tibial artery branches supplied the upper and middle portions of the medial (anterior or dorsal) side of the muscle. Its arterial pedicle passed with the superficial peroneal nerve and the nerve to the muscle. The peroneal (fibular) artery supplied the upper and middle portions of the muscle, and its periosteal branches supplied the lower part together with the periosteal branches of the posterior tibial artery. Its upper branches anastomosed with those of the anterior tibial artery. The middle portion of the muscle got additional supply from the proximal perforating branch of the posterior tibial artery. The distal perforating branch and the periosteal branches of the posterior tibial artery supplied the lower portion of the muscle as it penetrated about 4cm above the tip of the lateral malleolus. The study also showed that the peroneal artery was the main blood supply to the lateral (posterior or ventral) portion of the muscle while the anterior tibial is main blood supply to the medial (anterior) portion of the muscle. Consequently, the muscle is considered to have two main principal arterial pedicles, regarding the diameters of vessels, which have not matched with the outcomes of other researchers (Villarreal et al., 2004), who considered the anterior tibial artery as main principal artery and the peroneal

artery as supplementary vessel. A study reported that the muscle gets arterial supply from two sources only; the anterior tibial and the peroneal arteries (Ensat, 2015). In this study, the posterior tibial artery has shared its blood supply to peroneus brevis muscle through its two perforating branches and its periosteal branches to the lower part of fibula.

The current study also showed that the peroneus brevis muscle can be vascularized with the peroneal artery in 90% of cases, and can be used as a free vascularized muscle flap or free vascularized myo - osseous flap; using the peroneus brevis and fibula with the peroneal artery. The sizable diameter of the peroneal artery (fibular) would be suitable of micro - vascular anastomosis. Such a flap can be used in reconstruction of soft tissue defects in different areas of the body. It can be elevated with fibula as free vascularized osteo - muscular flap as the peroneal artery supplies the fibula too. The peroneus brevis can also be used as a proximally based muscle graft depending on the peroneal artery and anterior tibial artery branches to reconstruct defects around the knee or pretibial defects (Pers, 2009). The flap components are dependent on the peroneal vessels, and were used to reconstruct extensive radial and soft - tissue defects in a severely damaged forearm. However, the peroneus brevis nerve was coopted to the proper flexor carpi radialis (FCR) motor nerve to counterbalance ulnar abduction, as all radial abductors were lost in the injury.

The distally - based peroneus brevis muscle flap proved to be a reliable flap, and have been used extensively to cover defects in the lower leg and foot with successful clinical outcome (Barr et al., 2002; Saydam, 2002). Such flap will depend mainly on the anastomosis between the perforating branch of the posterior tibial artery and the peroneal artery. Being sizable, such anastomosis can support the distally based flaps with reliability and consequent successful outcome. The distally - based peroneus brevis flap also can depend on the perforating branch of the posterior tibial artery and the periosteal branches of the fibula as shown in the current work. One of the major problems in these flaps is their venous return, which can result in post - operative edema and can result in complications. Such a problem does not change opinions of reconstructive surgery that it is the most valuable flap for reconstruction defects in the lower leg and foot (Arnold, 1999; Hallock, 1991; Benito - Ruiz et al., 2004; Gonzalez et al., 2002). However, it was reported recently that applying post - operative negative pressure therapy (75mmHg) has a significant effect in reducing the postoperative complication of the flap (Erne, 2016).

The study has also shown that the peroneus brevis muscle gets two main principal arterial pedicles from the anterior tibial and the peroneal artery in addition to other small pedicles, which is in agreement with Villarreal, et al. (Villarreal et al., 2004). Consequently, it seems that the vascular pattern of the muscle is very near to Type III classification according Mathes and Nahai classification (Mathes and Nahai, 1981; Ensat, 2015). The peroneal artery was the dominant arterial pedicle for the muscle for its lateral (posterior) portion supplying its upper, middle and lower parts (through its periosteal branches) of peroneus brevis. The anterior tibial artery was the dominant arterial pedicle to the medial (or anterior) portion of the muscle supplying its upper and middle regions. Incorporation of the peroneus brevis tendon allograft to restore the anatomy of the labrum and also its function without morbidity at the donor site has been reported. The tendon has been used for reconstruction of non - repairable labra lesions located in the posterior aspect of the acetabulum and massive reconstructions in cases of global - pincer femur - acetabulum impingement and protrusion - acetabuli (Moya, 2016).

The current study showed that the perforating branches of the posterior and anterior tibial arteries that supplied the peroneus brevis passed through tough membranes. Consequently, local vascularized grafts of peroneus brevis cannot depend adequately on these perforating branches since rotation of the flaps may jeopardize their blood supply. These perforating branches can be kinked or damaged during rotation of local flaps. The peroneus brevis vascularized grafts can depend safely on the direct supply from the peroneal and anterior tibial arteries.

The current study also showed the normal averages of the total length and widths of the peroneus brevis together with the cross - sectional area of its tendon which is important to diagnose certain diseases of the muscle such as atrophy or traumatic injury. It is also important to choose it to cover certain areas of defects in the foot or in the leg or its use as a vascularized myo - osseus flap for distant areas (Dombek et al., 2001 & Park et al., 2022 & Koutsogiannis et al., 2022)

7. Conclusion

It has been concluded that peroneus brevis can be used as a distally - based flap, a proximally - based flap, as a distally - based split flap. It can be also considered as a free vascularized muscle graft in 90% of the cases. It can be further used as a composited vascularized free flap or as osteo - muscular flap with the fibula. For small defects, the peroneus brevis muscle flap can play an important role in reconstructive procedures of lower leg and foot.

Conflict of interest:
No conflict of interest.

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Legends:

1) Figure 1. It shows a branch (arrow) from the anterior tibial artery (ATA) to supply both peroneus brevis (PB) and peroneus longus (PL) muscles.
2) Figure 2. It shows the peroneal artery (PA) between peroneus longus (PL) and peroneus brevis (PB) supplying both. It also shows branch of the anterior tibial artery (arrow) passing with the superficial peroneal nerve (SPN) to supply peroneus brevis.
3) Fig.2: A stillborn shows the peroneal artery (PA) supplying the peroneus brevis muscle (PB) and anastomose with branches of the posterior tibial artery (PTA). FHL, flexor hallucis longus; PTN, posterior tibial nerve, F; fibula

Figures

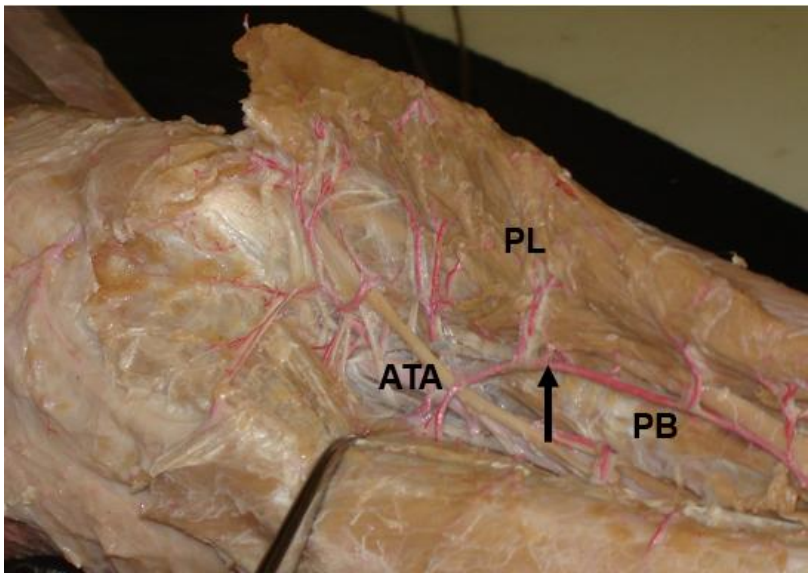

Figure 1:

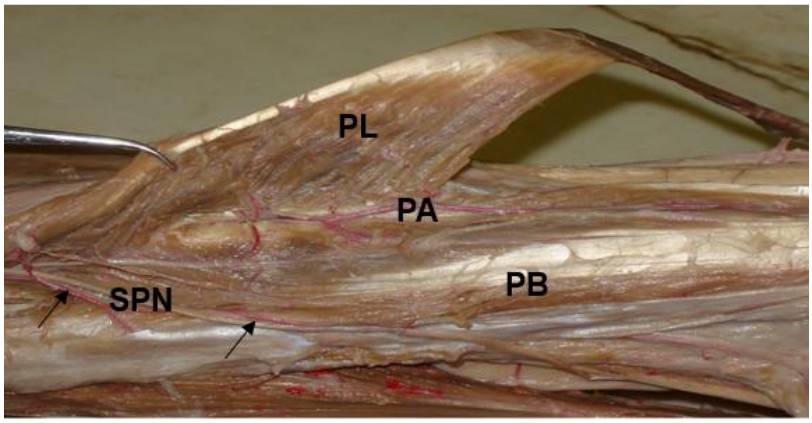

Figure 2

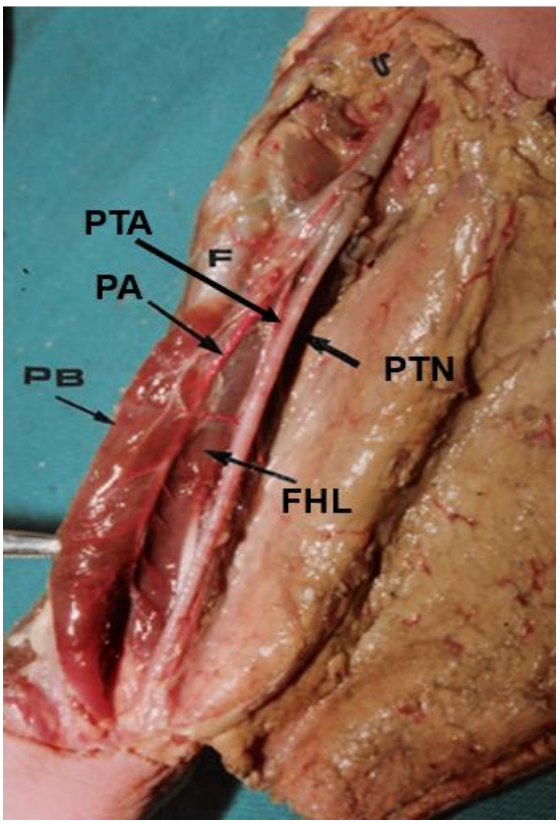

Figure 3