Surg Radiol Anat (2002) 24: 18–22
DOI 10.1007/s00276-002-0001-1

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Innervation of the abductor digiti minimi muscle of the human foot: anatomical basis of the entrapment of the abductor digiti minimi nerve

Received: 19 October 2001 / Accepted: 5 January 2002 / Published online: 29 March 2002

Abstract The origin, relationships and innervation of the abductor digiti minimi muscle were determined in 145 human feet, from formaldehyde-fixed cadavers. The muscle arises from both processes of the calcaneal tuberosity, from the plantar aponeurosis and from the septum which separates it from the flexor digitorum brevis muscle. The nerve to the abductor digiti minimi muscle arises next to the origin of the lateral plantar nerve, close to the abductor hallucis muscle, and descends becoming closely related to the medial face of the calcaneus and the deep face of the abductor hallucis muscle. Then, it passes inferiorly through the origin of the quadratus plantae muscle and later divides into two branches for the two heads of the muscle.

Innervation du muscle abducteur du petit orteil. Base anatomique de la compression de son nerf

Résumé L'origine, les rapports et l'innervation du muscle abducteur du petit orteil ont été étudiés sur 145 pieds humains issus de cadavres formolés. Le muscle naît des deux processus de la tubérosité calcanéenne, de l'aponévrose plantaire et du septum qui le sépare du muscle court fléchisseur des orteils. Le nerf du muscle abducteur du petit orteil naît près de l'origine du nerf plantaire latéral, juste à côté du muscle abducteur de l'hallux et descend en rapport étroit avec la face médiale du calcanéus et la face profonde du muscle abducteur de l'hallux. Il se dirige ensuite vers le bas à travers l'origine du muscle carré plantaire et se divise ensuite en deux branches destinées à chacun des chefs du muscle.

Keywords Foot · Muscles · Tibial nerve · Nerve compression syndromes

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Introduction

Traditionally, the plantar region has been divided into three parts: medial, intermediate and lateral. Therefore in most textbooks the abductor digiti minimi is located in the lateral compartment of the plantar region. The muscle arises from the two processes of the calcaneal tuberosity, from the intervening bone, from the plantar aponeurosis and from the intermuscular septum separating it from flexor digitorum brevis [11, 14, 17].

Subcalcaneal pain of non-traumatic origin can be caused by compression of the nerve of the abductor digiti minimi by the calcaneal spur [1, 2, 5]. This branch takes a lateral course through the sole, lies in the proximal portion of the long plantar ligament and divides into two branches, namely anterior and posterior, which enter the abductor digiti minimi immediately adjacent to the calcaneal tuberosity [3, 5].

It has been stated that this nerve arises from the lateral plantar nerve or directly from the tibial nerve in a common trunk with the plantar nerves and the medial calcaneal branches [1, 8]. In some cases, it arises from a common trunk with the posterior branch for the quadratus plantae [4]. The muscle receives sometimes two branches from the lateral plantar nerve: from a posterior branch which penetrates into the proximal part of the muscle, next to its origin in the calcaneus, and from another which penetrates into the muscle at the level of the fifth metatarsal [12]. This last branch is a branch for the flexor digiti minimi brevis [6].

Authors such as Tanz [15] and Henricson and Westlin [9] have described this muscular branch as being associated with the medial calcaneal branches, especially the inferior-anterior branches.

Due to the above-mentioned differences of opinion, the purpose of this study was to contribute more anatomical details about this muscular branch, to determine its course, relationships and distribution in the abductor digiti minimi.

Material and methods

We dissected 145 human feet (73 right, 72 left) from formaldehyde-fixed adult cadavers of both sexes. The corpses belonged to the Topographic and Descriptive Anatomy Discipline of the UNIFESP-EPM, Brazil and Faculty of Medicine, Universidad de La Frontera, Chile. Dissections were carried out under magnification using microdissection instruments and recorded by photography and drawings.

Results

The abductor digiti minimi is the largest of the intrinsic muscles of the fifth digit of the foot. Its muscular body forms the lateral margin of the foot and its origin is flat and broad, showing two aspects, superficial and deep, and two margins, medial and lateral (Fig. 1).

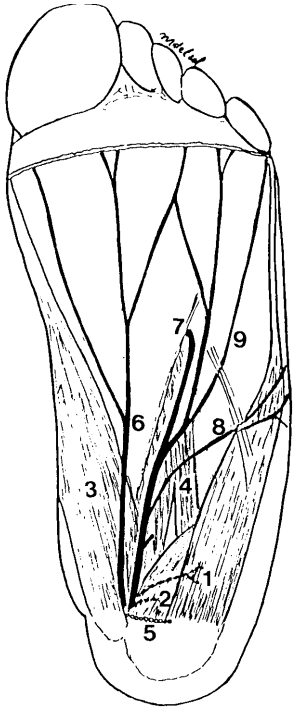

Fig. 1. Inferior aspect of the foot. *1*, Superficial head of the abductor digiti minimi; *2*, deep head of the abductor digiti minimi; *3*, abductor hallucis; *4*, quadratus plantae; *5*, origin of the flexor digitorum brevis (sectioned); *6*, medial plantar nerve; *7*, deep branch of the lateral plantar nerve; *8*, cutaneous branch; *9*, proper plantar digital nerve

This muscle originates in the calcaneal tuberosity in both processes: medial and lateral. Thus, we have considered the presence of two heads in this muscle: superficial and deep.

The superficial head of the muscle forms the lateral margin of the foot and it is covered only by its fascia, the plantar aponeurosis, the subcutaneous layer and the skin. On its deep surface it keeps contact, near its origin, with the lateral head of the quadratus plantae and medially with the long plantar ligament. On the other hand, the deep head is localized between the flexor digitorum brevis (lateral) and the abductor hallucis (medial) which cover it on its superficial surface. This head covers the proximal part of the long plantar ligament and partially the superficial surface of the medial head of the quadratus plantae, which contacts the medial face of the calcaneus.

The nerve to the abductor digiti minimi is the largest branch of the lateral plantar nerve. It arose near the plantar nerve division in 119 cases (82.1%); in 17 (11.7%) the nerve arose directly from the tibial nerve; in

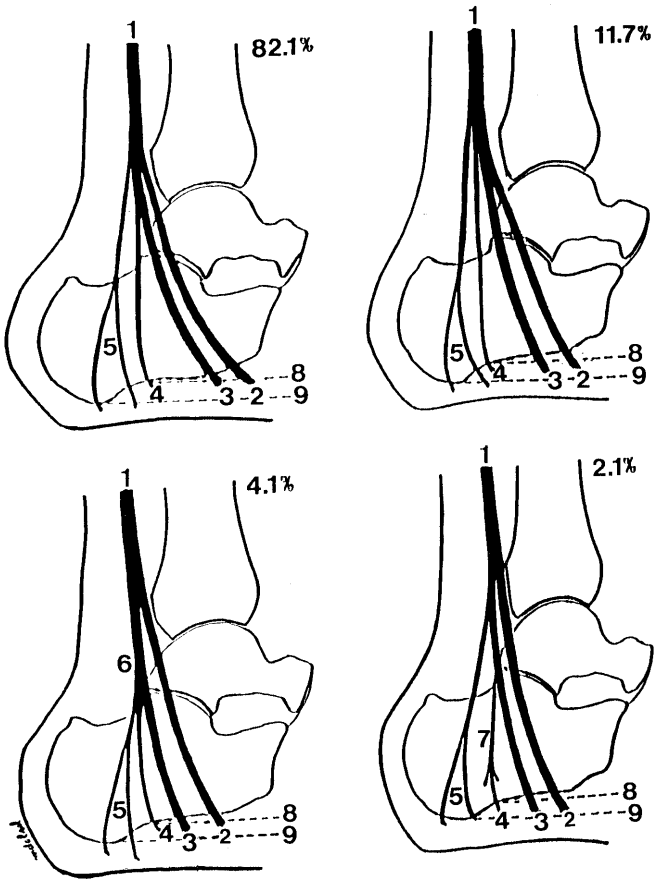

Fig. 2. Origin of the abductor digiti minimi nerve. *1*, Tibial nerve; *2*, medial plantar nerve; *3*, lateral plantar nerve; *4*, nerve for the abductor digiti minimi; *5*, medial calcaneal branch; *6*, common trunk for the nerve for the abductor digiti minimi, the lateral plantar nerve and medial calcaneal branch; *7*, common trunk for the nerve for the abductor digiti minimi and posterior branch for the quadratus plantae; *8*, long plantar ligament; *9*, plantar aponeurosis

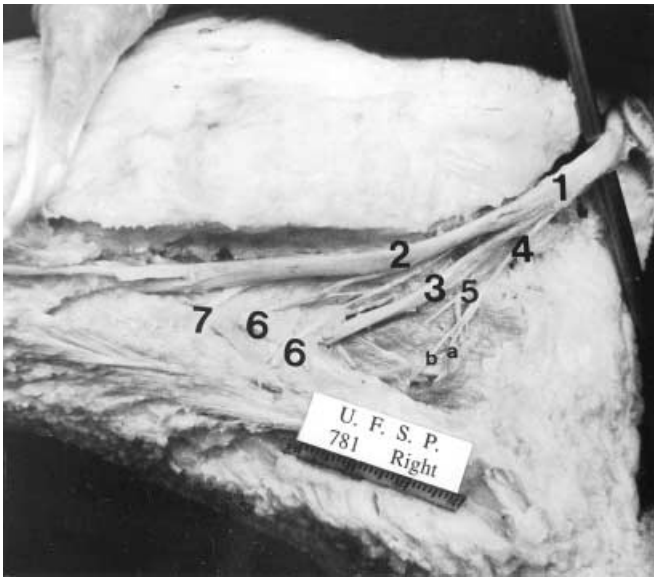

Fig. 3. Inferomedial aspect of the foot. *1*, Tibial nerve; *2*, medial plantar nerve; *3*, lateral plantar nerve; *4*, branch for the abductor digiti minimi with its posterior branch (*a*) and anterior branch (*b*); *5*, branch for the quadratus plantae; *6*, cutaneous branches from the medial plantar nerve; *7*, branch for the flexor digitorum brevis

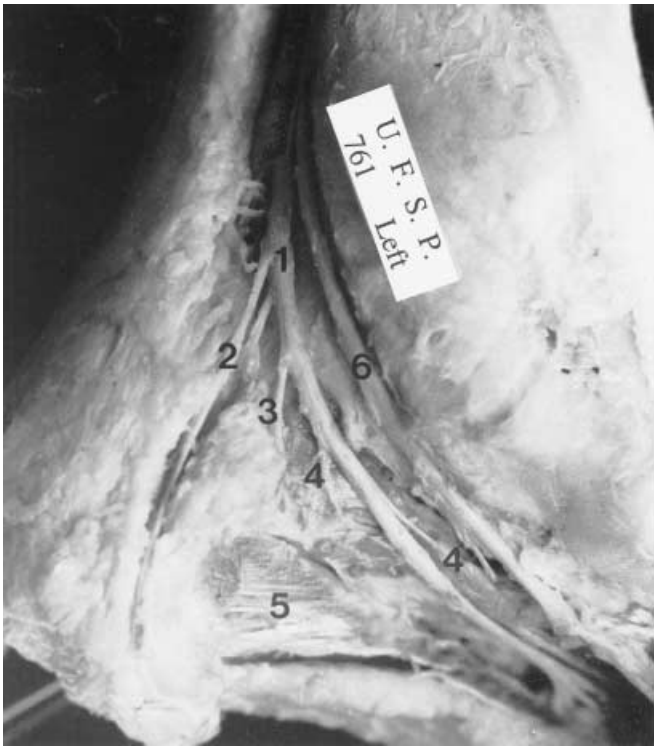

Fig. 4. Inferomedial aspect of the foot. *1*, Lateral plantar nerve; *2*, medial calcaneal branches; *3*, branch for the abductor digiti minimi; *4*, branches for the quadratus plantae; *5*, deep head of the abductor digiti minimi; *6*, medial plantar nerve

six (4.1%) it arose from a common trunk with the lateral plantar nerve and the medial calcaneal branch; and in three cases (2.1%) it arose from a common trunk with the posterior branch for the quadratus plantae (Figs. 2, 3).

On both sides the distance from the origin of the branch supplying the abductor digiti minimi to the origin of the lateral plantar nerve was between 9 and 12 mm, with a 95% reliability.

The branch for the abductor digiti minimi arose in 94.5% of cases proximal to the origin of the branch for the quadratus plantae, although in some cases its origin was also proximal to the superior margin of the abductor hallucis (Fig. 4).

On both sides the distance of the origin of the branch for the abductor digiti minimi to the superior margin of the abductor hallucis was between 8 and 10 mm with a 95% reliability.

The branch for the abductor digiti minimi at its origin is covered medially by the posterior tibial vein. This branch descends together with the lateral plantar nerve, and separates gradually; later it passes through an osteomuscular channel formed by the medial aspect of the calcaneus (sometimes separated by a high origin of the quadratus plantae) and by the deep face of the abductor hallucis. This branch is separated from the latter muscle by the lateral plantar vessels, mainly by veins which anastomose to form the posterior tibial veins. Generally, before crossing the superior margin of the abductor hallucis, the nerve is crossed medially by an arterial branch which arises from the posterior tibial artery or from the lateral plantar artery, which runs to the inferior part of the calcaneus region together with a medial calcaneal branch.

The branch under study courses down close to the medial surface of the calcaneus or the superficial surface of the medial head of the quadratus plantae. It descends in relation to the deep face of the abductor hallucis next to its calcaneal origin. The branch remains separated from the muscular fascia by the vessels which go with it, as far as its penetration in the abductor digiti minimi. Then, the branch changes direction and it passes around the medial process of the calcaneal tuberosity, going obliquely, anterior and laterally. In this part of its course it gives off a branch which goes into the long plantar ligament and its surroundings. At the same time it gives off one or two vascular branches, which are meant for the lateral plantar artery and for the muscular vessels for the abductor digiti minimi and quadratus plantae. This latter is found in only some cases. Then, it divides into two smaller branches, namely posterior and anterior, which penetrate both heads of the abductor digiti minimi.

The branch for the abductor digiti minimi reaches the medial margin of its deep head and, together with the muscular vessels, it passes over this muscular head, remaining separated from the inferior margin and the origin of the abductor hallucis.

It is necessary to emphasize that the origin of the deep head of the abductor digiti minimi is in the medial process of the calcaneal tuberosity. Therefore, in this position, it separates the nerve from the fascia of the

abductor hallucis. In this way, this muscle covers inferiorly the medial margin and a part of the origin of the deep head of the abductor digiti minimi. Sometimes the muscular branch crosses the inferior margin of the abductor hallucis almost directly. This happens when the origin of the deep head of the abductor digiti minimi does not reach the medial process of the calcaneal tuberosity.

The branch for the abductor digiti minimi passes between the origin of the medial head of the quadratus plantae and the deep head of the abductor digiti minimi and keeps a close relationship with the medial process of the calcaneal tuberosity, at a distance of between 3 and 15 mm.

Before its bifurcation this muscular branch gives off a fine branch which initially runs obliquely, inferior and laterally, passing over the deep head of the abductor digiti minimi, next to the medial process of the calcaneal tuberosity. Then the fine branch runs transversely to the lateral side, ending in three parts: the long plantar ligament, the deep portion of the origin of the muscle and in the adjacent region near the calcaneus periosteum. During its course, this branch for the long plantar ligament frequently gives off a vascular branch which accompanies the vessels for the abductor digiti minimi. In some cases, the vascular branch accompanies the lateral plantar vessels.

The nerve for the abductor digiti minimi bifurcated into posterior and anterior branches in 126 cases (86.9%). In only three cases (2.1%) did it divide into three branches: posterior, middle and anterior; and in 16 cases (11%) the branch penetrated the muscle without dividing.

When the branch for the abductor digiti minimi divided into two branches, before penetrating the muscle, the anterior branch was thicker in 90.5% of cases. These branches reached the medial margin of the abductor digiti minimi and lay on its deep surface. The anterior branch ran across the deep face of the deep head and ended in the superficial head. When the branch was undivided, it penetrated the deep head next to the superficial head.

Discussion

The abductor digiti minimi nerve arises from the lateral plantar nerve, before it divides into superficial and deep branches, as shown by Snell [13]. Baxter and Thigpen [1] described the muscular branch as one of the four or five terminal branches of the tibial nerve. We observed such a disposition in only 11.7% of cases.

We believe that the presence of two heads in the abductor digiti minimi, arising from both processes of the calcaneal tuberosity, determines the division of its nervous branch into two minor branches, and the posterior branch establishes a close contact with the calcaneal tuberosity – a fact which has already been stated as a cause of subcalcaneal pain [1] because of an eventual compression or stretching in the presence of a calcaneal spur.

Heel spurs seem more common in patients with heel pain, but they are not necessarily the etiology of such patients' pain. Nerve excision is not necessary or advisable to obtain good results [1]. Furthermore, it is relevant to evaluate other causes of subcalcaneal pain (fasciitis, perineural fibrosis, trauma, vascular spasm, etc.) before transsection of the nerve or resection of the calcaneal spurs.

Deep head of the abductor digiti minimi separates the nerve from the inelastic inferior margin of the abductor hallucis [1, 2] which is associated with the superficial aspect of the deep head of the abductor digiti minimi and with a portion of the superficial surface of the medial head of the quadratus plantae, in this way avoiding direct contact with that structure.

The muscle always receives only one nervous branch. We disagree with other opinions that have described two branches from the lateral plantar nerve: a posterior branch which penetrates into the proximal part of the muscle, next to its origin in the calcaneus, and an anterior branch which penetrates into the muscle at the level of the fifth metatarsal [12]. This last branch corresponds to a branch for the flexor digiti minimi brevis [6] or, then, it would be a cutaneous branch, always constant, which arises from the lateral plantar nerve before it divides [7]. This branch crosses inferiorly to the abductor digiti minimi and ends in the subcutaneous tissue of the lateral margin of the foot, in an arboriform fashion.

The branch which ends in the long plantar ligament and near to the medial process of the calcaneal tuberosity, would be more exposed to pressure from a calcaneal spur, to trauma and to venous pressure.

Acknowledgement Supported by DIUFRO Grant 99/29.

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