 DOI: 10.18231/2394-2126.2017.0028

Morphology and neurovascular supply of extensor digitorum brevis muscle of the foot in humans: Implications for reconstructive surgeries

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Abstract

Introduction: Extensor digitorum brevis (EDB) is a small muscle present on the dorsum of the foot assisting in the extension of toes. The use of EDB in various plastic surgery procedures has renewed interest of clinicians to study the variations in EDB, its arterial supply and nerve supply. However, a review of literature highlights the paucity of anatomical studies comprehensively describing the morphology of EDB and its variations.

The aim was to study the origin, insertion and morphological variants of EDB with emphasis on its arterial supply in embalmed human cadavers, which may have bearing on the use of EDB in various reconstructive surgical procedures.

Methods: EDB muscle was carefully dissected to display the attachments, arterial supply and nerve supply, by retracting the tendons of extensor digitorum longus and peroneus tertius muscles.

Results: EDB demonstrated many variations in its origin and insertion, had additional bellies and also had additional tendinous slips connecting its muscle bellies and having attachment over fascia covering the dorsal interossei and the metatarsals. Extensor hallucis brevis was the most prominent belly. In 13 cases, two lateral tarsal arteries supplied the muscle. Variations in the origin of dorsalis pedis artery were also observed. Accessory deep peroneal nerve was found to supply the muscle in addition to the lateral terminal branch of deep peroneal nerve in three specimens. In view of wide usage of EDB for clinical procedures, the knowledge of variations in its morphology, especially arterial supply and nerve supply is essential.

Keywords: Extensor Digitorum Brevis, Morphological Variations, Foot, Neurovascular Supply, Human Cadavers.

Introduction

Extensor Digitorum Brevis (EDB) is a thin muscle arising from the anterior part of superior and lateral surfaces of the calcaneus in front of the shallow lateral groove for peroneus brevis (PB), from the stem of the interosseous talocalcaneal ligament and from the stem of the inferior extensor retinaculum. It passes obliquely across the dorsum of the foot and gives off four tendons to the medial four toes. The medial part of the muscle is usually a more or less distinct slip, ending in a tendon that crosses the dorsalis pedis artery (DPA) superficially to insert into the dorsal aspect of the base of the proximal phalanx of the hallux; this slip is termed extensor hallucis brevis (EHB). The other three tendons attach to the lateral sides of the tendons of extensor digitorum longus (EDL) for the second, third and fourth toes. EDB is supplied by the lateral tarsal artery (LTA), which is a branch of DPA. It is supplied by lateral terminal branch of deep peroneal nerve (DPN).[(1)]

This muscle received little importance until recently, as it is a small muscle. It was only in 1977 that O'Brien first reported the use of EDB as a free flap.[(2)] This heralded the use of EDB in various plastic reconstructive procedures for the coverage of soft tissue defects of the lower limb.[(3)] The use of EDB also extended into the field of orthopaedic surgeries wherein the muscle is used for interposition after resection of talocalcaneal bar[(4)] and in the treatment of lateral ankle instability.[(5)] The micro vascular transfer of EDB is also being done for plastic reanimation of facial muscles following long established facial nerve palsy.[(6-8)]

Presence of variations in EDB have been reported in some of the standard books.[(1,9)] In view of wide clinical applications of EDB an attempt was made to study its morphology and variations with emphasis on its arterial supply and nerve supply.

Material & Methods

Fifty lower limbs from adult embalmed cadavers in the Department of Anatomy were used for the study. Limbs were already disarticulated from the hip joint. So the sex of the study population could not be determined. EDB muscle was carefully dissected to display the attachments, arterial supply and nerve supply, by retracting the EDL and peroneus tertius tendons. The variations observed in the specimen were grouped and analysed. Representative photographs were taken.

Results

Of the 50 lower limbs, 26 were of right side and the rest were of left side.

Origin: In all the fifty specimens, EDB originated from the anterior part of superior and lateral surface of calcaneum in front of groove for peroneus brevis (PB) in addition to the stem of inferior extensor retinaculum (IER) of the foot. EDB also originated from thick fascia covering the muscle in one specimen. The origin of the

muscle very frequently extended to the adjacent bones and ligaments as shown in Table 1.

Table 1: Showing additional origin of EDB from adjacent bones & ligaments

Structure	No. of specimens	Percentage
Cuboid	49	98
Cervical ligament	46	92
Bifurcate ligament	27	54
Lateral cuneiform	12	24
Intermediate cuneiform	5	10
Medial cuneiform	3	6
Base of 4th metatarsal	8	16
Base of 3rd metatarsal	9	18
Base of 2nd metatarsal	5	10

The muscle belly of EHB was prominent when compared to other bellies in 48 specimens. In one of the specimens (left side) the 1st and the 2nd bellies were equal in size. In one specimen (right side) EHB had split into two slips and hence was not the largest of the four.

Additional bellies: Additional bellies were observed in 28 specimens (Fig. 1). As shown in Table 2, these bellies mostly occupied the position between first and second bellies of EDB, originated from the main muscle mass of EDB and inserted, in majority of cases, onto the fascia covering the dorsal inter-osseous muscle.

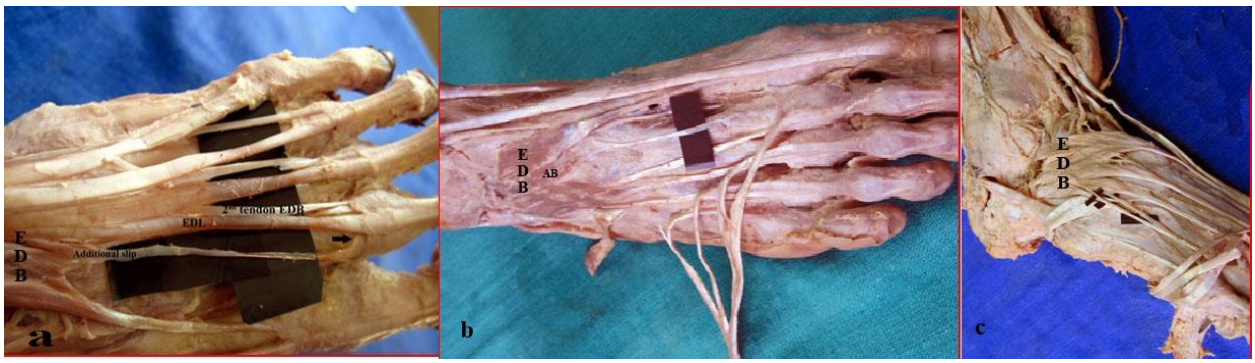

Fig. 1a-c: Showing additional bellies of EDB

a. Additional belly between the 1st & 2nd belly of EDB inserting to the medial side of dorsal aponeurosis of the 2nd toe
b. Additional belly (AB) from the main muscle mass & receiving a slip from EHB inserted into fascia over base of 2nd metatarsal
c. Two additional tendinous slips of 3rd EDB inserting to 4th tendon of EDB. Also note a tendinous slip from the 4th EDB inserting to 3rd tendon of EDB

Table 2: Showing additional bellies of EDB

No. of specimens	Position between bellies	Origin	Insertion
23	1 & 2	Main muscle mass	Fascia over 2nd DIM & the fascia over base of 2nd MT
	1 & 2		Fascia over 1st DIM & fascia over shaft of 2nd MT
	1 & 2		Fascia over the base of 1st MT
	1 & 2		Medial side of DDE of 2nd toe
	1 & 2		2nd DIM
	1 & 2		Shafts of 1st&2nd MT& fascia over 2nd DIM
	1 & 2		Medial side of DDE of 2nd toe, fascia over shaft of 2nd MT
	1 & 2		Fascia over the bas\e of 2nd MT
	1 & 2		Fascia over 2nd DIM
	3 & 4		Fascia over 3rd DIM
	1 & 2		2nd belly of EDB and fascia over the base of 2nd MT
	1 & 2		EHB tendon and fascia over the base of 2nd MT
	1 & 2		Lateral side of DDE of 2nd toe
	1 & 2 3 & 4		Fascia over 2nd DIM & fascia over shaft of 2nd MT Fascia over 3rd DIM & fascia over shaft of 3rd MT

	1 & 2		Additional retinaculum extending from the medial border to the lateral border of foot and fascia over shaft of 2nd MT
1	1 & 2	Main muscle mass & slip from EHB	DDE of 2nd toe deep to EDL
2	1 & 2	EHB & a slip from 2nd belly of EDB	As tendinous slips to fascia over 2nd DIM & fascia over 2nd MT
1	1 & 2	2nd belly of EDB	Fascia over 2nd DIM
1	1 & 2	Main muscle mass & additional retinaculum extending from the medial border to the lateral border of foot	As digastric belly with the accessory muscle of the 1st DIM to medial side of DDE of 2nd toe.

MT- Metatarsal DDE-Dorsal Digital Expansion DIM- Dorsal Interosseous Muscle

Insertion: EHB inserted into the dorsal aspect of the base of proximal phalanx of great toe and the middle two tendons into the dorsal digital expansion of second, third toes on its lateral aspect in all the specimens. The fourth tendon barring two cases also inserted into the dorsal digital expansion of the fourth toe. In these cases it is inserted into the fascia over 4th dorsal interosseous muscle in one specimen and directly to the 3rd tendon of EDL in the other.

The lateral three tendons were found to have small additional tendinous slips inserted either into dorsal digital expansion, the adjacent tendons of EDB, EDL and fascia over dorsal interossei or fascia over metatarsals.

Arterial supply: All the fifty specimens received arterial supply on the deep surface of the muscle from LTA, which was a branch of DPA. In 13 specimens, there were two LTA (instead of one) supplying the muscle (Fig. 2). The LTA formed an arterial anastomosis with the branches of lateral plantar artery and perforating branch of peroneal artery (PBPA) deep to the EDB muscle in all the specimens.

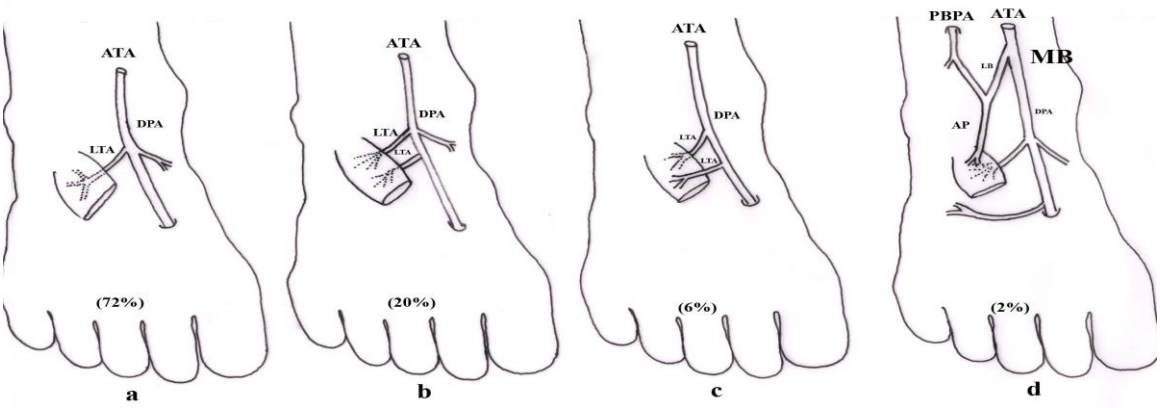

Fig. 2a-d: Showing various patterns of vascular pedicles supplying the EDB

a. Single LTA supplying EDB from deep surface
b. Double LTA supplying EDB from deep surface
c. Double LTA supplying the muscle from superficial and deep surfaces.
d. LTA supplying the muscle from deep surface and an additional pedicle supplying the muscle from superficial surface

As LTA is a branch from DPA, variations in the formation of DPA were also observed. The normal course of DPA as the continuation of anterior tibial artery (ATA) at the ankle joint was observed in 37 specimens (74%). Variations in the formation of DPA were also observed in the remaining 13 specimens are shown in Fig. 3 & 4.

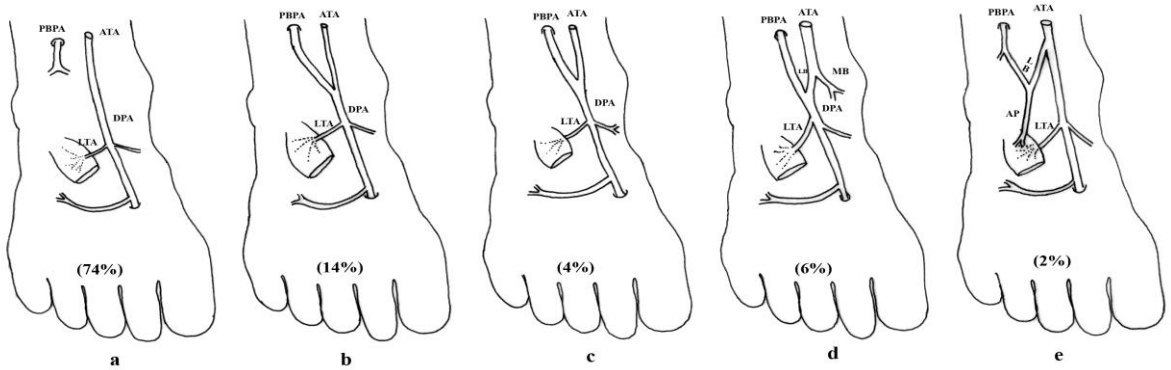

Fig. 3a-e: Showing various patterns of formation of DPA

a. ATA continuing as DPA
b. PBPA giving major contribution to DPA
c. ATA and PBPA giving equal contribution to DPA
d. ATA divides into medial and lateral branches, lateral branch is joined by PBPA and forms DPA
e. ATA divides into medial and lateral branches, lateral branch is joined by PBPA and contributes additional vascular pedicle to EDB and the medial branch continues as DPA

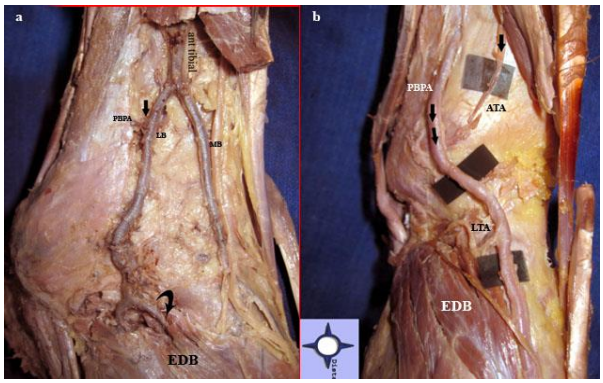

Fig. 4a & b: Showing variations in the formation of DPA

a. Lateral branch (LB) of ATA continuing as DPA after joining PBPA
b. DPA formed by major contribution from PBPA and minor contribution from ATA

Nerve Supply: EDB was supplied by the lateral terminal branch of the DPN from its deep surface. Additional supply to EHB was found to arise from the medial terminal branch of DPN in one specimen. ADPN, a branch of superficial peroneal nerve, supplied the muscle from its superficial surface, on the lateral side in addition to its nerve supply from the lateral terminal branch of DPN in 3 specimens (Fig. 5 & 6).

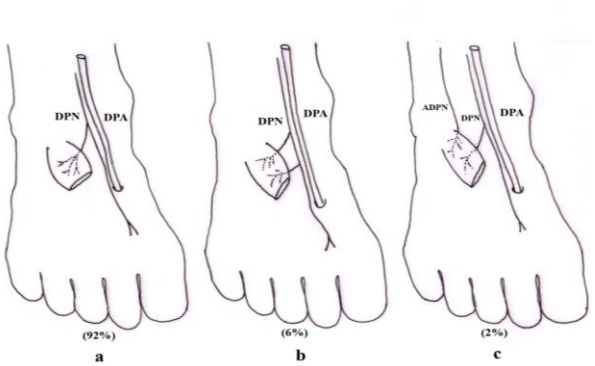

Fig. 5a-c: Showing various patterns of nerve supply to EDB

a. Single branch of DPN from deep surface
b. Two branches of DPN from deep surface
c. ADPN, in addition to DPN supplying EDB

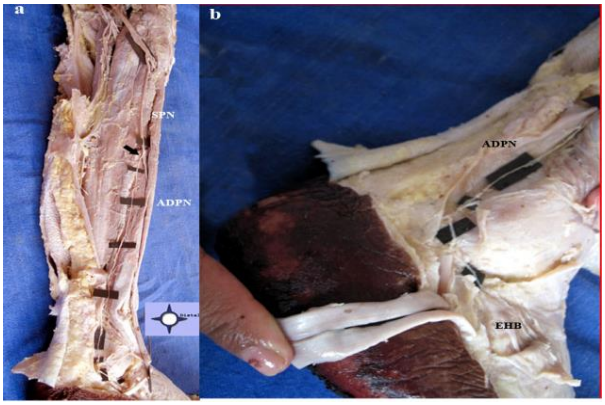

Fig. 6a & b: Showing ADPN supplying EDB

a. ADPN arising from superficial peroneal nerve(SPN)
b. ADPN supplying EDB

There was a localized thickening on the lateral terminal branch of DPN in 24 specimens with two

specimens having such thickenings. Similar thickenings were found on the DPN before division in 12 specimens. One specimen had two such thickenings before division. Thickenings were also seen on the medial terminal branch of DPN in 7 specimens; of which one of the specimen had two thickenings. The shape of these localized thickenings found on the nerves were fusiform in 35, spherical in 4 and elongated in 8 specimens.

Discussion

Origin: The origin of EDB from the anterior part of upper and lateral surface of calcaneus seen in the present study is similar to the description in Standard texts of anatomy.[9-12] The origin of EDB from the IER, nearby ligaments and the metatarsals as found in the current study substantiates the findings of other studies.[11,13]

Insertion: In 96% of the specimens in the present study, the lateral tendons of EDB was inserted as described in the standard text books of anatomy.[9-12,14]

Additional bellies: Additional bellies were seen in 56% of the specimens in the present study. The prevalence of additional bellies in earlier studies in different population groups ranged from 2.27 % to 72.5%.[13,15,16] Additional belly originated from the main muscle mass in most of the specimens in the present study.

Arterial supply: Several studies described the presence of two and rarely three LTA.[3,13,17] Landi et al. in their study found two vascular pedicles supplying the muscle in 71% of the seven specimens that they studied.[17] However in the present study, only 28% had two vascular pedicle. EDB getting additional vascular pedicle on superficial surface directly by DPA, as observed in the present study, has not been reported in literature.

The LTA supplying EDB is a branch of DPA. DPA is typically the continuation of ATA at the level of ankle joint. Any variation in the formation of DPA will influence the length of vascular pedicle and thereby the arc of rotation of EDB as an island flaps. According to Baltensperger and colleagues, the reliable consistency of the vascular pedicle (LTA-DPA-ATA) is an important feature of EDB island flap. In cases where the DPA originates from PBPA, this would cause substantial loss in length of the vascular pedicle.[3] Therefore the knowledge of variations in the formation of DPA is important before contemplating such procedures.

As observed in the present study the PBPA contributed to DPA largely in 14% and partially in another 12% specimen. Some workers have documented only PBPA contributing to DPA in 3-6%,[3,13,18] of cases but no such case was observed in present study.

Huber JF (as quoted by Sarrafian SK) while documenting the variations of formation of DPA reported that in 26.5% of cases the DPA is not a direct continuation of ATA. Our findings confirm closely with Huber JF (as quoted by Sarrafian SK).[13] As the length of vascular pedicle and thereby the arc of rotation for the EDB island flap is determined by the origin of DPA, it is suggested that, the awareness regarding these variations and also preoperative arteriography and doppler studies are essential prerequisite for planning an EDB muscle flap.

Nerve supply: It was observed in the present study that DPN is major nerve supply to EDB complemented occasionally by ADPN, also called accessory peroneal nerve. General consensus according to previous studies is also in favour of the above finding,[19-22] however occasional cases of complete innervation by ADPN has also been described in literature.[23]

The knowledge of the presence of ADPN is essential for the correct diagnosis of common and deep peroneal neuropathies, as its presence would alter the usual electrophysiological characteristics of peroneal nerve lesions.

In the present study, one specimen the medial terminal branch of DPN gave an additional branch to EHB. To the best of authors' knowledge this has not been reported in other studies.

Single or multiple localized enlargements were observed at different locations, especially subjected to friction, along DPN or its terminal branches. Though the standard textbook of anatomy[1] has mentioned the presence of pseudo ganglion in the lateral terminal branch of DPN, a detailed description of these is lacking in anatomical literature. Findings of the present study reported as localized thickenings in the nerve need to be substantiated by histological examination to classify them as pseudo ganglia.

Conclusions

From the results of our study we are of the opinion that awareness regarding the variations in the origin of DPA, which would influence the length of the vascular pedicle as well as the arc of rotation for EDB island flap, is essential for planning EDB muscle flap. This also necessitates preoperative arteriography and doppler studies before contemplating such procedures. We also suggest that awareness regarding the presence of ADPN is essential while dealing with common and deep peroneal nerve lesions, as its presence would alter the electrophysiological characteristics of peroneal nerve lesions. We are of the opinion that knowledge of anatomical details of ADPN is important while performing surgeries in the lateral ankle region to avoid injury to the nerve.

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