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A variant extensor indicis muscle and the branching pattern of the deep radial nerve could explain hand functionality and clinical symptoms in the living patient

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The purpose of this study is to document the topographic anatomy of an extensor indicis (EI) muscle with a double tendon and the associated distribution of the deep branch of the radial nerve (DBRN). Both EI tendons were positioned deep to the tendons of the extensor digitorum as they traversed the dorsal osseofibrous tunnel. They then joined the medial slips of the extensor expansion of the second and third digits. In all other dissected forearms, a tendon of the EI muscle joined the medial slip of the extensor expansion to the index finger. The DBRN provided short branches to the superficial extensor muscles, long branches to the abductor pollicis longus and extensor pollicis brevis muscles, and terminated as the posterior interosseous nerve. Descending deep to the extensor pollicis longus muscle, the posterior interosseous nerve sent branches to the extensor pollicis brevis and EI muscles. Understanding of the topographic anatomy of an EI with a double tendon, and the associated distribution of the DBRN,

L'objectif de cette étude est de documenter l'anatomie topographique du musculus extensor indicis (MEI), ou muscle extenseur de l'index, avec un tendon double et la distribution de la grosse branche du nerf radial (DGBNR) qui lui est associée. Les deux tendons du MEI sont positionnés profondément dans les tendons du extensor digitorum alors qu'ils traversent le tunnel osso-fibreux dorsal. Ils joignent ensuite les portions internes de l'expansion de l'extenseur au niveau du deuxième et troisième doigt. Dans tous les autres avant-bras disséqués, un tendon du MEI joint la portion interne de l'expansion de l'extenseur à l'index. La DGBNR fournit de petites branches aux muscles d'extenseur superficiels, de grosses branches aux muscles du long abducteur du pouce et du court extenseur du pouce, pour finir en tant que nerf interosseux postérieur. Le nerf interosseux postérieur descend profondément dans le muscle du long extenseur du pouce et envoie des branches au court extenseur du pouce et au MEI. Une bonne compréhension de l'anatomie topographique d'un MEI avec double tendon, et la DGBNR associée,

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may contribute to accurate diagnosis and treatment of hand lesions.

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peut favoriser des diagnostics précis et améliorer le traitement de lésions aux mains.

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MOTS CLÉS : musculus extensor indicis, neuropathie, nerf radial, variation, douleur au poignet

Introduction

Anatomical variations of the extensor muscles of the hand, including the extensor indicis (EI), are common, and no standard pattern has been described.[1-13] These variations are often a matter of concern to clinicians as they may lead to a misdiagnosis. For example, a variant EI muscle may give rise to dorsal wrist pain and hence may be diagnosed incorrectly as a ganglion, soft tissue tumor, synovial cyst or tenovaginitis.[14-18] For surgeons, the variations of EI tendons are of particular clinical importance, since this is the muscle that is commonly used to perform graft and tendon transfer operations and should be considered during extensor tendon exploration for trauma.[5,7,19] Since hand surgery relies mainly on applied anatomy, it is essential to revisit not only the anatomy of the presented variance of the EI muscle but also the distribution of the deep branch of the radial nerve (DBRN) as it may help to explain clinical symptoms developed by the partial or complete entrapment of the main trunk of this nerve or its branches.[20-24] To our knowledge, no studies have investigated the correlation between the variant EI and the branching pattern of the radial nerve. Even though the distribution of the DBRN is complicated and inconsistent,[23] enhancing our understanding of the relationship between the radial nerve and the variant EI may contribute to accurate diagnosis, effective surgical procedures, and the modeling of neurovascular compartments.[25] Familiarity with the variations of extensor muscles and their innervation are crucial for assessment and treatment of pathologic conditions with magnetic resonance imaging, diagnostic sonography, and magnetic resonance neurography.[26-30]

The rationale of the presented study is to document the existence and topographic anatomy of the EI muscle with a double tendon and the associated distribution of the DBRN. This is done to enhance clinicians' awareness, so as to provide adequate assessment and treatment of hand lesions. It may also be useful for modeling of neurovascular and muscular compartments of the forearm and hand.

The following questions are posed: i) Could the presented variant in the morphology of the EI muscle explain hand functionality and clinical symptoms in the living patient?, ii) What branching pattern of the radial nerve should be expected in the case of an EI with a double tendon?, iii) What are the clinical implications of the branching pattern of the DBRN?

We present the topographic anatomy of the EI muscle with a double tendon and discuss its functional and clinical implications. The distribution of the DBRN within forearms possessing single or double tendons of the EI muscle is investigated and its clinical significance is discussed.

Material and methods

This study utilized 16 embalmed cadavers (32 upper limbs) of both genders and of different ages using anatomical macro-and microdissections. An 89-year-old male had a double tendon of the extensor indicis muscle bilaterally. This variant muscle was dissected carefully to expose its origin, course and insertion. All of the forearms were dissected to examine the distribution of the radial nerve branches within the posterior forearm to determine whether the branching pattern of the radial nerve varies significantly within the forearms possessing single or double tendons of the EI muscle. The specimens were documented and photographed.

Results

In an 89-year–old male cadaver, the EI muscle with a double tendon to the second and third digits was found bilaterally within the deep layer of the extensor muscle compartment of the forearm (Figure 1A). This variant muscle originated from the posterior surface of the distal third of

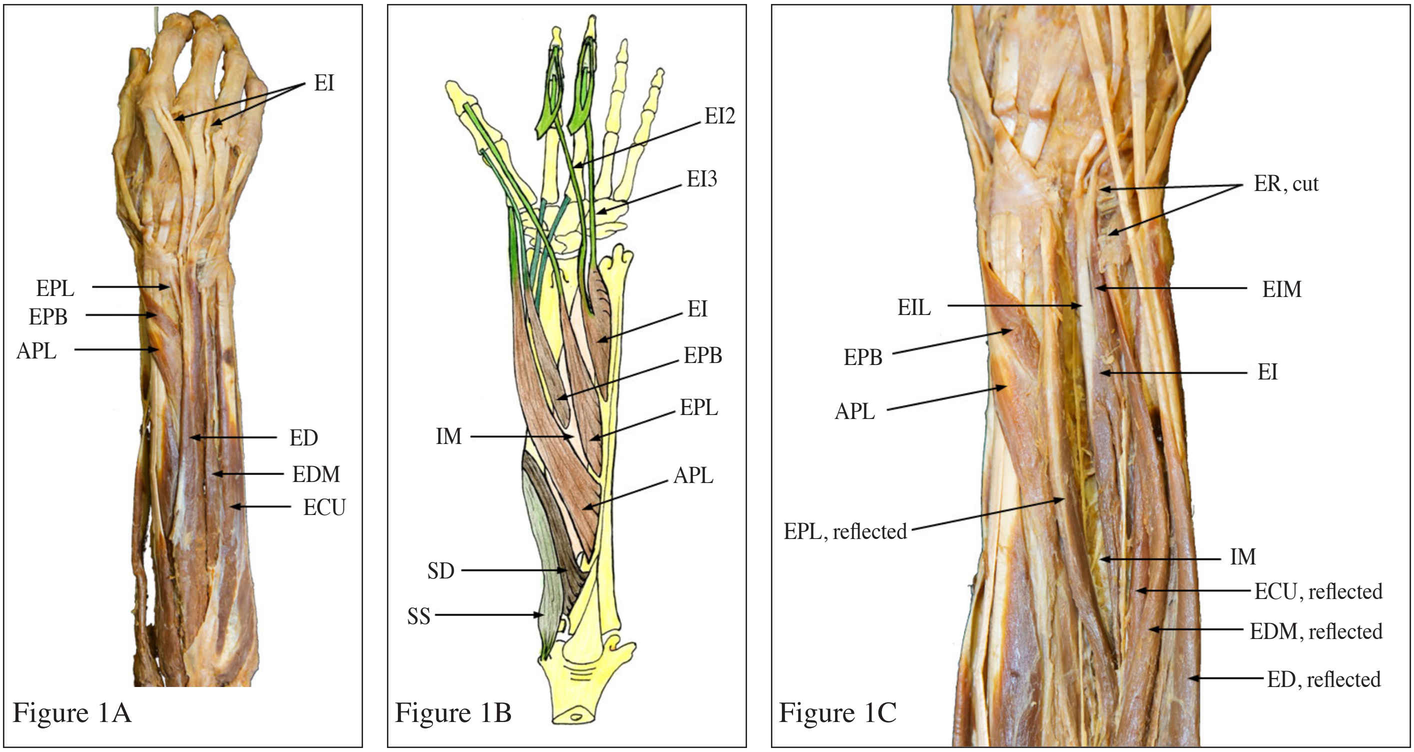

Figure 1
Topography of the extensor indicis (EI) muscle with a double tendon within the muscular layers of the extensor compartment of the forearm.
A – The superficial muscular layer includes ECU, extensor carpi ulnaris; EDM, extensor digiti minimi; ED, extensor digitorum. The deep layer includes EPL, extensor pollicis longus; EPB, extensor pollicis brevis; APL, abductor pollicis longus; EI with a double tendon.
B – Schematic representation illustrates the deep muscular layer. EI2, extensor indicis to the second digit; EI3, extensor indicis to the third digit; SS, supinator superficial part; SD, supinator deep part; APL; EPL; EPB; IM, interosseous membrane.
C – The extensor indicis lateral part (EIL) of the muscle belly becomes tendinous proximal to the extensor retinaculum (ER). The extensor indicis medial part (EIM) is longer with the musculotendinous junction descending deep to the superior margin of the ER. Both tendons of the EI are positioned medial and deep to the tendons of the ED, as they traverse the osseofibrous tunnel under the ER.

the shaft of the ulna, the adjacent interosseous membrane, and from the internal surface of the antebrachial fascia occupying the interface of the superficial-deep forearm extensors (Figure 1B). The lateral part of the muscle belly was shorter and became tendinous proximal to the extensor retinaculum. However, the medial part was longer, with the musculotendinous junction descending deep to the superior margin of the extensor retinaculum. Both tendons of the EI were positioned medial and deep to the tendons of the extensor digitorum (ED) muscle as they traversed the fourth osseofibrous tunnel under the extensor retinaculum (Figure 1C). On the dorsum of the hand, opposite the heads of the second and third metacarpal bones, the two tendons of the EI joined the ulnar sides of the tendons of the ED, enhancing the medial slips of the extensor expansion (EE) for the second and third digits

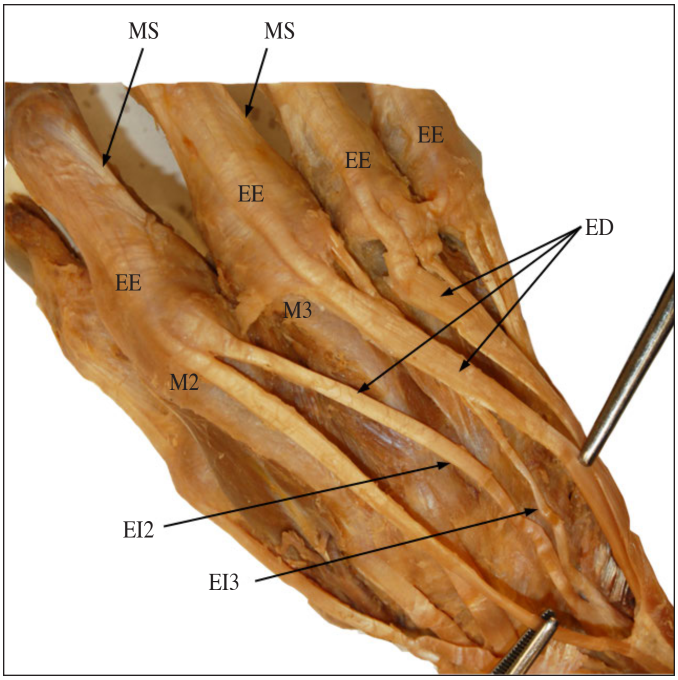

Figure 2
The distal attachments of the EI double tendon. On the dorsum of the hand, opposite the heads of the second metacarpal (M2) and the third metacarpal (M3) bones, the tendons of the EI to the second (EI2), and third (EI3) digits join the ulnar sides of the ED, enhancing the medial slips (MS) of the extensor expansion (EE) of the second and third digits.

(Figure 2). In all other dissected forearms, a tendon of EI muscle joined the EE to the index finger.

In consideration of the clinical importance of the distribution of the DBRN, we dissected 32 upper limbs to determine whether the branching pattern of the DBRN varied between the forearms possessing single versus double tendons of EI. The radial nerve arose from the posterior cord of the brachial plexus and incorporated the anterior primary rami of C5-T1 spinal nerves. From the axillary fossa, it wound around the posterior aspect of the humerus and pierced the lateral intermuscular septum to enter the anterior compartment of the arm dividing into superficial and deep terminal branches. In the literature, the DBRN is frequently called the posterior interosseous nerve (PIN).[31] Following the international anatomical terminology,[32] we classify the PIN as the terminal long branch of the DBRN.

The DBRN traversed the supinator muscle between the superficial and deep layers, emerging in the posterior compartment deep to the superficial layer of the extensor muscles, immediately providing the short branches to the ED, extensor digiti minimi, and extensor carpi ulnaris muscles. Descending superficial to the abductor pollicis longus (APL), the DBRN provided the long branches to the APL and the extensor pollicis brevis (EPB), and terminated as the PIN (Figures 3A and 3B). The PIN descended deep to the extensor pollicis longus (EPL) muscle on the posterior surface of the interosseous membrane sending two to three short nerve branches to supply the EPB and EI muscles (Figure 3C). Next, the PIN continued within the fourth dorsal osseofibrous tunnel between the tendon of the EPL and the lateral part of the EI terminating within the dorsal fascia and the dorsal surface of the fibrous capsules of the radiocarpal and intercarpal joints.

Discussion

It is important understand the anatomy of the variant EI muscle with a double tendon as this variant may explain clinical symptoms of certain hand lesions and should be considered in the differential diagnosis of a swelling, ganglion or other soft tissue tumors on the dorsum of the hand.[1,5,9,16]

Knowledge of the variant EI muscle with a double tendon is required for precise extensor muscle identification and confirmation of a preoperative diagnosis using dynamic sonography or magnetic resonance imaging, as well as for the planning of the best possible surgical treatments in this region.[28-38]

Schmidt et al.[39] argued that hand surgery informed by applied anatomy, and collaboration between anatomists and clinicians are essential to upgrading surgical technique and optimizing patient care.

The present study is congruent with the observations of Ritter et al.[40] and Doyle[41] with regard to the proximal attachments of the presented variant EI muscle to the posterior surface of the_shaft of the ulna, the adjacent interosseous membrane, and the connective tissue septum between the EI and the EPL muscles. Additionally, in the present case, the variant EI muscle attached to the internal surface of the antebrachial fascia within the superficial–deep extensor fascial plane. We hypothesize that

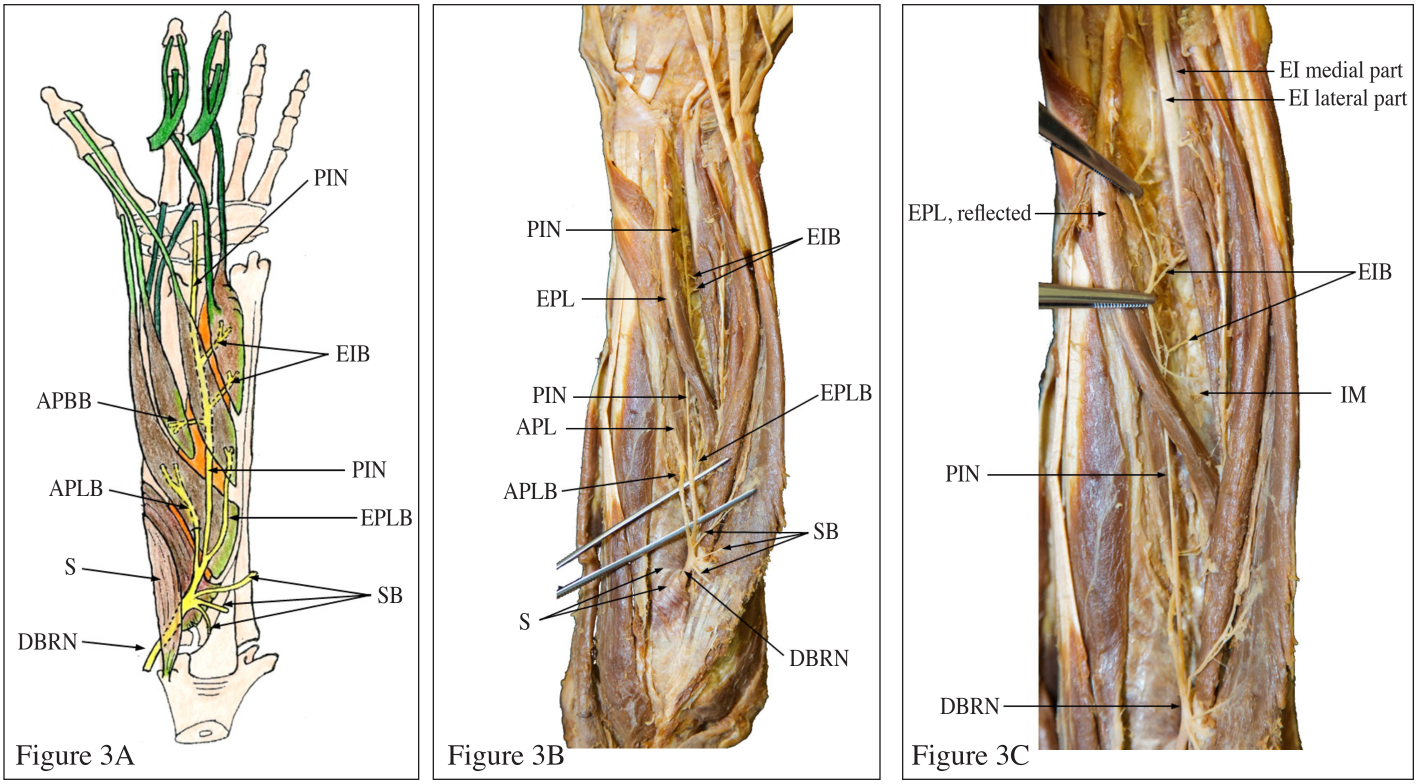

Figure 3
The branching pattern of the deep branch of the radial nerve (DBRN) in the forearm with the variant EI muscle.
A – Schematic representation illustrates the DBRN which traverses the supinator (S) muscle, and immediately provides the short branches (SB). The long branches include the abductor pollicis longus branch (APLB), the extensor pollicis longus branch (EPLB), and the posterior interosseous nerve (PIN). The PIN provides the abductor pollicis brevis branch (APBB), and the extensor indicis branches (EIB).
B – The DBRN descends superficial to the APL muscle providing the APLB and EPLB, and then as the PIN, descends deep to the EPL muscle.
C – The PIN descends deep to the EPL muscle on the posterior surface of the IM. Being located between the EPL and the lateral part of the EI muscle, the PIN provides the two to three EIB.

an overstretched EI muscle might lead to inflammation within this fascia and an increase in intracompartmental pressure. Moreover, the surgeon should take this attachment into consideration when performing any surgical procedure within the extensor forearm region.

Caudwell et al.[42] described the musculotendinous junction of the EI within the confines of the fourth dorsal osseofibrous tunnel in 75% of the specimens which they examined. Ritter and Inglis,[40] confirming the frequency of the musculotendinosus portion of EI within the fourth dorsal tunnel, remarked that the contents of the tunnel are extremely tightly confined when the hand and fingers are flexed. That is why an increase in the size of any of the components of the tunnel, including a hypertrophied EI, might produce pain and disability. Similarly, we believe that the presence of two tendons of the EI, especially the musculotendinous junction of its medial part, would increase the volume of the contents of the fourth dorsal osseofibrous tunnel and might cause pain and other clinical symptoms. We observed that in the tunnel itself, the two tendons of the EI muscle are positioned medial and deep to the tendons of the ED muscle. Knowledge of this relationship is essential in tendon identification when harvesting for tendon transfer during such procedures as opponensplasty.[43]

Review of the literature indicates that the EI muscle confers independence to the index finger. Acting alone or together with the ED, it extends the index finger at the metacarpophalangeal and proximal interphalangeal joints and assists with the extension of the hand at the wrist. As a result, the EI muscle enhances tight grip.[43, 44] For this reason, we assume that the double tendon of the EI muscle, joining the EE, may increase the independence not only of the index finger but also of the middle finger, and may further enhance tight grip.

The EE is formed by the four tendinous extensions of the ED muscle on the dorsum of the proximal phalanx of each digit. Each extension is made by three slips, one axial and two collateral slips. The lateral collateral slips are thickened by the tendons of lumbrical and interosseous muscles and the medial collateral slips by tendons of the interosseous alone.[1,31,40,43,45]

In the presented case, the two tendons of the EI muscle joined the medial collateral slips of the EE to the middle and index fingers, as reported previously in the literature.[40,43,45] We hypothesize that by equalizing the thickness of the medial slips of the EE to the index and middle digits, the EI double tendon assists with the balancing and dissipation of mechanical stresses during the coordinated extension of these digits.

Understanding the anatomical branching pattern of the radial nerve within the posterior forearm is an essential step in recognizing the clinical symptoms of peripheral neuropathy.[22,43,46] It is also important in identifying the level of nerve injury,[47] for use during surgical repair using nerve grafts,[48-51] performing nerve blocks,[52] neurography,[30] and for the modeling of neuromuscular compartments.[25] Since total or partial lesions are often encountered in clinical settings, we sought to determine the branching pattern of the radial nerve in a case of an EI muscle with a double tendon.

According to our observation, the DBRN after emerging from the supinator gives off short branches to the superficial extensor muscles. This observation is in agreement with the majority of investigations, except that the nerve penetrating the supinator is often referred to as the PIN.[22,23,25,31,38,48,49,52-55] Following the international anatomical terminology,[32] we classify the PIN as the terminal long branch of the DBRN.

In our study, the innervation of the deep extensor muscles is supplied by the long branches of the DBRN, including the nerve to the APL, nerve to the EPB, and the PIN. The PIN, descending deep to the EPL, provides two to three short branches to supply the EPB and EI muscles. In the literature, all long branches are described as branches of the PIN with morphometric and schematic variances.[23,38,49]

Thus, we conclude that there are no differences in the branching pattern of the DBRN within forearms possessing either single or double tendons of EI. In both cases, having longer branches to APL and EPL allow for the possibility of isolated neuropathy of these branches. The innervation of the EI and EPB muscles by the short branches from the PIN most likely would be disrupted by the neuropathy of either the main trunk of DBRN or PIN as it descends deep to the EPL muscle.

Conclusions

1. A double tendon of the EI increases the volume of the contents of the fourth dorsal osseofibrous tunnel, which may result in clinical symptoms.
2. By equalizing the thickness of the medial slips of the extensor expansion, the two tendons of the EI may assist with the balancing of the mechanical stresses within the extensor expansion, contributing to the coordination of the extension of the second and third digits.
3. The branching pattern of the DBRN may result in a predisposition towards isolated neuropathy of the long branches or the posterior interosseous nerve, resulting in specific clinical symptoms.

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