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Anatomy

SUPERFICIAL GROUP OF MUSCLES OF POSTERIOR COMPARTMENT OF THE FOREARM – AN ANATOMICAL STUDY

Dr. Harsimarjit Kaur	Associate Professor, Department of Anatomy, Government Medical College, Patiala, Punjab.
Dr. Divya Mahajan	Associate Professor and Head of Department, Department of Anatomy, Dr HSJ Dental College, Chandigarh.
Dr. Abha Bajaj*	Associate Professor, Department of Anatomy, Dr. HSJ Dental College, Chandigarh. *Corresponding Author
Dr. Apurba Patra	Assistant Professor of Anatomy, AIIMS, Bhatinda, Punjab.
Dr. Manjeet Singh	Professor and Head of Department, Maharishi Markandeshwar Institute of Medical Sciences and Research, Mullana, Ambala, Haryana.

ABSTRACT **Objective:** To understand the normal anatomical variations in the muscles of the posterior compartment.
Material and Methods: A total of 50 upper limbs from 25 phenol embalmed adult human cadavers were studied. The superficial and deep fascia were dissected carefully and reflected along skin incision. The origin, insertion, and other variations in the muscle bellies and tendons of the superficial extensor muscles were studied after careful dissection.
Results: Brachioradialis had origin extending up to the insertion of deltoid in 3 specimens and had insertion on the radius as two-slips in 4 limbs. The muscle bellies of ECRL and ECRB were fused in 2 limbs. The ECRL also had double and triple tendinous insertions. An accessory muscle, Extensor Carpi Radialis Intermedius, was noted in 2 limbs. The EDC tendon to little finger tendon was bifurcated in 20 limbs, had an intertendinous connection in 12 limbs. An accessory tendinous extension from lower part of ECU tendon was present in 5 limbs.
Conclusion: Extensor muscles of the forearm have undergone a dramatic change during the period of evolution; however, these are not uniform and there are number of anatomical variations which are of significance during the repair of extensor tendon injury or during tendon transfer surgeries.

KEYWORDS : Extensor muscles, Forearm, Posterior Compartment, Human Cadaver

1. INTRODUCTION

Hand is the most versatile organ for manipulating the physical environment. The fine movements of the hand are the result of the balance between the flexor and extensor muscle groups at the wrist and fingers[1]. The muscles of the posterior compartment of the forearm have undergone a number of variations while adapting to the bipedal walking compared to lower animals[2]. They ensure both gross and fine control of various activities, consequently any injury to these tendons can lead to loss of function affecting the quality of life.

A number of variations in the tendons, as well as their arrangements have been reported by various authors in clinical and anatomical studies[3]. When transplantation of extensor tendon is undertaken, confusion can result unless the surgeon is completely familiar with the possible arrangements of the tendons as well as the relative frequency of the variations[4]. A comprehensive knowledge of the anatomy of these tendons is essential to ensure adequate repair and restoration of the normal functions[5].

2. MATERIALS AND METHODS

A total of 50 upper limbs from 25 phenol embalmed adult human cadavers were included in the studied; of these, 28 were male and 22 were female specimens. Cadavers with visible abnormality of the upper limb, history of trauma to the limb in the past, any lesions in the upper limb were excluded.

Dissection Protocol:

The skin was reflected from the back of arm (lower two-third), forearm, the dorsum of hand and the digits by giving skin incisions. The superficial fascia was removed. Then the deep fascia was reflected carefully after isolating the extensor retinaculum and securing its attachments. This exposed the muscles and tendons of the posterior group of the forearm. The pattern of arrangement of the tendons of these muscles as they pass beneath the extensor retinaculum was studied. Then the extensor retinaculum was divided longitudinally over each of its compartment for the full exposure of the tendons.

Brachioradialis and extensor carpi radialis longus muscles were identified on the lateral aspect of lower third of upper arm. Anconeus was identified and cleaned between the posterior aspect of the lateral epicondyle of humerus and the lateral border of the olecranon process of ulna. Other superficial extensor muscles of the forearm were also identified and separated from one another by splitting the fascial septa through which they were united in their proximal parts. The origin of these muscles was cleaned from the posterolateral aspect of the humerus and their tendons were followed as they passed beneath the extensor retinaculum and on the dorsum of the hand as far as their insertions.

The radial nerve was identified between the brachioradialis and the brachialis muscles. Its branches to the brachioradialis & extensor carpi radialis longus were traced and then its deep branch i.e. posterior interosseous nerve was identified and followed through the substance of the supinator muscle. The branches of this nerve from proximal to distal were then traced up to the neurovascular hilum of the remaining forearm extensors, which it supplies.

Any variation regarding the mode of origin, insertion and nerve supply of the individual muscles was noted along with the presence of any accessory or anomalous muscle and the variations were photographed. The observations were recorded on the proforma and master chart was made of the muscle and tendon lengths. The data was compiled, analyzed and compared to the standard textbook and the variant patterns of the posterior group of forearm muscles.

3. RESULTS:

In the present study there were variations observed in origin, number of tendons of various muscles of the posterior compartment.

Brachioradialis:

In 86% of the specimens, brachioradialis was found to have origin from the proximal two thirds of the lateral supracondylar ridge of the humerus and inserted by a single tendon on to the lateral aspect of the distal end of the radius just proximal to its styloid process. In the remaining 14% of the specimens, variations were observed. In 6% (3/50) of the specimen the origin extended proximally up to the insertion of deltoid. There were two slips of the tendon inserting on the lateral aspect of radius in 8% (4/50) of the specimens (Figure 1).

Figure 1: *Splitting of the tendon of Brachioradialis (BR) into two slips.*

The extensor carpi radialis longus and brevis

In the present study, in all the 50 cases, the ECRL arose from the distal third of lateral supracondylar ridge of humerus and anterolateral aspect of the lateral epicondyle of humerus (common extensor origin) and ECRB from the common extensor tendon, conforming to the standard pattern regarding their site of origin. The following variations were observed regarding the number of bellies and the number and insertions of the tendons of these two muscles:

i) The extensor carpi radialis longus and brevis were found to have fused muscle bellies in 4% of the specimens. The fused belly ended in three tendons one of which inserted on to the dorsal aspect of the base of 2nd metacarpal and the other two inserted on to the dorsal aspect of the base of 3rd metacarpal.
ii) ECRL had insertion by three tendons in 4% of the cases, wherein two tendons inserted normally on to the dorsal aspect of the base of 2nd metacarpal and remaining one inserted along with the tendon of ECRB on to the dorsal aspect of the base of 3rd metacarpal.
iii) A single specimen (2%) had a double tendon for ECRL inserting normally on to the dorsal surface of the base of 2nd metacarpal bone (Figure 2).

Figure 2: *Double tendon of Extensor Carpi Radialis Longus (ECRL) muscle. Both of them are separately inserting onto the dorsal aspect of the base of second metacarpal (MC).*

iv) ECRB was found to have double tendon in two specimens (4%), in which one of the tendons inserted normally on to the dorsal aspect of the base of 3rd metacarpal and other tendon inserted along with tendon of ECRL, on to the dorsal aspect of the base of 2nd metacarpal bone.
v) In two of specimens (4%) an accessory muscle, Extensor Carpi Radialis Intermedius (ECRI), was found in between ECRL and ECRB. It had a small muscular belly, which arose along with the belly of ECRL. The belly ended into a tendon that inserted on to the dorsal aspect of the base of third metacarpal. A separate branch from the radial nerve supplied it (Figure 3).

Figure 3: *Extensor Carpi Radialis Intermedius (ECRI) muscle. The muscle has a small muscular belly which is arising from the belly of extensor carpi radialis longus (ECRL) muscle. Its belly is seen to end in a tendon which is inserting onto the dorsal aspect of the base of third metacarpal (MC) along with the belly of extensor carpi radialis brevis (ECRB) muscle*

The nerve supply of ECRB though supplied by the muscular branches of the radial nerve supplied the ECRL as it passed between the BR and the Brachialis muscles. It was found to be quite variable, where 56% had origin from deep branch of radial nerve and 34% of them had origin from superficial branch of radial nerve. The remaining 10% had origin from bifurcation of radial nerve.

Extensor digitorum communis

In the present study, EDC–I was the most consistent single tendon (100% limbs). No variation was found with reference to the mode of origin or insertion of the EDC-I. The most common variations were observed in the EDC-M, with 7 of the 50 limbs (14%) receiving two tendons for the middle finger. In all the cases, tendons inserted into the dorsal digital expansion of the middle finger. In case of EDC-R, 5 limbs had variations in the number of tendons. Among these, two limbs had double and three limbs had triple tendons. The EDC-L tendon was found to have wide variations in insertion. EDC-L tendon was connected to the dorsal digital expansion of the little finger in one of the three ways:

i. Most commonly, by a tendon which bifurcated to be inserted into the dorsal digital expansion of little and ring fingers (20 limbs, 40%). (Figure 4)

Figure 4: *Splitting of tendon of Extensor Indicis (EI) into two slips. One slip is inserting onto the 'radial' aspect of Extensor Digitorum Communis tendon for index finger (EDC-I) and second slip is inserting onto the 'ulnar' aspect of EDC-I.*

ii. By a single tendon (18 limbs, 36%)
iii. By an intertendinous connection (junctura tendinii) between the EDC-R tendon and tendons of EDM (12 limbs, 24%).

These findings suggest that in most of the cases either the EDC-L tendon was absent or was sharing its tendon with EDC-R (Figure 5). In all the 50 limbs, a branch from the posterior interosseous nerve supplied the EDC.

Figure 5: *Multiple tendons of Extensor Digitorum Communis (EDC) muscle. There are two tendons going to the middle finger (M) whereas the tendon to the little finger (L) is absent. The tendon of Extensor Indicis (EI) and double tendon of Extensor Digiti Minimi (EDM)*

Extensor Digiti Minimi (EDM)

The origin, insertion and nerve supply of EDM conformed to the standard described patterns. It arose from the common extensor tendon and inserted into the dorsal digital expansion of fifth digit. It was supplied by a branch from the posterior interosseous nerve. A number of variations were found regarding the number of the tendons inserting on to the dorsal expansion. There were 48 limbs with two slips whereas, remaining 2 limbs had three slips inserting on to the dorsal expansion.

Extensor carpi ulnaris

ECU was consistent regarding its origin from the lateral epicondyle of humerus via the common extensor tendon and from the middle third of posterior border of ulna. It was supplied by a branch from the posterior interosseous nerve in all the 50 limbs. In all the 50 limbs, the tendon of ECU inserted onto the medial side of the base of fifth metacarpal. An accessory tendinous extension from the lower part of the tendon of ECU was present in 5 out of 50 limbs. This extension ran towards the proximal phalanx of the little finger and was sometimes connected with the medial slip of EDM at the head of the fifth metacarpal bone.

4. DISCUSSION

The evolutionary changes in the muscles of the posterior compartment have resulted in a number of variations which are encountered during routine surgical interventions in the dorsal compartment. They may have important influences on predisposition to illness, symptomatology, clinical examination, investigation and patient management including surgery. Recognition of variations enables clinicians to distinguish features which merit further investigation or treatment from those that do not. Awareness of the anatomy and variations of the extensor tendons on the dorsum of hand is also necessary when assessing traumatized or diseased hand and when considering tendon transfer operations. In the present study, the pattern of arrangement of the posterior group of forearm muscles and their tendons as they pass beneath the extensor retinaculum was found to be quite variable. The standard described pattern was observed in only 10 out of 50 (20%) limbs.

Brachioradialis is of special interest to the hand surgeon because it can be used as a motor for the wrist or hand in cases in which most of the forearm muscles are paralysed[6]. The variations encountered have been previously reported by various authors [7–11]**.** In the present study, it was found that in 8% of cases the tendon of BR split into two slips before getting inserted on to the lateral aspect of lower end of radius. Le Double observed the splitting of BR tendon into two or three slips in 7% of his cases [7]. He suggested that occasionally the superficial branch of radial nerve may pass through these slips and thus is in danger of getting compressed in between these slips.

ECRL is a useful muscle to transfer in median or ulnar nerve palsy because it has a long tendon of insertion, making change of direction rather easy, and because wrist extension may be handled well by ECRB and radial deviation by APL[8]. In the present study, there were fused bellies of the ECRL and ECRB which ended in 3 tendons with one of these inserting on to the dorsal aspect of the base of 2nd metacarpal and the other two inserted on to the dorsal aspect of the base of 3rd metacarpal. Romanes et al explained this fusion of the bellies on the phylogenetic basis [10]. He mentioned that in some lower mammals the two extensor carpi radialis muscles are represented by a single muscle, thus this fusion is a classic example of reappearance of primitive pattern of musculature. This fusion of the bellies can also be explained on the ontogenetic basis as embryologically these two muscles are derived from a common sheet of embryonic mass and failure of that mass to differentiate into two radial extensors leads to the fusion of their muscular bellies. There were double tendons of ECRL and ECRB observed in 2% and 4% of the limbs, respectively. A number of authors have also described similar variations in the mode of origin and insertion of ECRL & ECRB[9–13].

An accessory muscle, extensor carpi radialis intermedius (ECRI), has been described in literature to arise, not infrequently, as a slip from one or both radial extensors. It is inserted into the second or third metacarpal bone or into both [9]**.** In our study, ECRI was present in 2 out of 50 limbs. It had a small muscular belly, which arose along with the belly of ECRL. The belly ended into a tendon that inserted on to the dorsal aspect of the base of third metacarpal. The presence of this muscle is clinically significant as the tendon of this muscle can be used independently in tendon transfer operations especially in patients with semiquadriplegia.

EDC has been known to be have number of variations. Variations of EDC include the occasional deficiency of one or more tendons of insertion or an increase in their number to five, supplying the five digits. If one of the tendons is absent, it is usually that to the fifth digit. More frequently, however, the tendons are limited to the index or middle finger alone, although an additional slip to the thumb is occasionally seen. Any digit may receive two tendons [14]. EDC to the index finger (EDC–I) was the most consistent single tendon present in all limbs. Godwin et al[15] and El Badawi et al[5] have also found it to be single in 100% of their cases. It was never duplicated in the present study as reported by Mori et al[16] and von Schroeder et al[17]. EDC to middle finger (EDC-M) has a longer free tendon than any other muscle on the back of forearm. This allows it to be easily redirected around the radius or ulna through interosseous space[6]. In the present study the variations observed where lower compared to those reported by Mestdagh et al[3] and El-Badawi 1995[5]. There was no triple tendon arrangement in our study as compared to other authors who reported triple tendon in 2% - 4% of the specimens, respectively[15,17]. EDC to ring finger (EDC-R) was single in 45 (90%), double in 2 (4%) and triple in 3 (6%) limbs. These are comparable to the reports by Godwin et al[15] and von Schroeder 1995[17]. However few authors like Mestdagh et al[3] and El-Badawi[5] have reported a larger number of double tendons. EDC-L was connected to the dorsal digital expansion of the little finger by bifurcated tendon in 40% of the limbs, through a single tendon (36%) and by an intertendinous connection between EDC-R and EDM in 24% of the limbs. Most of the authors have reported similar results[4,5]. From these observations, it can be inferred that in most of the cases either the EDC-L tendon was absent or was sharing its tendon with EDC-R. These findings support the suggestion that the EDC-L may be undergoing evolutionary reduction [18]. It has also been observed that in cases where the EDC-L tendon was absent, the EDM had double or triple tendons of insertion.

EDM is a slender muscle, which is used in the tendon transfer operations. It lies to the ulnar side of EDC– L with which it may be connected [6]**.** Most commonly, there was double tendon arrangement (96%) which was similar to the previously reported observations. [15,19]. In no case it was found to have single or quadruple tendons as reported by some workers[3,15].

ECU is well placed for transfer around the ulnar border of wrist for abduction of thumb or pronation of the forearm or to serve as motor for digital flexors[6]**.** In the present study, ECU was consistent regarding its origin and nerve supply. An accessory tendinous extension from the lower part of the tendon of ECU was present in 5 out of 50 limbs. This extension ran towards the proximal phalanx of the little finger and was sometimes connected with the medial slip of EDM at the head of the fifth metacarpal bone. Kaplan called it as an accessory extensor digiti minimi arising from ECU [20]. Similar variations were also reported in three cases with tendinous slip[21]. They suggested that the presence of such accessory slip differs phylogenetically from other tendon abnormalities in that one part of the tendon crosses on joint and another part crosses two joints before inserting into the dorsal digital expansion of the little finger. The presence of such accessory slips is important clinically as it can cause impairment of function at wrist and of little finger. The prevalence of accessory tendinous slip, in the present study, on Indian population, is one of the lowest so far reported. The prevalence reported earlier was variable and was found to be high in Japanese [22] and Europeans subjects [3]**.**

5. CONCLUSION:

Extensor muscles of the forearm have undergone a dramatic change during the period of evolution; however, these are not uniform and there are number of anatomical variations which may be of significance during any surgery in the posterior compartment like tendon reconstructions or tendon transfers.

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