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A comparison of fine wire insertion techniques for deep finger flexor muscle electromyography

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ABSTRACT

Introduction: Intramuscular electromyography electrodes targeting flexor digitorum profundus (FDP) are inserted via the anterior or medial aspect of the forearm. These two methods pose different risks to neurovascular structures which overly FDP. This study aimed to compare the insertion depth and consider advantages and limitations of two different techniques to insert intramuscular electrodes into FDP.

Methods: Using ultrasound imaging, neurovascular structures were identified along the path of FDP electrode insertion at the junction of the proximal and middle third of the ulna, bilaterally, in ten healthy individuals. Insertion depth was compared between the anterior and medial approaches for the mid muscle belly and targeted insertion to the index finger fascicle of FDP.

Results: In our sample the ulnar artery was superficial to the FDP muscle when viewed anteriorly and was beyond the furthest border of FDP when viewed medially. Compared to the anterior approach, the medial insertion depth was 1.5 cm (95%CI 1.4–1.7, $p < 0.001$) less to the mid-belly of FDP and 0.6 cm (95%CI 0.4–0.7, $p < 0.001$) less to the index finger fascicle of FDP.

Discussion: The medial approach involves less depth and lower risk for perforation of neurovascular structures when inserting intramuscular electrodes into the FDP muscle.

1. Introduction

The flexor digitorum profundus (FDP) muscle originates from the proximal three quarters of the medial and anterior aspects of the ulna, the coronoid process and the interosseous membrane, and inserts into the distal phalanges (Saladin, 2011) (Fig. 1). The FDP muscle includes fascicles for each digit (II to V) (Wheeless et al., 2012). Proximally, the index finger fascicle divides from the medial three fascicles, which permits greater independence of the index finger (Wheeless et al., 2012). The median nerve innervates the lateral two digits (II and III) and the ulnar nerve innervates the medial two digits (IV and V) (Saladin, 2011).

Electromyographic (EMG) investigation of human forearm flexor muscles are commonly undertaken to explore the use of targeted muscle activation for hand prosthetics (Birdwell et al., 2013, Birdwell et al., 2015, Cipriani et al., 2014) and to investigate changes in motor control between those with and without pathology (Heales et al., 2016, Heales et al., 2015, Kelley et al., 1994). These investigations of human forearm muscles using EMG are challenging given their relatively small cross sectional area, their close proximity to one another, and their proximity to adjacent neurovascular structures. Surface EMG electrodes avoid risk to neurovascular structures but are limited in their capacity to monitor individual forearm muscle activity because of cross talk (Mogk and Keir, 2003, Kong et al., 2010). Fine-wire intramuscular EMG electrodes can reduce cross talk because of their small recording area and location within the target muscle.

Two techniques are used to insert fine wire EMG into FDP: (1) insertion via the anterior aspect of the forearm (Burgar et al., 1997), and (2) insertion via the medial aspect of the forearm (Preston and Shapiro, 2005, Perotto, 2011) (Fig. 1). An anterior approach for FDP intramuscular insertion involves some risk as this muscle lies deep to the median and ulnar nerves and ulnar artery (Saladin, 2011). In addition, there are several muscles that lie superficial to FDP (e.g. flexor digitorum superficialis, palmaris longus) and it is possible that EMG electrodes could be inaccurately placed in these muscles if the needle is inserted to an insufficient depth (Fig. 1). The medial approach reduces

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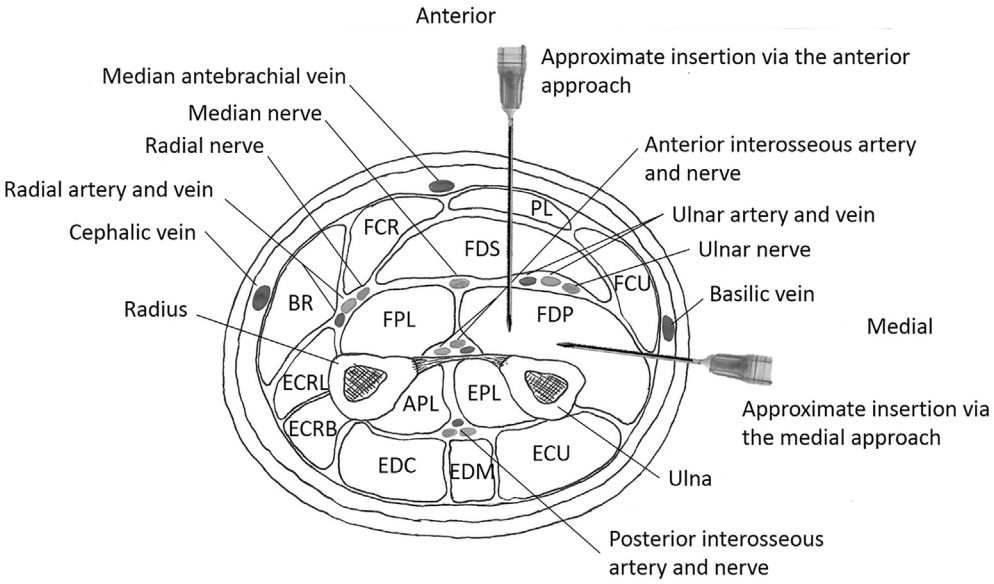

Fig. 1. Schematic cross sectional representation of the right forearm at the junction of the middle and proximal third (viewed from distal end). It should be noted that the lateral FDP fascicles might be difficult to reach with the medial insertion approach and if that is the target for investigation the anterior insertion approach under US guidance may be required. BR – brachioradialis, FCR – flexor carpi radialis, PL – palmaris longus, FCU – flexor carpi ulnaris, FDS – flexor digitorum superficialis, FDP – flexor digitorum profundus, FPL – flexor pollicis longus, ECRL – extensor carpi radialis longus, ECRB – extensor carpi radialis brevis, EDC – extensor digitorum comminus, EDM – extensor digiti minimi, ECU – extensor carpi ulnaris, APL – abductor pollicis longus, EPL – extensor pollicis longus.

the potential for neurovascular damage and allows access to the majority of the FDP muscle belly with a potentially shorter insertion depth, although the lateral fascicles (digits II and III) are proposed to be deeper and harder to accurately place electrodes. This study aimed to compare the insertion depths required for each technique, provide an overview of the advantages and limitations of each technique, and discuss the safety implications of FDP fine-wire EMG using each technique.

2. Methods

2.1. Participants

Ten healthy participants were included (Table 1). Participants were excluded if they had: musculoskeletal pain/injury within the preceding 12 months (e.g. elbow pain); upper limb surgery; major trauma within 5 years (e.g. fractures); and/or metabolic disorders (e.g. diabetes). The Institutional Human Research Ethics Committee approved the study and written informed consent was obtained prior to participation.

2.2. Protocol

B-mode ultrasound was used to measure FDP depth from skin to the middle of the muscle belly (4–15 MHz linear array transducer, Aixplorer® SuperSonic Imaging, Aix-en-Provence, France). Insertion depth was measured to the: (1) middle of the muscle belly and (2) the index finger fascicle of FDP. The left and right arms of each individual were measured. To determine the FDP depth (mid muscle belly and index finger) using the anterior approach, participants sat with their forearm fully supported in full supination (Fig. 2A) (Burgar et al., 1997). To determine the FDP depth (mid muscle belly and index finger) using the medial approach, participants sat with their elbow flexed, forearm supinated and the hand resting on the shoulder of the same side (Fig. 2B) (Preston and Shapiro, 2005, Perotto, 2011). This position allows FDP to be viewed medial to the ulna. Power Doppler was used to visualise neurovascular structures and their location was considered with respect to the path for insertion of the EMG electrode into FDP. To investigate the variability associated with the location of the ulnar artery with respect to FDP, the distance from the FDP lateral border to the middle of the ulnar artery was measured using the image made from the anterior aspect of the right forearm of all individuals. Finally, forearm circumference was measured as a method to normalize the insertion depth for each individual. Aligned with published methods (Preston and Shapiro, 2005), all measures were made at the junction of the middle and proximal third of the forearm, which is approximately four finger breadths distal to the olecranon.

2.3. Statistical analysis

Statistical analysis was completed using Statistica (StatSoft Inc., Tulsa, Oklahoma, USA). Two separate repeated measures analysis of variance (ANOVA) were used to compare depth measures for; (1) the mid muscle belly, and (2) the targeted fascicle of the index finger (digit II). For each analysis, Technique (anterior versus medial) and Arm (right versus left) were both included as within-subject effects. The difference between approaches for each ANOVA are presented as mean differences (MD) and 95% confidence interval (95%CI). Alpha was set at $P < 0.05$. Variation in ulnar artery location is presented as a range of distances from the lateral FDP muscle border. The estimated insertion depth, as a percentage of forearm circumference, is reported as a range for the anterior and medial approach.

3. Results

3.1. Mid muscle belly of flexor digitorum profundus

There was no significant difference in FDP muscle depth between an individual's arms (Interaction: Arm × Technique $p = 0.17$; Main Effect: Arm $p = 0.73$). The FDP muscle belly was deeper (Main effect: Technique $p > 0.001$) when approached from the anterior aspect of the forearm (3.1 ± 0.4 cm, Fig. 2A) than the medial aspect (1.5 ± 0.2 cm, Fig. 2B) (MD 1.5 cm [95%CI 1.4–1.7], $p < 0.001$). When participants were considered individually, the shortest distance to the mid FDP muscle belly with an anterior approach was 2.7 cm, and 1.2 cm using the medial approach (Table 1). The greatest distances were 4.0 and 2.0 cm for the anterior and medial approach, respectively (Table 1). Viewed anteriorly, the ulnar artery was always observed immediately superficial to the FDP muscle with substantial variation in medial-lateral location. The location of the artery ranged between 2.2 and 3.8 cm from the lateral border of the muscle (Table 1). The insertion depth as a percentage of forearm circumference ranged between 10.4 and 12.8% (mean 11.6 ± 0.6%) for the anterior approach and between 5.0 and 6.5% (mean 5.9 ± 0.5%) for the medial approach.

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