Quantitation of and landmarks for the muscular branches of the ulnar nerve to the forearm for application in peripheral nerve neurotization procedures

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Object. In neurotization procedures, donor nerves—either whole or in part—with relatively pure motor function can be carefully chosen to provide the optimal nearby motor input with as little donor site morbidity as possible. In this context, the ulnar nerve branches to the forearm muscles are relatively dispensable; however, quantitation of and landmarks for these branches are lacking in the literature.

Methods. The ulnar branches to the flexor carpi ulnaris (FCU) and flexor digitorum profundus (FDP) muscles in 20 upper extremities obtained in adult cadaveric specimens were dissected and quantified.

In the forearm, a mean of four nerve branches led to the FCU and FDP muscles. A mean of 3.4 branches led to the FCU muscle; of these, one to three were medial branches and zero to two were lateral. Medial branches to the FCU muscle originated a mean of 2.7 cm inferior to the medial epicondyle. Lateral branches to the FCU muscle originated at a mean of 3.3 cm inferior to the medial epicondyle. The mean length of the medial branches was 3.2 cm, whereas the mean length of the lateral branches was 3.3 cm. All nerves had a single trunk for the FDP muscle, and in all specimens this branch was located deep to the main ulnar nerve trunk, originating from the ulnar nerve a mean of 2.7 cm inferior to the medial epicondyle. These branches had a mean length of 5.6 cm. The mean diameter of all medial and lateral branches to the FCU muscle was 1 mm, and the mean diameter of the branch to the FDP muscle was 2.1 mm. All branches to both the FCU and FDP muscles arose from the ulnar nerve, over its first approximately 5 cm from the level of the medial epicondyle. Additionally, all branches could be easily lengthened by gentle proximal dissection from the main ulnar nerve.

Conclusions. Ulnar branches to the forearm can be easily localized and used for neurotization procedures. The branch to the FDP muscle had the greatest diameter and longest length, easily reaching the median nerve and posterior interosseous nerve via a transinterosseous membrane tunneling procedure. Furthermore, this branch could be teased away from the main ulnar nerve trunk and made to reach the distal branches of the musculocutaneous nerve in the arm.

Key Words • ulnar nerve • flexor carpi ulnaris muscle • flexor digitorum profundus muscle • neurotization

The ulnar nerve, the largest derived from the medial cord of the brachial plexus, leaves the ulnar sulcus posterior to the medial humeral epicondyle and passes between the humeral and ulnar heads of the FCU muscle as the nerve enters the forearm. The two heads of this muscle are often connected by the arcuate ligament (the Osborne ligament)\textsuperscript{10,12} a tendinous arch that is a continuation of the fibroaponeurotic covering of the epicondylar groove and defines the roof of the cubital tunnel.\textsuperscript{12} When important motor nerves are injured, it is advantageous for the surgeon to have donor options for neurotization procedures. Donor nerves should be chosen so that there is as little donor site morbidity as possible or that the function gained is greater than the function lost.\textsuperscript{2} In this regard, the ulnar nerve branches to the forearm muscles are relatively dispensable given that the dominant nerve of the forearm musculature is the median nerve and that denervation of the ulnar-innervated FCU muscle and medial half of the FDP muscle can be compensated for if these branches are disconnected.\textsuperscript{3} On occasion, the median nerve may provide some or all of the motor innervation to the FCU muscle. In the present study we sought to quantitate the motor branches of the ulnar nerve in the forearm and better localize these branches with the goal of assisting the surgeon who may choose to use these branches for neurotization procedures.

Materials and Methods

The ulnar nerve branches to the FCU and FDP muscles were dissected in 20 formalin-fixed upper extremities from 10 adult cadavers (mean age 73 years at the time of death, range 62 to 84 years). Four male and six female cadavers were used in this study. After splitting

Abbreviations used in this paper: AIN = anterior interosseous nerve; FCU = flexor carpi ulnaris; FDP = flexor digitorum profundus; PIN = posterior interosseous nerve.
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the ulnar and humeral heads of the FCU muscle, the ulnar branches were counted and measurements were obtained from their origin at the ulnar nerve to the medial epicondyle. All measurements were obtained using calipers. Measurements also included the diameters and lengths of the ulnar nerve branches to the FCU and FDP muscles (Fig. 1). A statistical analysis of the difference between left and right sides and between the sexes was performed using the Student t-test.

Results

No specimen had an anconeus epitrochlearis or other anomalous muscle of the proximal forearm near the ulnar nerve. Furthermore, no scar from a previous surgery was found in this region. In the forearm, one to five branches (mean four branches) led to the FCU and FDP muscles. Branches to the FCU muscle numbered from one to five, with a mean of 3.4 branches. Of these, one to three were medial branches (mean 2.2 medial branches) and zero to two were lateral branches (mean 1.25 lateral branches). Medial branches to the FCU muscle arose 0 to 6 cm (mean 2.7 cm) inferior to the medial epicondyle (Fig. 1). Lateral branches to the FCU muscle arose 1 to 5 cm (mean 3.3 cm) inferior to the medial epicondyle. The length of the medial branches ranged from 1 to 5.5 cm (mean 3.2 cm), and the length of the lateral branches ranged from 1 to 5 cm (mean 3.3 cm). All nerves had a single trunk for the FDP muscle, and this branch was found deep to the main ulnar nerve trunk in all specimens. This branch arose from the ulnar nerve from 1 to 3.5 cm (mean 2.7 cm) inferior to the medial epicondyle and had a mean length of 5.6 cm (range 4.5 to 7.5 cm). The diameter of all medial and lateral branches to the FCU muscle ranged from 0.5 to 1.2 mm (mean 1 mm), and the diameter of the branch to the FDP muscle ranged from 1.5 to 2.3 mm (mean 2.1 mm). All branches to both the FCU and FDP muscles arose from the ulnar nerve, over its first 4.5 to 7 cm (mean 5.5 cm) from the level of the medial epicondyle and distally. The more proximal medial branches and the branch to the FDP muscle could routinely be teased away from the main ulnar trunk to increase the lengths to about 10 cm, which approximately doubled the length. We found that the ulnar nerve branch to the FDP muscle could be made to reach the PIN very easily by passing this branch posteriorly through the interosseous membrane by using a hemostat with little if any manipulation of it from the main ulnar nerve trunk (Fig. 2). The diameter of the PIN ranged from 1 to 1.8 mm (mean 1.5 mm). No significant difference in the nerve was noted between the sexes or left and right sides (p > 0.05).

Discussion

Reportedly, the ulnar nerve provides two to four branches to the deep surface of the FCU muscle and transection of one of these branches may not cause significant clinical morbidity; we found a mean of 3.4 branches leading to the FCU muscle. The muscular branches of the ulnar nerve to the forearm are said to make up the posterolateral part of this nerve in the cubital tunnel. The first branch of the ulnar nerve normally originates in the cubital tunnel as an articular branch. The first muscular branch from this nerve is destined for the FCU muscle and usually branches after the articular branch to the elbow. Note, however, that this branch may arise as much as 4 cm superior to the medial epicondyle. We found that these branches originated over the first approximately 3 cm of the ulnar nerve distal to the medial epicondyle. The first motor branch to the FCU muscle divides in 5% of limbs to supply the ulnar half of the FDP muscle, although this phenomenon was not seen in the present study. The solely ulnar-innervated hand generally does not supply the forearm muscles. Boutros, et al., have found that the mean cross-sectional area of the ulnar nerve branches leading to the FCU muscle is approximately 142 μm². Klone and Hudson have stated that the ulnar nerve branch leading to the FDP muscle is usually found 2.5 to 5 cm distal to the olecranon notch. We found that this distance measured a mean of 2.7 cm inferior to the medial epicondyle.

As first reported in the study by Oberlin and colleagues, Leechavengyong, et al., described 32 cases in which one or two fascicles (unspecified) of the ulnar nerve in the mid-

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Fig. 1. Upper: Photograph of the right posteromedial elbow region from a cadaver showing the split FCU muscle with the ulnar nerve moved laterally over the medial epicondyle. Note the forearm muscular branches from the ulnar nerve (arrows). Lower: Schematic of details featured in upper photograph. Note the positions of the olecranon process (A) and the distal humerus (olecranon fossa, B) for reference. Note the medial epicondyle of the humerus (C). The ulnar nerve was removed from the ulnar groove (D), seen over the medial epicondyle. The FCU muscle appears to the left in the drawing, with branches of the ulnar nerve entering it.
arm were transferred to the musculocutaneous nerve to recover biceps muscle function. No impairment of hand function was noted postoperatively, and signs of biceps muscle recovery were demonstrated in all cases but one. According to Oberlin and associates,\textsuperscript{10} at the arm level, the ulnar nerve is intermingled with both motor and cutaneous fibers. Thus, the potential for injury to both cutaneous and motor nerve fibers to the hand exists with this technique. We were able to dissect the proximal medial branches of the ulnar nerve leading to the FCU muscle as well as the branch leading to the FDP muscle, almost doubling their lengths and thereby allowing the branches to be brought proximally to the musculocutaneous branches to the brachialis muscle. This technique obviates injuring ulnar hand fibers in the arm.

Üstün, et al.,\textsuperscript{15} and Novak and Mackinnon\textsuperscript{6} have found that reinnervation of the intrinsic hand muscles served by the ulnar nerve can be achieved by performing AIN to ulnar nerve anastomosis. Furthermore, Schultz and Aiache\textsuperscript{13} have reported success in a case of median nerve injury in the proximal forearm in which reinnervation of the thenar muscles occurred following a transfer of the ulnar nerve branch leading to the third lumbral to the recurrent branch of the median nerve. Haase and Chung\textsuperscript{5} have used a sural nerve graft to coapt the AIN to the ulnar nerve at the wrist, with good success in one patient. Interestingly, Wang and Zhu\textsuperscript{16} have reported transferring the AIN to the deep branch of the ulnar nerve. Three of fourteen patients in their study regained normal muscle strength at the most recent follow-up examination.

Loss of PIN function in relationship to motion in the hand is a significant disability.\textsuperscript{15} Given that the ulnar nerve is composed of fibers from C-7, C-8, and T-1 and, more specifically, its muscular forearm branches are from C-7 and C-8 (C-7 is thought to be primarily for the FCU muscle),\textsuperscript{5} the use of ulnar nerve branches to the forearm muscles for neurotization procedures to the PIN (C-7 and C-8)\textsuperscript{5} may be ideal. We found that the ulnar nerve branch leading to the FDP muscle could be made to reach the PIN very easily by passing this branch posteriorly through the interosseous membrane with little if any manipulation of it from the

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main ulnar nerve trunk (Fig. 2). Moreover, this branch and the more proximal medial branches leading to the FCU muscle could be easily teased away from the main ulnar nerve trunk and made to reach the musculocutaneous nerve branches (mean diameter 4.1 mm, range 3 to 5 mm) to the brachialis muscle located more proximally. Note, however, that these branches of the ulnar nerve in the forearm were too short to reach the majority of the branches of the musculocutaneous nerve to the biceps brachii muscle.

Conclusions

The surgeon must try to balance the neurological needs of each patient against the potential deficits that will ensue following sectioning of nerves available for transfer procedures. We hope that our quantitation and landmark data for the muscular branches of the ulnar nerve in the forearm will assist the surgeon who may choose to use the motor branches of this nerve in the forearm for neurotization procedures. Unlike previous procedures in which ulnar nerve fascicles in the arm have been applied in neurotization procedures, the use of ulnar nerve branches in the forearm in which they are distinct entities obviates potential injury to the ulnar nerve fibers destined for the hand.

References


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