ELECTRODIAGNOSTIC REFERENCE VALUES FOR ULNAR MOTOR NERVE CONDUCTION RECORDED FROM THE FLEXOR CARPI ULNARIS MUSCLE

Chanasak Hathaiareerug, Hemmarat Pareesri, Chanwit Phongamwong

Department of Rehabilitation Medicine, Phramongkutklao Hospital and Phramongkutklao College of Medicine, Bangkok, Thailand

Abstract

Background: Ulnar nerve entrapment at the elbow is the second most common compressive neuropathy of the upper extremity. The flexor carpi ulnaris (FCU) muscle may improve diagnostic accuracy in localizing ulnar neuropathy, particularly when distal recording is not feasible because of severe muscle atrophy

Objective: The present study aimed to establish the electrodiagnostic reference values for the ulnar nerve recorded at the FCU muscle.

Methods: A total of 73 upper extremities from 44 patients with suspected carpal tunnel syndrome underwent nerve conduction study. For the FCU muscle, the active electrode was placed 10 cm below the medial epicondyle, and the reference electrode was placed at the pisiform bone. The ulnar nerve was stimulated at the wrist, the medial epicondyle, and 10 cm proximal to the medial epicondyle. The recorded parameters included onset latency at the elbow and above the elbow, as well as CMAP amplitude, area, and duration.

Results: The mean DML and CMAP amplitude following stimulation at the medial epicondyle were 2.35 ± 0.35 ms and 8.89 ± 2.84 mV, respectively. The mean NCV across the elbow was 65.12 ± 10.28 m/s.

Conclusion: The upper limit of normal for DML was 3.05 ms, and the lower limit of normal (LLN) for CMAP amplitude was 3.21 mV, both derived using the mean ± 2 SD. In contrast, the LLN for NCV across the elbow was 50.51 m/s, based on the 2.5th percentile.

Keywords: electrodiagnosis, nerve conduction study, ulnar nerve, reference values, flexor carpi ulnaris

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Correspondence to:
Phongamwong C, Department of Rehabilitation Medicine, Phramongkutklao Hospital and Phramongkutklao College of Medicine, Bangkok 10400, Thailand.
E-mail: chanwit.p@pcm.ac.th

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Introduction

Cubital tunnel syndrome, or ulnar nerve entrapment at the elbow (UNE), is the second most common compressive neuropathy of the upper extremity.[1, 2] It results from compression of the ulnar nerve at the elbow, where the nerve passes posterior to the medial epicondyle of the humerus. Patients typically present with numbness involving the ring and little fingers. Symptoms are usually intermittent and often worsen at night, particularly when the elbow is flexed during sleep. As the condition progresses, numbness may also occur during the daytime.[3, 4]

UNE is usually diagnosed based on clinical symptoms and electrodiagnostic studies. In standard motor nerve conduction studies, responses are commonly recorded from the abductor digiti minimi (ADM) muscle, with stimulation performed proximal and distal to the ulnar notch.[5] However, chronic ulnar neuropathy may lead to atrophy of the intrinsic hand muscles, particularly the first dorsal interosseous (FDI) and ADM muscles. Patients with cubital tunnel syndrome have been reported to have intrinsic hand muscle atrophy approximately four times more often than patients with carpal tunnel syndrome.[4]

Ulnar motor nerve conduction studies recorded from the flexor carpi ulnaris (FCU) muscle may improve diagnostic accuracy in localizing ulnar neuropathy, particularly when distal recording is not feasible because of severe muscle atrophy.[6, 7] For example, Benecke and Conrad examined 23 healthy subjects (44 ulnar nerves); the ulnar nerve was stimulated 2 cm proximal to the medial epicondyle, and the FCU muscle action potential was recorded using a concentric needle electrode placed 10 cm distal to the medial epicondyle. Distal motor latency (DML) was measured from stimulus onset to the onset of the evoked muscle action potential. The mean DML of FCU was 3.1 ± 0.3 ms. Using 3SD above the mean, a DML >4.0 ms was considered abnormal, with a sensitivity of 82.4%.[6]

Nevertheless, standardized reference values for FCU motor nerve conduction parameters remain limited. In addition, demographic and anthropometric factors, including sex, age, and body mass index, may influence electrodiagnostic reference values and contribute to regional differences in normative data.[8-11] Therefore, this study aimed to establish reference values for ulnar motor nerve conduction studies recorded from the FCU muscle. The objective was to determine reference values for DML, compound muscle action potential (CMAP) amplitude, and nerve conduction velocity (NCV) of the FCU muscle.

Methods

Study design and participants

This cross-sectional study was conducted at the Electrodiagnostic Clinic, Department of Rehabilitation Medicine, Phramongkutklao Hospital, between April 2022 and March 2023. The Institutional Review Board of the Royal Thai Army Medical Department approved this study protocol (R028h/65). Participants were eligible if they were aged 20 years or older, were referred for electrodiagnostic evaluation for suspected median nerve entrapment at the wrist, and provided written informed consent before undergoing the electrodiagnostic examination. Because ulnar nerve conduction studies are routinely performed as part of the electrodiagnostic evaluation of patients with suspected carpal tunnel syndrome, this population provides an opportunity to establish reference values without subjecting healthy volunteers to unnecessary electrical stimulation and associated discomfort.

Participants were excluded if they had clinical symptoms or signs suggestive of ulnar neuropathy, including numbness or pain involving the ring or little finger or intrinsic hand muscle atrophy; numbness involving the lower extremities or body regions other than those suggestive of median nerve entrapment; a medical emergency requiring immediate treatment; a previous history of upper-extremity peripheral nerve injury or wrist surgery; anatomical variations of the median or ulnar nerve, including a bifid median nerve, Martin–Gruber anastomosis, or other anomalous neural communications; endocrine disorders known to affect peripheral nerve function, including diabetes mellitus, thyroid disease, or acromegaly; neurological disorders affecting hand function other than ulnar nerve entrapment,

such as cervical radiculopathy, polyneuropathy, or mononeuropathy; or pregnancy.

Sample size calculation

The sample size was calculated using the formula for estimating a population mean,[12] based on the standard deviation of the CMAP amplitude recorded at the distal elbow reported by Felsenthal et al.[7] A two-sided significance level of 0.05, a standard deviation of 1.8, and an acceptable margin of error of 0.4 were assumed. The required sample size was approximately 75 upper extremities.

Nerve conduction studies

All nerve conduction studies (NCS) were performed using a Synergy On Nicolet EDX System (Natus Medical, Middleton, WI, USA). Disposable surface electrodes were used for recording, with the active, reference, and ground electrodes secured to the skin using adhesive tape. Supramaximal electrical stimulation was delivered using a pulse duration of 0.2 ms. Distances between stimulation and recording sites were measured with a flexible measuring tape, and skin temperature was maintained between 30°C and 33°C throughout the examination.

Rehabilitation medicine residents performed electrodiagnostic examinations under the supervision of board-certified physiatrists with more than 5 years of experience in electrodiagnostic medicine, following the recommendations of the American Association of Neuromuscular & Electrodiagnostic Medicine (AANEM).[7, 13]

For the standard ulnar motor NCS, the active recording electrode was placed over the ADM muscle, with the reference electrode positioned over the fifth metacarpophalangeal joint. An additional recording was obtained from the FCU muscle by placing the active electrode 10 cm distal to the medial epicondyle on the volar aspect of the forearm and the reference electrode over the pisiform bone, as shown in **Figure 1.**

The ulnar nerve was stimulated at the wrist, the medial epicondyle (elbow), and 10 cm proximal to the medial epicondyle (above the elbow). During across-elbow testing, the elbow was flexed approximately 70–90 degrees. The ulnar nerve was stimulated at the level of the medial epicondyle, as the motor branches to the FCU typically arise 15–25 mm distal to the medial epicondyle, allowing stimulation of the main nerve trunk before branching.[14]

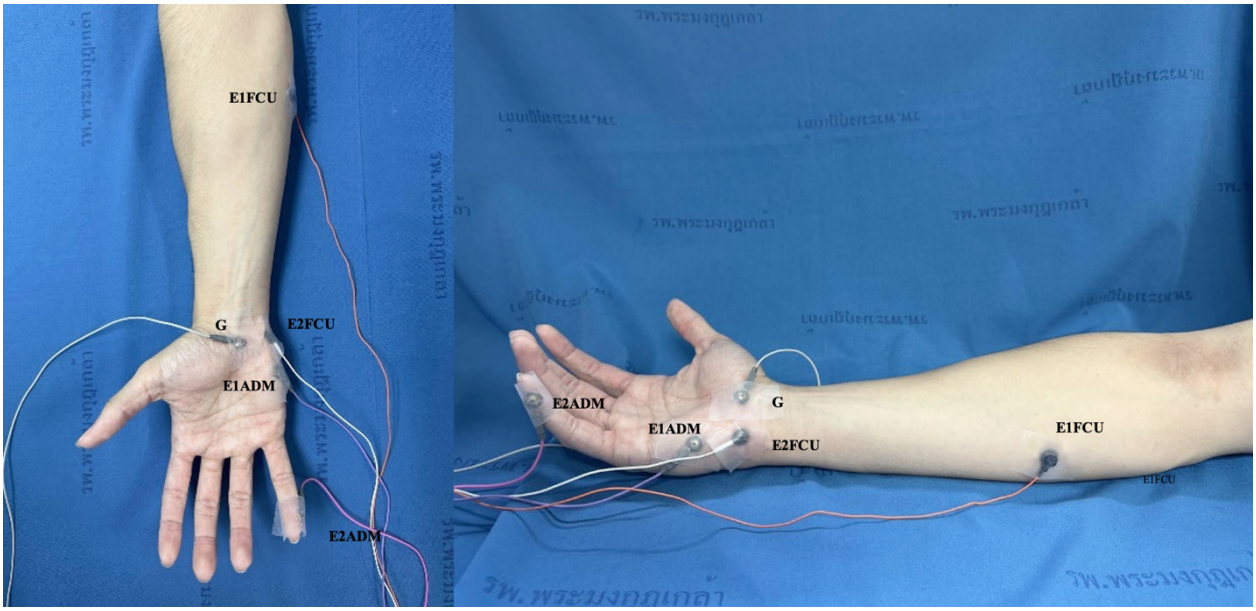

Figure 1. Electrode placement for ulnar motor nerve conduction study recorded from the flexor carpi ulnaris (FCU) muscle.

Active recording electrode (E1FCU) was placed over the belly of the FCU muscle, with the reference electrode positioned distally over the FCU tendon (E2FCU). Surface electrodes over the abductor digiti minimi (E1ADM and E2ADM) were used to monitor volume-conducted responses. The ground electrode (G) was positioned at the wrist.

For FCU recording, DML was defined as the onset latency following stimulation at the medial epicondyle. CMAP amplitude, CMAP duration, and negative area were obtained following stimulation at the medial epicondyle, whereas NCV across the elbow was calculated using responses elicited by stimulation at the medial epicondyle and 10 cm proximal to the medial epicondyle.

Ulnar motor NCV was also recorded from the ADM muscle for comparison. Hands with abnormal ulnar nerve conduction studies recorded from the ADM muscle, defined as a forearm conduction velocity ≤52 m/s or an across-elbow conduction velocity ≤43 m/s, were excluded from the final analysis.[13]

Statistical analysis

Participant characteristics were summarized using descriptive statistics. Categorical variables are presented as frequencies and percentages, whereas continuous variables are presented as means, standard deviations, minimum values, and maximum values. The Shapiro–Wilk test was used to assess normality, whereas the t-test was used to compare mean differences. A p-value < 0.05 was considered statistically significant.

Results

A total of 44 participants were enrolled in the study. Of these, 35 (79.55%) were female. The mean age was 53.84 ± 15.23 years, and the mean BMI was 24.92 ± 5.28 kg/m². Most participants were right-hand dominant (40/44, 90.91%). Fifteen participants contributed data from only one upper extremity because the contralateral upper extremity had a history of surgery, a local injection, or met other exclusion criteria. Consequently, a total of 73 upper extremities were included in the final analysis.

Of 73 upper extremities, the mean DML following stimulation at the elbow and above the elbow was 2.35 ± 0.35 ms and 3.91 ± 0.38 ms, respectively. The mean NCV across the elbow was 65.12 ± 10.28 m/s. The mean CMAP amplitude, duration, and negative area recorded following stimulation at the elbow were 8.89 ± 2.84 mV, 9.92 ± 1.13 ms, and 30.15 ± 9.61 mV·ms, respectively. **Table 1** summarizes the electrodiagnostic findings recorded from the FCU muscle by age group.

Discussion

To the best of our knowledge, the present study was the first to establish reference values for ulnar motor nerve conduction to the FCU muscle in the Thai population. We calculated the upper limit of normal (ULN) and lower limit of normal (LLN) as the mean ± 2SD, following the conventional parametric approach widely used in electrodiagnostic reference studies, provided the data were normally distributed. However, we used the percentile-based method if the data

Table 1. Electrodiagnostic findings of ulnar motor nerve conduction recorded from the FCU muscle categorized by age group.

	Age 20 – 59 years (n = 41)				Age 60 – 80 years (n = 32)			
	Mean	SD	Median	Min - Max	Mean	SD	Median	Min - Max
DMLE	2.27	0.26	2.29	1.67 - 3.07	2.53	0.22	2.55	2.08 - 3.07
DMLAE	3.84	0.37	3.85	2.92 - 4.60	4.06	0.27	4.06	3.50 - 4.64
NCV	65.22	10.34	66.23	50.76 - 89.29	65.75	10.19	66.9	50.51 - 87.72
CMAP	10.11	2.95	9.7	3.12 - 17.6	7.36	1.91	6.735	3.96 - 11.25
DUR	10.24	1.03	10.42	7.48 - 12.24	9.54	1.16	9.45	7.14 - 12.6
AREA	34.04	10.03	33.8	9.48 - 51.38	25.48	6.73	23.86	15.40 - 41.43

DMLE: Distal motor latency recorded following elbow stimulation; DMLAE: Distal motor latency recorded following above-elbow stimulation; NCV = Nerve conduction velocity across the elbow; CMAP = Compound muscle action potential amplitude following elbow stimulation; DUR = CMAP duration following elbow stimulation; AREA: Negative CMAP area following elbow stimulation

Table 2. Reference values for ulnar motor nerve conduction recorded from the FCU muscle

Parameters	Shapiro–Wilk test	Reference limit method	Cut-off values
DML	$p = 0.273$	Mean + 2 SD	3.05 ms
CMAP amplitude	$p = 0.052$	Mean − 2 SD	3.21 mV
NCV across the elbow	$p = 0.023$	2.5th percentile	50.51 m/s

$p > 0.05$ indicates no significant deviation from normality.

deviated from normality. These parameters may be useful for diagnosing UNE, particularly in severe cases where reliable responses cannot be obtained from the ADM or FDI. However, a normal FCU response does not exclude UNE, as the FCU may be spared in some cases.

Older adults (≥60 years) had slightly longer DMLs (2.53 ± 0.22 vs. 2.27 ± 0.26 ms, $p < 0.001$) and lower CMAP amplitudes (7.36 ± 1.91 vs. 10.11 ±2.95 mV, $p < 0.001$) than younger adults, whereas NCV across the elbow was comparable between groups (65.75 ± 10.19 vs. 65.22 ± 10.34 m/s, $p = 0.83$). Despite these age-related differences, they were modest. Furthermore, the AANEM reference values for adult nerve conduction studies do not provide age-stratified reference values for the ulnar nerve.[13] Accordingly, ULN and LLN values for the electrophysiological parameters of the FCU muscle in the present study were derived from the overall study population rather than from age-specific subgroups, as shown in **Table 2.**

The study by Benecke and Conrad was most comparable to ours because it used a fixed distance. However, their stimulation-to-recording distance was approximately 12 cm, 2 cm longer than ours, and they recorded FCU responses using a concentric needle electrode.[6] In contrast, Felsenthal et al. used surface electrodes placed over the FCU motor point, resulting in variable stimulation-to-recording distances of 8.0–11.3 cm (mean, 9.4 cm).[7]

This study encountered several limitations. First, the sample size was relatively small compared with those used to establish AANEM reference values, which may limit the precision of the estimated reference limits. Second, because some participants contributed measurements from both upper extremities, within-subject correlation may have been present. Next, this was a single-center study conducted in Bangkok using a specific electrodiagnostic protocol and equipment; therefore, the findings may not be directly generalizable to other populations, laboratories, or recording techniques. Finally, the inter- and intra-rater reliability of the electrophysiological measurements was not evaluated.

Conclusion

The reference values for ulnar motor nerve conduction recorded from the FCU muscle were derived from 73 upper extremities. The ULN for DML was 3.05 ms, and the LLN for CMAP amplitude was 3.21 mV, both based on the mean ± 2SD, whereas the LLN for NCV across the elbow was 50.51 m/s, based on the 2.5th percentile. Future studies should validate these reference values and investigate their diagnostic performance for identifying ulnar neuropathy at the elbow in clinical practice.

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