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Nerve length measurement method in a radial motor nerve conduction study

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Background: Previous studies of radial nerve conduction study (NCS) did not present how to measure the length of the radial nerve across the elbow, and did not even mention how to manage the spiral course of the nerve. This study aimed to applicate the most reliable method to measure the length of the radial nerve during NCS.

Methods: Three points (A, B, and C) were determined along the relatively straight course of the radial nerve. The distance was measured using three different methods: L1) straight distance corresponding to the A-C distance, L2) sum of the distances corresponding to the A-B-C distance, L3) based on the L2, but the elbow is flexed at a 45° angle. We compared the three methods of distance measurement and the calculated nerve conduction velocities (V1, V2, and V3) in normal healthy subjects.

Results: 19 normal participants were enrolled. The mean value for method L1, L2 and L3 were 22.5 ± 1.8 cm, 24.0 ± 2.1 cm, and 23.2 ± 2.1 cm ($p < 0.001$). Calculated conduction velocities using those distance measurement methods as follows ($p < 0.001$): V1 (60.9 ± 2.7 m/s), V2 (64.6 ± 3.3 m/s), and V3 (63.4 ± 3.9 m/s). V2 was significantly greater than V1 and V3 ($p < 0.001$, $p = 0.010$, respectively).

Conclusions: The distance measurement using a stopover point near the lateral epicondyle between two stimulus points in position of a fully extended elbow with forearm pronation is the most appropriate posture for radial motor NCS.

Key words: Radial nerve; Nerve conduction study; Length measurement; Conduction velocity

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INTRODUCTION

We often calculate the nerve conduction velocity by measuring the distance between two points on a nerve, which represent the length of the nerve during a nerve conduction study (NCS). However, the course of a nerve in the body may be convoluted, and the segment across the elbow is a hypermobile area due to the movement of the elbow joint,[1,2] distance measurements using only surface landmarks often do not reflect the true pathway of the nerve.

As the ulnar nerve which is recommended a flexed elbow posture for NCS due to tortuous course at the elbow with extended posture,[3-6] the radial nerve also has a convoluted course. Several previous studies have investigated the appropriate technique for performing an NCS for the radial nerve across the elbow with normal subjects. These studies suggested that a fully pronated posture should be used to locate the medial position of the radial nerve[7,8] and that a fully extended elbow posture should be used to straightened the radial nerve. However, those studies did not present how to measure the length of the radial nerve across the elbow, and did not even mention how to manage the spiral course of the nerve.[9-11]

We have recently published a study that suggested a length measurement method using 10 cadavers.[12] However, the study was limited to cadaveric investigation, so we needed to prove that the suggested method is appropriate in clinical practice.

We performed this study to apply the most appropriate method for a NCS of the radial nerve across the elbow in normal healthy subjects to determine the variance of calculated nerve conduction velocity (NCV) based on the different nerve length measurement methods.

MATERIALS AND METHODS

Study design and subjects

We recruited normal volunteers ranging in age from 18 to 40 years without any history of diseases affecting nerve conduction, such as peripheral nerve diseases, myopathies, or neuromuscular junction disorders. We also excluded people with diabetes mellitus, chronic alcohol use or other metabolic disorders, malignant neoplasm, or chronic medication use that may influence the peripheral nerve. The study protocol was approved by our institutional review board. Written informed consent was obtained from all study participants.

Nerve conduction study in normal healthy subjects

NCS was performed on each subject by one examiner (J-G Kim). A Nicolet Viking Select machine (Natus Co., Pleasanton, CA, USA) was used to perform the study. The sweep speed was 2 ms/division and the low and high filter settings were 5 Hz and 5 KHz. The stimulating electrode was bipolar. The frequency response of the amplifier was 2 to 10,000 Hz. Every stimulus was supramaximal and was between 0.1 and 0.2 ms in duration. The gain for a compound muscle action potential was 500 microvolts/division. All of the equipment settings were made in accordance with a protocol to ensure proper results.[13] We used 2-cm-diameter disposable surface electrodes for the active and reference electrodes. The active recording electrode was placed on the belly of the extensor indicis (EI) muscle. The reference recording electrode was placed on the ulnar styloid process. The ground electrode was placed on the dorsum of the hand. The subject lay in a supine position, with his or her shoulder naturally abducted. The forearm was fully pronated, and the elbow was fully extended or flexed to a 45° angle. The angle was measured by a manual goniometer. The skin temperature on the ventral forearm was maintained above 32°C. If the temperature fell below 32°C, a warm blanket or warm bag was applied to each limb.

We selected 3 points along the course of the radial nerve that had a relatively straight course between them considering the location of the stimulation points in NCS. The selected points on the radial nerve were marked as A, B, and C (Fig. 1). Point A was where the nerve emerged from the posterior aspect of the humerus, which is the proximal stimulation site in the upper arm during NCS. We found the exact point A by low intensity stimulation with NCS equipment. Point B was located at the point nearest to the lateral epicondyle of the humerus at the elbow crease. As the nerve follows a curved course to the forearm at the elbow, Point C was the distal stimulation site in NCS, which is a point 5 cm above the EI muscle belly.

Surface stimulation was conducted over A, and C points. The distance between two stimulation points was measured with a flexible tape ruler (Hoechstmass Balzer GmbH, Sulzbach, Hessen, Germany) using three different methods. The first method (L1) was the straight distance between the two stimulation points corresponding to the A-C distance. The second method (L2) was the sum of the distances from the two stimulation points to the midpoint between the biceps tendon and lateral epicondyle on the crease of the elbow. This method corresponded to the A-B-C distance method. The L1 and L2 methods were performed with a fully extended elbow posture. In addition to these two methods, we repeated measurement method L2 (A-B-C distance) in all study participants with a flexed elbow posture at a 45° angle as the L3 method (Fig. 1). Nerve conduction velocities that were automatically calculated using L1 were named V1 (velocity 1), those calculated using L2 were named V2, and those calculated using L3 were named V3.

Statistical analysis

We compared the three methods of distance measurement (L1, L2, and L3) and the calculated nerve conduction velocities (V1, V2, and V3) using repeated measures analysis of variance with Bonferroni post-hoc analysis. Additionally, Pearson's correlation coefficient was calculated to measure the linear correlation among the results obtained from the three different methods of surface measurement. IBM SPSS statistics software version 22 (IBM Co., New York, NY, USA) for Windows was used for statistical analysis.

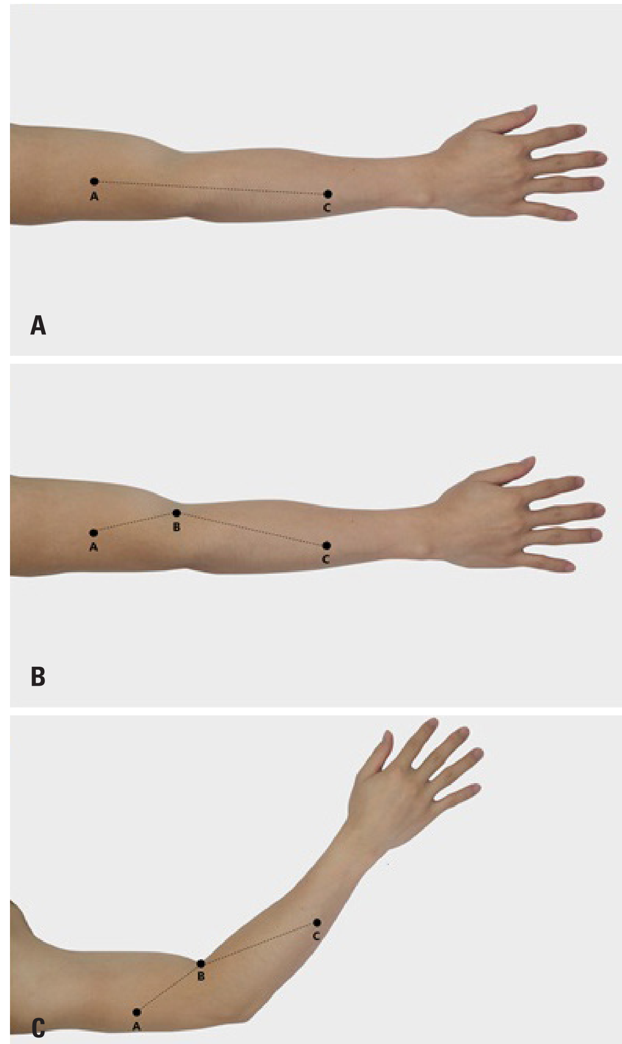

Fig. 1. Illustration of the measurement of L1, L2, and L3. (A) Measurement L1 based on the A-C distance represents a linear measurement between the proximal and distal stimulation point. The elbow is extended fully. (B) Measurement L2 based on the A-B-C distance has a segmented course as contrasted to the single segment of L1. Point B is added on the elbow crease between the biceps brachii tendon and the lateral epicondyle. The elbow angle is the same as that of L1. (C) Measurement L3 is also based on the A-B-C distance, but the elbow is flexed at a 45° angle.

RESULTS

19 normal participants were enrolled in our study. Among them, fifteen were male and four were female, with a mean age of 27.7 years (range, 24-35 years).

Comparison of measured distances

The estimated length along the radial nerve was determined by measuring the distance along the arm between designated landmarks using methods L1, L2, and L3. The mean value for method L1 was 22.5 ± 1.8 cm, that for L2 was 24.0 ± 2.1 cm, and that for L3 was 23.2 ± 2.1 cm. There were significant differences among the results as determined by the different methods ($p < 0.001$). These differences remained significant in relation to one another in a post-hoc test (L1-L2: $p < 0.001$, L2-L3: $p < 0.001$, L1-L3: $p = 0.010$). The distances measured by method L2 were significantly larger than those measured by methods L1 and L3. These methods showed a strong linear correlation with one another (L1-L2: $r = 0.975$, $p < 0.001$; L2-L3: $r = 0.956$, $p < 0.001$, L1-L3: $r = 0.923$, $p < 0.001$). There was no significant difference between measurements made on the right side of the body and measurements made on the left ($p = 0.452$), and the laterality of the distance measurement did not show a statistically significant interaction with the measurement methods ($p = 0.593$).

Comparison of calculated velocity

Velocities were calculated using distances measured by the three methods. The mean value of V1, the calculated velocity using the distance measured by method L1, was 60.9 ± 2.7 cm/sec, while V2 was 64.6 ± 3.3 cm/sec and V3 was 63.4 ± 3.9 cm/sec. The velocities also showed statistical differences among the methods ($p < 0.001$). V2 was significantly greater than V1 and V3 ($p < 0.001$, $p = 0.010$, respectively). The estimates of velocity were strongly linearly correlated with one another (V1-V2: r = 0.878, $p < 0.001$; V2-V3: r = 0.778, $p < 0.001$, V1-V3: r = 0.819, $p < 0.001$) in velocity. The velocity measurement was not significantly influenced by the side of the body on which the measurement was made ($p = 0.789$), and there was no significant interaction between measurement laterality and the measurement methods ($p = 0.918$).

DISCUSSION

Previous reports suggesting that a fully extended posture lengthens and tightens the nerve.[14] We also considered NCS in the flexed posture, because the flexed posture is frequently used in practice. We found that the mean nerve length discrepancy between full extension (method L2) and 45° angle flexion (method L3) was approximately 0.8 cm. This value is similar to the value of 1 cm reported based on cadaver dissection in a prior report.[15] NCS with normal subjects also showed that there is, in practice, a significant difference in distances and conduction velocities obtained between study participants with fully extended elbows and elbows flexed at a 45° angle. We concluded that the fully extended posture (0° elbow flexion) is a better posture for performing distance measurements and NCS.

The mean NCV across the elbow using the A-B-C measurement with an extended elbow posture (L2) was 64.6 ± 3.3 m/s (V2), which was faster velocity compared to previous reports by Jebsen[10] (58.4 ± 6.7 m/s), Trojaborg and Sindrup[16] (62.0 ± 5.1 m/s), and Ma and Liveson[17] (62.3 ± 6.4). Jebsen[10] included data for participants with both the arm pronated and with the elbow in a 10° flexed position. Trojaborg and Sindrup[16] used an obstetric caliper to make their measurements. Ma and Liveson[17] obtained results for study participants with the arm pronated and with the elbow fully extended. Those studies did not mention about how to measure the length between stimulus points. It is possible that the slower motor nerve conduction velocities they reported might be related to error in distance measurement.

On the other hand, faster conduction velocities were reported in studies by Humphries and Currier[14] (69.8 ± 12.9 m/s) and Date et al.[15] (71.7 ± 4.7 m/s). The difference in the Humphries and Currier[14] study could be due to the particular muscles that were recorded, as they used the abductor pollicis longus and the extensor pollicis brevis, which are located more proximally than the EI muscle used in our study. Nerves that innervate more proximal muscles have larger fiber diameters than distal muscles, and there is a positive correlation between nerve fiber diameter and conduction velocity.[18] However, we have not been able to explain the difference between our results and those obtained by Date et al.[15] Their NCS method was similar to ours, which set a stopover point and used EI as the recording muscle. These previous reports are summarized in Table 1.

According to the various measurement method, the calculated NCV could be different. The calculated NCV in one subject was 63 m/sec using the L1 method (A-C distance measurement), while the calculated NCV in the same subject was 70 m/sec using the L2 method (A-B-C distance measurement). This 7 m/sec difference in calculated NCV could affect the sensitivity of NCS especially in cases of focal neuropathy.

Our study has some limitations. First, the surface distance measured by a flexible tape ruler may be affected by the volume of subcutaneous tissues and muscles. For instance, the measured distance in a lean person may appear to be shorter than that of an obese person, although they have the same true nerve length. Thus, the use of an obstetric caliper which has better intra- or inter-rater reliability may avoid this problem.[19] However, a flexible tape ruler reflected the spiral course of the radial nerve more accurately than an obstetric caliper in a previous study, although this study addressed a more proximal segment of the radial nerve.[20] Second, the normal healthy volunteers who underwent NCS in the current study had a narrow age range and were younger than the usual age in which radial neuropathy is prevalent. The parameters of the NCS could be affected by

Table 1. Summary of previous radial nerve motor conduction studies involving a segment across the elbow

Author	Age range of subjects (mean age)	Stimulation site	Recording muscle	Measurement tool	Velocity
Jebsen et al.[10]	14-62 years (33 years)	(1) 3-4 cm proximal to the needle; (2) 5-6 cm proximal to the LE, groove between the BC and BR	EI	Not mentioned	58.4 ± 6.7 m/s
Trojaborg and Sindrup[16]	16-28 years (not mentioned)	(1) 8 cm proximal to ulnar styloid; (2) 6 cm proximal to the LE, between the BR and BB	EI (TB, BR, EDC, EPL)	Obstetric caliper	62 ± 5.1 m/s
Humphries and Currier[14]	20-30 years (22 years)	(1) lateral surface of the brachium 6 to 10 cm proximal to the LE; (2) middle third of the forearm between the BR and extensor	APL, EPB	Steel tape measure	69.8 ± 12.90 m/s
Ma and Liveson[17]	Not mentioned	(1) forearm (several centimeters proximal to the recording electrodes); (2) Lateral brachium (6-10 cm proximal to the LE)	EI	Not mentioned	62.3 ± 6.4 m/s
Date et al.[15]	27-52 years (36.4 years)	(1) 8 cm proximal to the recording site; (2) 8-10 cm proximal to the LE, over the radial groove	EI	Flexible tape measure (across the antecubital fossa, just lateral to the BB tendon)	71.7 ± 4.7 m/s

LE, lateral epicondyle of the humerus; BC, brachialis; BR, brachioradialis; EI, extensor indicis; BB, biceps brachii; TB, triceps brachii; EDC, extensor digitorum communis; EPL, extensor pollicis longus; APL, abductor pollicis longus; EPB, extensor pollicis brevis.

age, so the results obtained might be more variable.[21-23] The aim of this study was to determine the best distance measurement method for the radial nerve. We applied different NCS measurement methods in normal healthy subjects to determine if they are clinically applicable. In a small sample size, a young and narrow age range is much better for obtaining a statistically significant result. If elderly patients were enrolled in the present study, the conduction velocities may have been lower and more variable. A young and narrow age range in our study population compared to previous studies resulted in a relatively small standard deviation for conduction velocity in our study (Table 1).

We confirmed the multi segment distance measurement (L2) with a fully extended prone forearm posture is the most appropriate posture for radial motor NCS. Further studies will be needed to overcome the effect of tissues above the nerve or differences in measurement tools, and to determine an accurate normal conduction velocity range for a larger sample of the population.

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