Interrater Repeatability of Motor Nerve Conduction Velocity of the Ulnar Nerve

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Objective: The purpose of this study was to obtain data on interrater repeatability of the motor nerve conduction velocity (NCV) of the ulnar nerve of different segments, ulnar distal motor latency (DML), and compound muscle action potential (CMAP) amplitudes.

Design: Twenty-four healthy volunteers were examined in consecutive order. Ulnar motor NCV of different segments, ulnar DML, and CMAP amplitudes were determined. Based on a randomization list of various combinations and sequences, 1 of 3 examiners performed the first measurement. A second examiner repeated the evaluation within half an hour.

Results: There were no significant differences between the first and second measurements for all parameters. For the ulnar motor NCV of the different segments, the intraclass correlation coefficient (ICC) ranged from 0.38 to 0.51, and the coefficient of repeatability (CR) ranged from 8.0 to 11.6 m/s. For the ulnar DML, the ICC was 0.44, and the CR was 0.49 millisecond. For the CMAP amplitudes at the different stimulation sites, the ICC ranged from 0.53 to 0.76, and the CR ranged from 1.5 to 2.3 mV.

Conclusions: A moderate amount of interrater variability of the ulnar motor NCV must be taken into account. Compared with the CMAP amplitudes, the interrater repeatability of the ulnar motor NCV is poorer.

Key Words: Electrodiagnosis, Motor nerve Conduction Velocity, Repeatability, Ulnar Nerve


Determining a method’s repeatability is an important point in its validation. A good interrater repeatability is a prerequisite for follow up-investigation made by different observers. There are not much data on the repeatability of the assessment of ulnar motor nerve conduction velocity (NCV) yet. Previous studies in healthy subjects mostly deal with the reproducibility of F-wave and distal motor latencies (DMLs), compound muscle action potentials (CMAPs), and sensory nerve action potentials of the ulnar nerve.1–4 With regard to the ulnar DML of healthy subjects, in a study by McNulty et al.,4 the intraclass correlation coefficient (ICC) for the interrater reproducibility was 0.71, and that for the intrarater reproducibility was 0.76. A higher repeatability of the DML with an ICC of 0.83 was presented by Kong et al. using an automated nerve conduction study system. Johnson et al. did not find significant interrater differences in the evaluation of the CMAP with supramaximal stimulation of the ulnar nerve at the wrist, below the elbow, above the elbow, in the axilla, or at the point of Erb. Pinheiro and Kong et al. evaluated the ulnar motor NCV. Pinheiro et al. presented a low intrarater reproducibility with an ICC of 0.39 for the ulnar motor NCV of the forearm segment. In comparison, Kong et al. described a high intrarater repeatability of the motor ultran NCV across the elbow with an ICC of 0.89 using a modern electrodiagnostic instrument with a computer-based waveform cursor assignment. In the subgroup analyses, the repeatability of subjects with more severe symptoms follows the same trend as the overall study population.7 Up to this point, there are no data about the interrater repeatability of motor NCV of different segments of the ulnar nerve available. In order to interpret the results of serial NCV studies conducted by different examiners, it is essential to know the amount of interexaminer repeatability present. The aim of this blinded study was to obtain data on the interrater repeatability of the motor NCV of the ulnar nerve for the below elbow–to–wrist (BE-to-W) segment, the above elbow–to–below elbow (AE-to-BE) segment, the axilla–to–above elbow (AX-to-AE), and the ulnar DML. In addition, the interrater repeatability of the CMAP amplitudes at different stimulation sites of the ulnar nerve will be determined.

METHODS

Participants

Twenty-four asymptomatic adult volunteers (14 women and 10 men) with a mean age of 38 (SD, 13) years were consecutively included in the prospective study. People with symptoms or signs of peripheral neuropathy, as well as patients with pacemakers or epilepsy, or pregnant women and obese subjects with a body mass index of more than 30 kg/m² were excluded.

The subjects were asked in great detail about symptoms of ulnar neuropathy and carefully examined. In the presence of sensory symptoms in the area of the ulnar nerve, even in discrete expression, a weakness of the ulnar muscles, a positive Tinel sign in the course of the ulnar nerve, or a side-to-side difference of tendon reflexes as an indication of possible radiculopathy subjects were excluded.
All participants had been fully informed about the aims and procedures of this study and signed a written informed consent. They were medical doctors, therapists, or medical technical assistants. The study followed the principles of the Declaration of Helsinki and was approved by the head of the department.

Measurement of the Segmental Ulnar Motor Nerve Conduction Velocity

Nerve conduction studies of the motor ulnar nerve were performed using the Keypoint device (Medtronic, Dantec Medical A/S, Skovlunde, Denmark). All subjects were examined in supine position. The elbow joint was flexed to 90 degrees, the forearm supinated, and the wrist in a neutral position. The arm was abducted to 40 degrees and externally rotated in the shoulder joint. According to a randomization list, either the dominant or nondominant arm was examined. The investigations were conducted at a skin temperature of at least 32°C at the elbow, volar forearm, and wrist. Temperatures were recorded at the beginning of each testing. Subjects with cool arms were warmed to at least 32°C with hot packs.

The recording electrode (disk electrode) was applied to the abductor digiti minimi muscle, and the reference electrode to the metacarpophalangeal joint of the fifth finger. The earth strap was placed around the wrist between the recording and stimulating electrodes. Supramaximal stimulation was performed just proximal to the earth strap at the wrist on the ulnar side, just 3 cm distal to the medial epicondyle, just proximal to the medial epicondyle, and in the axilla. The distance between the active recording electrode and the stimulation site at the wrist was 7 cm. The across-elbow distance was 10 cm. The length of the nerve segment was measured with a measuring tape with the arm in the same position as the stimulation was performed. The latencies from the stimulation sites to the onset of the initial negative deflection of the CMAP were determined by computer-generated latency markers, whereas the segmental motor NCVs were automatically calculated by the device, based on the distances between the stimulation sites and the recording site.

The investigators checked that the computer-generated latency markers were set to the onset of the negative deflection of the CMAPs and not to an occasionally recorded artifact. If the initial deflection from baseline was positive, the active recording electrode was removed and correctly placed over the motor point. If necessary, a manual correction of the assignment of the waveform cursors was performed. The ulnar motor NCVs for the BE-to-W, AE-to-BE, and AX-to-AE segments and the ulnar DML were determined. Furthermore, CMAP amplitudes with stimulation site at the wrist, BE, AE, and the AX were measured from the first negative peak to the next positive peak. Cursors were set at an amplification between 2 and 10 mV/division and sweep speed between 1 and 5 ms/division. For each single measurement, cursors were set at the same sensitivity and sweep speed for the different stimulation sites. The low- and high-frequency filters were set at 20 Hz and 10 kHz, respectively.

According to a randomization list of various combinations of 2 investigators (3 investigators in total), the measurement was repeated within half an hour by a second investigator who was blinded to the first investigation (Table 1). The investigators were senior physicians and had been performing NCV studies regularly for several years.

<table>
<thead>
<tr>
<th>Sequence No.</th>
<th>Session 1</th>
<th>Session 2</th>
<th>No. of Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>A</td>
<td>B</td>
<td>4</td>
</tr>
<tr>
<td>II</td>
<td>A</td>
<td>C</td>
<td>4</td>
</tr>
<tr>
<td>III</td>
<td>B</td>
<td>C</td>
<td>4</td>
</tr>
<tr>
<td>IV</td>
<td>B</td>
<td>A</td>
<td>4</td>
</tr>
<tr>
<td>V</td>
<td>C</td>
<td>A</td>
<td>4</td>
</tr>
<tr>
<td>VI</td>
<td>C</td>
<td>B</td>
<td>4</td>
</tr>
</tbody>
</table>

TABLE 1. Study design with 3 different investigators (A, B, C)  
Each sequence consisted of 2 consecutive measurements (sessions 1 and 2). The subjects were assigned randomly to 1 of the 6 sequences.

Statistical Analysis

First, the obtained values of the ulnar motor NCV of the BE-to-W, the AE-to-BE, and the AX-to-AE segments; the ulnar DML; and CMAP amplitudes of the different stimulation sites for the first and second measurements were presented descriptively. The Kolmogorov-Smirnov test was used to test the normal distribution of data. In order to determine whether the results of the first and second measurements were significantly different, the paired-samples t test was used because the data were normally distributed. An α level of 0.05 was used.

Second, to assess the agreement between the investigators, the ICC and the Bland-Altman coefficient of repeatability (CR) were calculated for the examined parameters. The ICC represents the proportion of variance due to the variability among individuals. The CR is based on the calculation of 2 SDs of the interrater difference. Thus, approximately 95% of repeated measurements will have a difference in the range mean ± CR. This coefficient was calculated in the following way: we squared all the differences between the first and second measurements, added them up, divided it by n, and took the square root, to get the SD of the differences. The CR was twice of this. The CR is the range of differences between the first and second tests, where agreement between the tests can be expected to be reached for 95% of the examined persons. All statistical analyses were conducted using SPSS for Windows (SPSS Inc, Chicago, Ill).

The number of cases was calculated based on data of a study by Buschbacher,12 in which norm values for the ulnar motor NCV had been established. In this study, the SD of the ulnar motor NCV for the AE-to-BE segment was 9 m/s. A slowing of more than 10 m/s of the ulnar motor NCV for the AE-to-BE segment was defined as a diagnostic criterion of the American Association of Neuromuscular and Electrodiagnostic Medicine (AANEM).9 To compare the results of the first to the second measurement, the required sample size for a paired-samples t test was calculated to be 9 subjects to detect a difference of 10 m/s on the size of 1 SD (9 m/s) with an α level of 5% and a power of 80%. To allow a proper randomization and to obtain a balanced distribution of various combinations of investigators (Table 1), a sample size of 24 subjects was chosen.

RESULTS

Tables 2 and 3 show the descriptive data of the ulnar motor NCVs of the BE-to-W, AE-to-BE, and AX-to-AE segments and the CMAP amplitudes at the first and second measurements.
Data were normally distributed. There was no statistical significant difference between the first and second measurements. Tables 4 and 5 present the ICC and the CR between the first and second examinations for BE-to-W, AE-to-BE, and AX-to-AE segments and the CMAP amplitudes obtained from different stimulation sites. The average ulnar DML was 2.7 (SD, 0.2) milliseconds for the first and 2.8 (SD, 0.2) milliseconds for the second measurement. This difference was not statistically significant. For the ulnar DML, the ICC was 0.44 (95% confidence interval, 0.06–0.71), and the CR was 0.49 millisecond.

None of the subjects fulfilled the electrodiagnostic criteria of Martin-Gruber anastomosis, with the CMAP amplitude at the BE site less than 80% of the CMAP amplitude at the wrist site.13

For a high repeatability of electrophysiological results, the minimizing of possible bias such as technical or physiological factors is necessary. Therefore, in this study, the second test was carried out within half an hour, with constant maintained skin temperature, both examinations in a standardized arm position and the stimulation in a defined distance of 10 cm over the elbow segment. Thus, it can be assumed that the variability of the measured NCVs can be explained by the influence of different investigators and not by biological variability. Landau et al.18 described in their study that by imprecise measurement of the distance across the elbow a difference in motor NCV in the forearm to the elbow segment of 14 m/s is possible. The amount of error in the distance measurement depends on the elbow angle, the anatomical course of the nerve, skin movement by the stimulation electrode, and the localization of the cathode of the stimulation electrode. A very important point is the angle of the elbow joint during the examination. In an extended elbow position, the ulnar nerve is tortuous in its course across the elbow, and the measurement of the distance between the stimulation points above and below the elbow turns out too short and does not match the true length of the nerve. In a maximum flexed elbow position, however, the nerve is under strain.19,20 This induces that the results of the NCV of the ulnar nerve across the elbow segment are significantly slower in an extended position than in a flexed position of the elbow joint. As optimum examination position, an angle of 70- to 90-degree flexion is indicated.12,14-17 However, Landau et al.18 discussed that the NCV over a bent segment has a higher variability than over a straight segment of the same length. In our study, the CR of the straight forearm segment was slightly lower than that of the more proximal segments. Between the flexed elbow segment and the stretched upper arm segment, no relevant difference of the interrater dependent variability was shown (Table 4). Interestingly, interrater reliability in the

### TABLE 2. Results of the first (1) and second measurements (2) of the segmental ulnar motor NCV (n = 24)

<table>
<thead>
<tr>
<th>Segment</th>
<th>1</th>
<th>2</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>BE-to-W</td>
<td>58.9 (3.1)</td>
<td>58.8 (4.2)</td>
<td>NS</td>
</tr>
<tr>
<td>AE-to-BE</td>
<td>55.2 (5.9)</td>
<td>54.7 (5.9)</td>
<td>NS</td>
</tr>
<tr>
<td>AX-to-AE</td>
<td>60.2 (4.7)</td>
<td>60.7 (3.8)</td>
<td>NS</td>
</tr>
</tbody>
</table>

Data are expressed as mean (SD) (m/s).

NS, not statistically significant at α = 0.05 level.

### TABLE 3. Results of the first (1) and second measurements (2) of the CMAP of the ulnar nerve at the different stimulation sites (n = 24)

<table>
<thead>
<tr>
<th>Segment</th>
<th>1</th>
<th>2</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wrist</td>
<td>14.9 (3.2)</td>
<td>15.2 (3.2)</td>
<td>NS</td>
</tr>
<tr>
<td>BE</td>
<td>14.3 (3.3)</td>
<td>14.4 (3.4)</td>
<td>NS</td>
</tr>
<tr>
<td>AE</td>
<td>13.8 (3.4)</td>
<td>14.1 (3.4)</td>
<td>NS</td>
</tr>
<tr>
<td>AX</td>
<td>13.7 (4.3)</td>
<td>13.4 (3.2)</td>
<td>NS</td>
</tr>
</tbody>
</table>

Data are expressed as mean (SD) (mV).

AB, above elbow; AX, axilla; BE, below elbow; NS, not statistically significant at α = 0.05 level.

### TABLE 4. Interrater agreement of the results of the first and second measurements of the segmental ulnar motor NCV (n = 24)

<table>
<thead>
<tr>
<th>Segment</th>
<th>ICC (95% CI)</th>
<th>CR (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BE-to-W</td>
<td>0.38 (−0.02 to 0.67)</td>
<td>8.0</td>
</tr>
<tr>
<td>AE-to-BE</td>
<td>0.50 (0.13 to 0.75)</td>
<td>11.6</td>
</tr>
<tr>
<td>AX-to-AE</td>
<td>0.51 (0.14 to 0.75)</td>
<td>10.2</td>
</tr>
</tbody>
</table>

*Significant ICC at α = 0.05 level.

CI, confidence interval.

### TABLE 5. Interrater agreement of the results of the first and second measurements of the CMAP of the ulnar nerve at the different stimulation sites (n = 24)

<table>
<thead>
<tr>
<th>Segment</th>
<th>ICC (95% CI)</th>
<th>CR (mV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wrist</td>
<td>0.70 (0.42 to 0.86)</td>
<td>1.5</td>
</tr>
<tr>
<td>BE</td>
<td>0.76 (0.52 to 0.89)</td>
<td>1.5</td>
</tr>
<tr>
<td>AE</td>
<td>0.73 (0.47 to 0.87)</td>
<td>1.6</td>
</tr>
<tr>
<td>AX</td>
<td>0.53 (0.17 to 0.76)</td>
<td>2.3</td>
</tr>
</tbody>
</table>

*Significant ICC at α = 0.05 level.

AB, above elbow; AX, axilla; BE, below elbow.
forearm segment shown with the ICC is slightly worse than in the other segments, but in contrast to that, the interrater variability shown by the CR in the forearm is somewhat lower than in the other segments (Table 4). Therefore, ICC and CR seem to provide different and complementary information. Because of the influence of the between-subjects variance on the ratio, the ICC is likely to be greater for a group of subjects with a wide range of measurements than for a homogenous sample group. The ICC cannot be interpreted clinically because it gives no indication of the magnitude of discrepancy between measurements. It should therefore be complemented by calculation of the Bland-Altman 95% limits of agreements. Ninety-five percent of the differences between the measurements are within the range of the CR according to Bland-Altman. It indicates a range of error, but it must be interpreted with reference to the range of measurement values obtained. In our study, the CR of the ulnar motor NCV for the different segments ranged from 8.0 to 11.6 m/s (Table 4) with absolute mean values ranging from 54.7 to 60.7 m/s (Table 2). These CRs are rather wide, reflecting the great variation of differences, but may also partially be due to the small sample size. This can be considered as a limitation of the study.

When determining NCV, the distance across the elbow segment should not be shorter than 10 cm in order to keep the effect of a possible error during distance measurement as small as possible. With shorter distances, an error of distance measurement can have a disproportionately large effect. Based on receiver operator characteristics and Bayesian analyses, a 10-cm across-elbow distance was optimal in ulnar nerve conduction testing. The optimal distance of 6 to 8 cm for an electrophysiological screening of an ulnar neuropathy in the elbow was calculated in an experimental study applying a mathematical model but was not confirmed in a clinical study. This requires a careful and exact testing procedure to avoid measuring errors and inadvertent diffuse stimulation propagation. With chronic axonal damages, frequently a focal slowing of motor NCV and normal values proximal and distal to the lesion can no longer be determined because of retrograde and antegrade nerve degeneration. The diagnostic sensitivity of the short-segment nerve conduction study in ulnar neuropathy at the elbow was only little improved from 85% to 90% compared with 10 cm across elbow distance.

The interrater dependent differences are smaller for the CMAP amplitudes at the wrist, BE, and AE stimulation sites than for the motor NCV of the different segments of the ulnar nerve (Tables 4 and 5). There may be a higher likelihood of inappropriate positioning of latency markers and incorrect latency measurements than inappropriate positioning of amplitude markers. To determine amplitudes, the markers merely have to be placed at the negative and positive peak. To determine conduction velocities, the correct positioning of latency markers, as well as correct measurement of distances, increases the likelihood of errors and differences in sequential recordings.

Compared with the segmental sensory antidromic NCV, the interrater repeatability of the segmental motor NCV of the ulnar nerve is better. For healthy subjects, the CR for the antidromic sensory ulnar NCV across the elbow segment is 16.2 m/s, and the interrater repeatability of the antidromic sensory measurement of the ulnar nerve is better in distal segments than in proximal segments. In contrast to this, within a certain range, the interrater repeatability of the motor NCV of the ulnar nerve is similar for the individual measurement segments (Table 4).

The interrater dependent variability must be considered in follow-up examinations. Especially for control investigations in the course of disease, conducted by different investigators, it is necessary to know the extent to which the results obtained by various researchers may vary. A statement about the actual biological dynamics can be made only after the range of such a variation is known.

CONCLUSIONS

During the assessment of the ulnar motor NCV, a moderate amount of interrater variability must be taken into account. Compared with the CMAP amplitudes, the interrater repeatability of the ulnar motor NCV is poorer, but compared with the ulnar sensory antidromic NCV assessed in a previous study, the interrater repeatability of the ulnar motor NCV is better. But it is possible that the measured values of the ulnar motor NCV are outside the norm merely because of interrater variability. This must be considered in the application of the AANEM-proposed diagnostic criteria for ulnar neuropathy, and the diagnosis should not be based on only 1 parameter.

REFERENCES