The importance of arm-elbow velocity difference in the diagnosis of ulnar neuropathy at the elbow

Halit Fidancı ⬡, Yusuf Savrun ⬡, Bülent Cengiz ⬡, Hidayet Reha Kuruoğlu ⬡

Department of Clinical Neurophysiology, Gazi University School of Medicine, Ankara, Turkey

Abstract

Objective: Diagnosis of ulnar neuropathy at the elbow (UNE) by measuring the forearm-elbow velocity difference (FEVD) is subject to significant limitations because Wallerian degeneration might occur in severely affected patients. The contribution of the arm-elbow velocity difference (AEVD) in the diagnosis of UNE may be more valuable because this segment is less affected by pathologic changes.

Methods: The charts of patients who were diagnosed as having UNE were reviewed. Ulnar neuropathy at the elbow was classified as mild, moderate or severe. Motor nerve conduction studies of the ulnar nerve were performed with the elbow flexed to 90º in the supine position. Needle electromyography, as well as sensory and mixed nerve conduction studies, were also performed. Electrophysiologic findings were compared with controls.

Results: The upper limit of FEVD and AEVD were 14.2 m/s and 21.8 m/s, respectively. In UNE, 13 of 23 limbs (56.5%) had AEVD abnormality, and 14 (61%) limbs demonstrated FEVD abnormalities. Arm-elbow velocity difference or FEVD abnormalities were present in 82.6% of UNE extremities. There was no statistically significant difference between AEVD and FEVD abnormalities in patients with mild, moderate or severe UNE. The evaluation of patients without sensory and mixed nerve conduction abnormalities revealed an increased AEVD in 6 (75%) out of 8 limbs.

Conclusion: Diagnostic sensitivity of UNE is increased when FEVD and AEVD are evaluated together. The detection of high rates of AEVD abnormalities in patients without sensory and mixed nerve abnormalities supports the usefulness of this measure.

Keywords: Arm-elbow velocity difference, nerve conduction study, ulnar neuropathy at the elbow

INTRODUCTION

The diagnosis of ulnar neuropathy at the elbow (UNE) is usually made by demonstrating a slow motor nerve conduction velocity (NCV) at the elbow segment and by assessing the difference between the motor NCV of the forearm and elbow segments (FEVD). Sensory nerve conduction abnormalities are also observed mainly in the form of reduced amplitude of the compound nerve action potential (CNAP) (1, 2). Short-segment motor nerve conduction studies across the elbow are considered as the gold standard for diagnosing UNE (3-6). The American Association of Neuromuscular and Electrodiagnostic Medicine (AANEM) recommends using the following criteria in the diagnosis of UNE: motor NCV at the elbow segment <50 m/s and FEVD >10 m/s, a 20% reduction in the compound muscle action potential (CMAP) amplitude or a CMAP morphology change above the elbow, compared with the elicited morphology by stimulating the ulnar nerve below the elbow (1). In the event of uncertainty, other options include recording from the first dorsal interosseous muscle or performing a short-segment motor nerve conduction study at the elbow segment (5 x 2 cm) (7-9). In 2016, the AANEM revised the electrodiagnostic reference values in the upper and lower extremities. Based on these reference values, a FEVD >15 m/s or a reduction in ulnar motor NCV of the elbow segment by more than 23% compared with ulnar motor NCV of the forearm segment is considered abnormal (10). FEVD varies between 10 to 25 m/s, depending on the position of the elbow (7-10). The assessment of the motor NCV differences between the upper arm and elbow segments (AEVD) may be more valuable compared with FEVD values because Wallerian degeneration may occur in the forearm segment in severe UNE (1). We aimed to study the diagnostic contribution of assessing AEVD in UNE because this measurement seems superior to FEVD, especially in more severely affected individuals. Secondly, we aimed to contribute to establishing reference values

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for AEVD because they have not yet been published in the literature.

METHODS

Subjects

The charts of patients who were diagnosed as having UNE and underwent electromyography (EMG) in our laboratory between July 2016 and November 2017 were reviewed, retrospectively. Adult patients with ulnar mononeuropathies were included in the study. All patients displayed at least one of the following clinical manifestations: paresthesias or objective sensory loss at the ulnar dermatome or weakness of the ulnar innervated muscles. Latency prolongation or CMAP amplitude reduction in a short-segment motor nerve conduction study (5 x 2 cm) at the elbow segment had to be present to be eligible for the study. Patients with multiple mononeuropathies, polyneuropathies or history of elbow fracture or elbow surgery were excluded. The control group was composed of healthy individuals. Exclusion criteria for controls consisted of elbow trauma or surgery, paresthesia at the ulnar dermatome or weakness of the ulnar innervated muscles, diseases such as diabetes that would predispose to peripheral neuropathy or a neuromuscular disorder of other kinds. Written informed consent was obtained from all individuals who participated in this study. The study was approved by the Ethics Committee of Gazi University School of Medicine.

Ulnar neuropathy grading was performed according to Padua's classification system (11). Patients demonstrating motor NCV slowing of the ulnar nerve at the elbow segment were classified into the mild group. When an additional CNAP amplitude reduction was detected, the grading of the neuropathy was determined to be moderate. An unobtainable ulnar CNAP placed the neuropathy into the severe UNE group. In extreme UNE, the ulnar CMAP could not be obtained; therefore, these patients were excluded from the study. Axonal damage was thought to occur when the ulnar nerve conduction study showed either reduced CNAP/CMAP amplitudes or active denervation in the form of fibrillation potentials or positive sharp waves in the ulnar innervated muscles on needle EMG.

Electrodiagnostic Tests

All nerve conduction studies were performed using surface stimulating and recording electrodes. The ulnar motor nerve conduction study was performed by recording from the abductor digiti minimi (ADM) muscle. The Buschbacher method was used with the patient in the supine position with the elbow flexed at 90° and the arm abducted at 45° (7). Supramaximal constant current stimulation was delivered with a pulse duration of 100 μs. The terminal latency distance was 5 cm from the recording electrode. Below-elbow stimulation was delivered 4 cm distal to a line drawn at the level of the ulnar sulcus between the medial epicondyle and the olecranon. The above-elbow stimulation point was 6 cm proximal to this line. Stimulation at the axilla was delivered just medial to the axillary artery. For the short- segment motor nerve conduction study at the elbow, three stimulation points (P2, P4, P6) and two stimulation points (D2, D4), both at 2-centimetre intervals, respectively proximal and distal to the drawn line were used (the Kanakamedala method) (3). The CMAP latency difference and the percentage of amplitude reduction in these segments were calculated. Median nerve was also stimulated at the level of the elbow and wrist and a recording was obtained from the abductor pollicis brevis muscle. High-pass and low-pass filters were set at 20 Hz and 10 kHz respectively. Sensitivity was 2 mV and sweep speed was 5 ms/division. CMAP amplitude was measured from peak-to-peak. Ulnar and median minimum F-wave latency measurements were also made by obtaining at least 10 responses. Ulnar and median sensory nerve conduction studies were performed orthodromically employing a pulse duration of 100 μs, by stimulating the fifth and second fingers, respectively, and recording from the distal motor stimulation points. Bandpass filters were set at 20 Hz to 2 kHz. Sensitivity was 10 μV and sweep speed was 1 ms/division. Latency was measured to the negative peak and amplitude was measured from peak-to-peak. Forearm mixed nerve conduction studies were performed by stimulating the distal motor stimulation points and recording at the ulnar sulcus and the elbow on the proximal stimulation points for the ulnar and median nerves, respectively. For mixed nerve conduction studies of the upper arm, stimuli were delivered to the recording points of the forearm segment and recording was made on the axillary artery. Measurements and the amplifier settings were the same as in the sensory nerve conduction studies. The skin temperature was controlled by heating cold extremities above 32°C. Needle EMG was performed with concentric electrodes using a bandpass filter of 10 Hz to 10 KHz. All studies were performed either with the Keypoint net software program of a Keypoint (Medtronic, Skovlunde, Denmark) or Synergy program of a Nicolet (Natus Medical, Ca, USA) device.

Statistical Analysis

Normal distribution of the data was tested using the Shapiro-Wilk test. Group comparisons were made using the t-test for independent samples or the Mann-Whitney U test depending upon the normality of the distribution. Receiver operating characteristics (ROC) analysis was performed to calculate the sensitivity and specificity of the measurements. Pearson's and Fisher's Chi-square tests were used to analyze categorical variables. The mean ± standard deviation (SD) of numeric data was calculated for descriptive statistics. A p value less than 0.05 was considered significant. Categorical variables are expressed in percentages. Lower and upper limits were calculated as mean ± 1.64 SD (single-tail exclusion of 5% of data) for normally distributed variables and as 5th or 95th percentile values for data that were not normally distributed (single-tail exclusion of 5% data) (12). Statistical Package for

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the Social Sciences (SPSS IBM Corp; Armonk, NY, USA) 22.0 was used to perform the statistical analysis.

RESULTS

Subjects and Clinical Findings

Twenty-two patients (13 men and 9 women, 23 extremities) and 33 control subjects (17 men and 16 women, 33 extremities) were reviewed. Twenty-three patients with UNE were excluded from the study because they met the exclusion criteria. The mean ± SD (range) ages of the patients with UNE and control subjects were 47.0±12.6 (range 15-61) years and 45.9±14.7 (range 20-73) years, respectively. The mean body mass indexes (BMI) of patients with UNE and control subjects were found as 25.9±2.9 kg/m^2 and 26.4±3.2 kg/m^2, respectively. No statistically significant difference between the UNE and control groups in terms of age, sex, height, weight, and BMI were found. Nerve conduction studies were performed on the right arm in 9 patients and left arm in 12 patients. One patient had bilateral UNE. Fifteen subjects in the control group underwent nerve conduction studies on the right arm and 18 on the left arm.

Paresthesia at the 4th and 5th digits were present in all affected extremities. Objective sensory loss in the ulnar dermatome was also a common finding. Pain and weakness were present in many patients. Clinical and neurologic examination findings in UNE are shown in Table 1.

Electrophysiologic Findings

Needle EMG findings, as well as abnormal ulnar nerve conduction studies in the UNE group, as defined according to the reference values calculated from the nerve conduction data

of control subjects, are presented in Table 2. Values obtained from the median motor, sensory, and mixed nerve conduction studies were found to be normal both in patients and controls. Needle EMG abnormalities were more prominent in intrinsic hand muscles in comparison with the more proximal forearm muscles. Motor nerve conduction study reference values including the short segment latency and amplitude changes across the elbow segment of the ulnar nerve are presented in Table 3. The most prominent latency changes at the elbow were observed in the P2-ME and ME-D2 segments in controls. Latency was prolonged in the P2-ME (16 extremities), ME-D2 (6 extremities), and P4-P2 (1 extremity) segments in UNE. Terminal latency was prolonged in 4 (17.5%) UNE extremities, including 1 limb with moderate UNE and 3 limbs with severe UNE, accompanied by axonal damage in all.

Receiver operating characteristics analysis revealed that the sensitivity of FEVD was slightly higher than AEVD (Figure 1). Ulnar neuropathy at the elbow was classified as mild in 16 (69.5%), moderate in 4 (17.5%), and severe in 3 (13%)

Table 1. Clinical and neurologic examination findings in UNE

	Number of extremities (n=23)
Symptom	
Paresthesia: 4th/5th finger	23
Pain: Elbow	11
Pain: Forearm	6
Pain: Hand	3
Pain: 4th/5th finger	5
Weakness in hand muscles	9
Neurologic examination	
Hypoesthesia: 4th/5th finger	16
Hypoesthesia: Hypothenar area	5
Weakness: ADM	8
Weakness: FDI	6
Atrophy: ADM	3
Atrophy: FDI	5
ADM: abductor digiti minimi; FDI: first dorsal interosseous; UNE: ulnar neuropathy at the elbow	

Table 2. Abnormal nerve conduction study and needle EMG findings in UNE

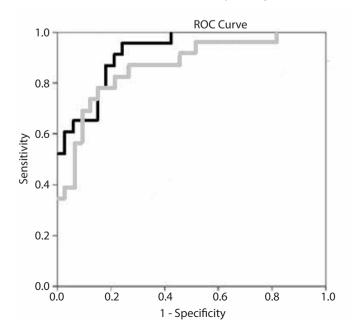|	Number of extremities with abnormal values (%)
Sensory nerve conduction	
(5th finger- wrist segment)	
Amplitude (<7.3uV)	6 (26)
NCV (<37.6 m/s)	4 (17.5)
Mixed nerve conduction	
Forearm segment: NCV (<49.6 m/s)	4 (17.5)
Upper arm segment: NCV (<51.2 m/s)	8 (35)
Motor nerve conduction	
Elbow segment: NCV (<45.1 m/s)	15 (65)
FEVD (>14.2 m/s)	14 (61)
AEVD (>21.8 m/s)	13 (56.5)
FEVD or AEVD abnormality	19 (82.6)
Short segment motor NCV study at the elbow	
Abnormal latency prolongation	23 (100)
Abnormal CMAP amplitude reduction	13 (56.5)
Needle EMG	**Abnormal/Total no of extremities studied**
ADM	16/23 (69.5)
FDI	12/21 (57)
FCU	4/14 (28.5)
FDP (ulnar)	2/10 (20)
NCV: nerve conduction velocity; FEVD: forearm-elbow velocity difference; AEVD: arm-elbow velocity difference; CMAP: compound muscle action potential; ADM: abductor digiti minimi; FDI: first dorsal interosseous; FCU: flexor carpi ulnaris; FDP: flexor digitorum profundus; UNE: ulnar neuropathy at the elbow; EMG: electromyography	

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Table 3. Motor nerve conduction studies of the UNE (mean±SD) compared with controls

Measurement	UNE	Controls	Normal Limit	p
NCV (m/s)				
Below elbow-wrist	57.7±6.8	60.6±5.8	>51.1	0.136
Elbow	39.8±9.8	55.3±6.3	>45.1	<0.001
Axilla-above elbow	64.3±7.4	67.2±4.5	>59.7	0.59
NCV Difference (m/s)				
FEVD	17.9±8.7	5.3±4.4	<14.2	<0.001
AEVD	24.5±10.8	11.9±6	<21.8	<0.001
Latency (ms)				
Terminal	2.5±0.6	2.3±0.3	<2.8	0.127
F-wave	27.7±2.7	25.2±2	<28.5	<0.001
D2-D4	0.3±0.1	0.3±0.1	<0.4	0.344
ME-D2	0.8±1.3	0.4±0.1	<0.6	0.202
P2-ME	1±0.9	0.5±0.1	<0.6	<0.001
P4-P2	0.4±0.4	0.3±0.1	<0.5	0.385
P6-P4	0.3±0.1	0.3±0.1	<0.5	0.045
Amplitude (mV)				
Distal CMAP	11.8±4.6	13.6±2.2	>10.0	0.125
Amplitude Reduction Across the Elbow (%)				
D4-D2	1.0±3	0.9±1.2	<3.7	1
D2-ME	7.2±16	2.5±2.9	<9.0	0.165
ME-P2	19.2±25	2.9±3	<9.6	<0.001
P2-P4	20.9±28.1	4.2±3.6	<12.5	0.03
P4-P6	21.7±28.8	5.1±3.5	<10.9	0.02

UNE: ulnar neuropathy at the elbow; NCV: nerve conduction velocity; FEVD: forearm-elbow velocity difference; AEVD: arm-elbow velocity difference; D: distal; ME: medial epicondyle; P: proximal; CMAP: compound muscle action potential; SD: standard deviation

Figure 1. Assessment of the sensitivities of forearm-elbow velocity difference (FEVD) and arm-elbow velocity difference (AEVD) using receiver operating characteristics analysis. The dark line denotes FEVD, the light line represents AEVD. The area under the curve values of FEVD and AEVD are 0.921 and 0.826, respectively

extremities. Forearm and elbow segments and AEVD abnormalities were present in 8 (50%) and 7 (44%) limbs, respectively, in the mildly affected group. Moderately affected limbs demonstrated 3 (75%) FEVD and AEVD prolongations each, and severe UNE led to abnormal FEVD and AEVD in all. However, these abnormalities showed no significant associations in regard to the severity of UNE (p>0.05). Limbs with axonal damage demonstrated greater mean FEVD values (22.2±8 m/s) in contrast to limbs with no axonal damage (11.2±4.4) (p<0.001). The mean AEVD was also more prominent (29±10.3 m/s) in limbs with an axonal injury compared with those without (17.6±7.7 m/s) (p=0.013). Out of 14 limbs demonstrating axonal damage, 12 (85.5%) and 10 (71.5%) had a prolonged FEVD and AEVD, respectively (p=0.495). In 8 UNE limbs without sensory or mixed nerve conduction abnormalities, 6 (75%) demonstrated prolonged AEVD, whereas only 2 (25%) FEVD values were found to be above the upper limit of normal.

DISCUSSION

In close agreement with previous reports, the most common manifestation of UNE was paresthesia in the 4th and 5th fingers, whereas the neurologic examination most often revealed the loss of superficial sensation in these digits (13). Although paresthesia had an important role in localizing the lesion, pain

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was a rather unspecific finding. Weakness was observed in the ADM and first dorsal interosseous muscles, but never in the ulnar innervated forearm muscles such as flexor digitorum profundus or flexor carpi ulnaris. Likewise, needle EMG abnormalities are more frequently encountered in the intrinsic hand muscles, similar to the findings of our study (14, 15). This selective involvement of hand muscles can be explained on the basis of the topographic distribution of the ulnar nerve fascicles innervating the forearm muscles, which are better protected against compressive insults (16).

The lower limit of the motor NCV of the elbow segment of the ulnar nerve obtained in our study was closer to the defined values by the AANEM and to Buschbacher's lower limit of 43 m/s (7, 10). In regard to the short-segment motor nerve conduction studies at the elbow, the upper limit for the latency difference in 2 cm segments ranged from 0.4 to 0.6 ms in the control group, as observed in earlier studies (3-6). The CMAP amplitude reduction in short segments is also of major importance because most patients with UNE demonstrate this finding. Therefore, obtaining reference values for short-segment motor nerve conduction studies at the elbow is crucially important in the diagnosis of UNE. Our values demonstrate that latency prolongation is a more sensitive indicator of neuropathy compared with amplitude reduction, in agreement with previous studies (4, 5, 17). The sensitivity of abnormal reduction in amplitude was found as 58% by Visser et al. and 51% by Omejec and Podnar; it was 56.5% in our study (5, 17). It is of note that the diagnosis of conduction block is less stringent in short segments, because a 10-15% reduction in CMAP amplitude, depending upon the localization of the segment, is sufficient for diagnosis. Prolonged terminal latency of the ulnar nerve was observed in less than one-twentieth of the extremities, accompanied by axonal damage in all, suggesting that Wallerian degeneration was a prerequisite for this condition, probably brought about by the loss of fast-conducting motor nerve fibers. Mean F-wave latency of the ulnar nerve was significantly prolonged in UNE compared with controls, supporting the diagnosis (18).

Our motor nerve conduction study findings suggest that a FEVD greater than 14 m/s can be helpful in the diagnosis of UNE, just close to the reference value of the AANEM. AEVD is even more prolonged compared with the FEVD, due to the fact that the motor NCV of the upper arm is faster than the elbow and forearm segments of the ulnar nerve (8, 19). We found no clear superiority of AEVD over FEVD in diagnosing UNE. The presence of axonal damage did not change the results, although the velocity differences became more pronounced. This may be due to the loss of fast conducting fibers brought about by Wallerian degeneration, as well as prominent segmental demyelination, a consequence of more severe compression injury, leading to the slowing of motor NCV in the elbow segment of the ulnar nerve (20).

Sensory and mixed nerve conduction studies are also important in the diagnosis of UNE. Compound nerve action potential amplitude abnormalities localize the lesion distal to the spinal ganglion. Slow sensory NCV was present in 17.5% of the UNE group, most likely due to the loss of fast conducting fibers. Mixed nerve conduction studies of the ulnar nerve in particular can be helpful in localizing the lesion, because NCV slowing or absent CNAP can be observed in the upper arm segment along with the forearm segment in UNE. In the event that sensory or mixed nerve conduction studies are not helpful, measuring AEVD has definite importance because the difference is more often prolonged compared with FEVD studies.

The retrospective nature of the study and the low number of patients are the limitations of the study. However, it should be noted that a considerable number of patients were excluded because they met the exclusion criteria, including the presence of diabetes or a history of elbow fracture, carpal tunnel syndrome or a neuromuscular disorder of other kinds.

In conclusion, the addition of the arm segment to the routine ulnar nerve motor nerve conduction studies and the combined assessment of FEVD with AEVD definitely increased the diagnostic sensitivity in UNE. Arm-elbow velocity difference seems to be more helpful diagnostically when no sensory or mixed nerve conduction abnormalities are present, but this observation has to be confirmed in further studies.

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