https://doi.org/10.1590/0004-282X-ANP-2020-0193

ARTICLE

Determining the utility of minimum F-wave latency alterations in the electrodiagnosis of ulnar neuropathy at the elbow

Determinação da utilidade das alterações mínimas da latência da onda F no eletrodiagnóstico da neuropatia ulnar do cotovelo

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ABSTRACT

Background: Ulnar neuropathy at the elbow (UNE) is the second most common entrapment neuropathy. There is little information about the application of F-wave studies for evaluation of UNE. **Objective:** The aim of this study was to evaluate the diagnostic value of minimum F-wave (F-min) latency alterations by comparing this with nerve conduction analyses in UNE-suspected patients. **Methods:** Ninety-four UNE-suspected patients were admitted to this study. Sensory and motor nerve conduction and F-wave analyses on the median and ulnar nerves were performed on both upper extremities. **Results:** A total of 188 upper extremities of 94 patients were examined. Their mean age was 41.4±12.9 years, and 69 patients were female (73.4%). The mean ulnar-nerve across-elbow motor conduction velocity (MCV) in the affected arms was significantly slower than the velocity in healthy arms. The mean ulnar-nerve F-min latencies were significantly longer in the affected arms. Fifty-one patients were electrophysiologically diagnosed as presenting UNE (54.2%). Significantly slower mean ulnar-nerve across-elbow MCV, longer mean ulnar-nerve F-min latency and longer distal onset latency were detected in UNE-positive arms. Lastly, patients who were symptomatic but had normal nerve conduction were evaluated separately. Only the mean ulnar F-min latency was significantly longer in this group, compared with the healthy arms. **Conclusion:** Our study confirmed the utility of F-min latency measurements in the electrodiagnosis of UNE. F-wave latency differences can help in making an early diagnosis to provide better treatment options.

Keywords: Cubital Tunnel Syndrome; Median Nerve; Ulnar Nerve; Electrodiagnosis.

RESUMO

Introdução: A neuropatia ulnar do cotovelo (NUC) é a segunda neuropatia por encarceramento mais comum. Existem poucas informações sobre a aplicação dos estudos da onda F para avaliação da NUC. **Objetivo:** O objetivo deste estudo foi avaliar o valor diagnóstico das alterações mínimas de latência da onda F (F-min), comparando-as com análises de condução nervosa em pacientes com suspeita de NUC. **Métodos:** Noventa e quatro pacientes com suspeita de NUC foram admitidos neste estudo. A condução nervosa sensitiva e motora e as análises da onda F nos nervos mediano e ulnar foram realizadas em ambas as extremidades superiores. **Resultados:** Um total de 188 membros superiores de 94 pacientes foi examinado. A média de idade foi 41,4±12,9 anos e 69 pacientes eram do sexo feminino (73,4%). A velocidade de condução motora média do nervo ulnar através do cotovelo (VCM) nos braços afetados foi significativamente mais lenta do que a velocidade em braços saudáveis. As latências médias F-min do nervo ulnar foram significativamente mais longas nos braços afetados. Cinquenta e um pacientes foram diagnosticados eletrofisiologicamente como apresentando NUC (54,2%). Pacientes com presença de NUC tiveram, de forma significativa, detecção de VCM mais lenta no nervo ulnar ao nível do cotovelo, presença de latência mais longa da onda F-mínima no nervo ulnar, bem como latência de início distal mais longa. Por fim, os pacientes sintomáticos, e com condução nervosa normal, foram avaliados separadamente. Apenas a latência da onda F mínima média do nervo ulnar foi significativamente maior neste grupo, em comparação com os braços saudáveis. **Conclusão:** Nosso estudo confirmou a utilidade das medidas de latência da onda F-mínima no eletrodiagnóstico da NUC. As diferenças de latência da onda F podem ajudar a fazer um diagnóstico precoce para fornecer melhores opções de tratamento.

Palavras-chave: Síndrome do Túnel Cubital; Nervo Mediano; Nervo Ulnar; Eletrodiagnóstico.

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Conflict of interest: There is no conflict of interest to declare.

Authors' contribution: AT: concept, design, definition of intellectual content, literature search, clinical studies, experimental studies, data acquisition, data analysis, manuscript preparation, manuscript editing, manuscript review. VG: concept, design, definition of intellectual content, literature search, clinical studies, experimental studies, data acquisition, manuscript preparation, manuscript editing, manuscript review. AT: concept, design, definition of intellectual content, clinical studies, experimental studies, data acquisition, data analysis, manuscript preparation, manuscript editing, manuscript review. YŞ: concept, design, data analysis, statistical analysis, manuscript preparation, manuscript editing, manuscript review.

Received on May 10, 2020; Received in its final form on June 28, 2020; Accepted on July 24, 2020.

INTRODUCTION

Ulnar neuropathy at the elbow (UNE) is the second most common entrapment neuropathy[1]. It is characterized by sensory and motor deficiencies caused by ulnar nerve compression at the elbow. UNE patients usually have numbness or paresthesia in the ulnar half of the 4th finger and 5th finger[2]. UNE can be diagnosed clinically, but electrophysiological analyses are highly recommended for enabling appropriate treatment in clinical practice[3].

The F wave is a late electrophysiological response elicited through supramaximal antidromic stimulation of motor nerves[4]. F waves provide an evaluation of conduction between peripheral stimulation sites and the related motor neurons of the spinal cord[5]. These measurements contribute the diagnoses of various peripheral nerve disorders[6]. F waves are used for diagnostic evaluation of radiculopathies, polyneuropathies, Guillain-Barré syndrome and amyotrophic lateral sclerosis. F waves are also used in the early detection of motor fiber abnormalities[6,7]. In most previous studies, the diagnostic value of F waves was investigated in relation to carpal tunnel syndrome (CTS)[8,9]. However, there is little information about the application of F-wave studies for evaluation of UNE[3,10].

The ulnar and median nerves originate from the medial cord of the brachial plexus and C8 and T1 roots. Therefore, F-wave records of these two nerves share a common pathway. Any possible damage to the medial cord of the brachial plexus or C8-T1 roots would be expected to prolong the latencies of F waves in median and/or ulnar motor nerves. Therefore, it is important to rule out these situations in order to demonstrate the diagnostic value of F-wave responses in UNE.

In this study, we aimed to evaluate minimum F-wave latency abnormalities by comparing these with the results from nerve conduction analyses in UNE-suspected patients.

METHODS

This prospective case-control study was performed at the electroneuromyography (ENMG) laboratory of Bezmialem Vakıf University, Istanbul, Turkey. A total of 140 patients aged between 16 and 84 years were admitted over a one-year period. The patients were referred to the ENMG laboratory from the neurology, physical medicine and rehabilitation, orthopedics, or neurosurgery outpatient clinics with an initial diagnosis of UNE. Ethics committee approval for this study was obtained from our institution and a written informed consent statement was obtained from all the participants.

Only the patients who were symptomatic and had a complaint of paresthesia and/or pins-and-needles in the ulnar half of the 4th finger and 5th finger were admitted to the study. Among the patients admitted, 130 met these criteria and the remaining 10 were excluded. The exclusion criteria for this study were as follows: any history of deformity, fracture or surgery in the upper extremities; any signs of cervical radiculopathy, plexopathy, polyneuropathy, entrapment neuropathy of the ulnar nerve in Guyon's canal, Martin-Gruber anastomosis or carpal tunnel syndrome in physical examination or electrophysiological evaluation; total loss of sensory and motor responses in ulnar nerve conduction analyses; pregnancy; or presence of diabetes, malignancy, thyroid diseases, amyloidosis or connective tissue diseases. Among these 130 participants, only 94 patients were admitted to the study after considering the exclusion criteria.

The Dantec Keypoint electromyograph system (Natus, Copenhagen, Denmark) was used for electrophysiological tests. These tests were carried out at a fixed time of the day (between 09.00 and 12.00 h). The electrophysiological examinations were conducted in accordance with the practice guidelines of the American Association of Electrodiagnostic Medicine (AAEM)[11]. The temperature in the electrophysiology laboratory was maintained at 25°C. Filter calibrations for sensory nerve conduction were adjusted between 20 Hz and 2 kHz. The stimulation frequency was set at 1 Hz, stimulation period at 0.2 ms; motor conduction at between 20 Hz and 10 kHz; stimulation frequency at 1 Hz; and stimulation period at 0.2 ms. Sensory and motor nerve conduction and F-wave analyses on the median and ulnar nerves were performed in both upper extremities. Needle electromyograph (EMG) and antebrachial cutaneous sensory examinations were performed when required. Nerve conduction analyses were carried out while the wrist was in its neutral position and the forearm was flexed at 35° to 45°.

Supramaximal percutaneous stimulation with constant current stimulant and surface electrode recording was carried out by using standard techniques. Median and ulnar sensory nerve conductions were measured antidromically by placing recording electrodes on the 2nd and 5th fingers and the stimulant electrode on the wrist. In motor conduction evaluations, median nerve responses were recorded over the abductor pollicis brevis (APB) muscle. Ulnar motor nerve conduction was assessed using surface electrodes, with stimulation on the wrist (at a distance of 7 cm) and below and above the medial epicondyle (at a distance of 10 cm). The responses over the belly of the abductor digiti minimi (ADM) muscle were recorded. The inching technique was used to complete the diagnosis by stimulating from distal to proximal in 10 mm steps in all affected arms[12]. The F waves of the median and ulnar nerves were recorded from the APB and ADM muscles through stimulation over the wrist. The usual antidromic supramaximal stimulation was applied, and 16 repetitions were provoked in both nerves. The amplifier was set at 200 to 500 mV/cm and the oscilloscope was set to sweep at 5 ms/cm. The shortest F-wave latency (F-min) was measured through elicitation of at least six F-wave responses (persistence over one third of

the F wave firings was required). Both automatic and manual marking (if needed) was used.

In the present study, the control group consisted of the healthy arms of the patients. Distal latencies, nerve conduction velocities and F-min latencies were compared between symptomatic and asymptomatic upper extremities. The affected arms of patients diagnosed with UNE and the affected arms of patients with symptomatic but normal nerve conduction analyses were then compared separately with the healthy arms of these patients. There were no patients diagnosed with bilateral UNE in the study group. Among the patients who were symptomatic but electrophysiologically normal (except for F-wave alterations), cervical magnetic resonance imaging and needle electromyography were performed to rule out radiculopathies and plexopathies.

Statistical analysis

The data were transferred into the IBM SPSS Statistics 22.0 software (SPSS, Inc., Chicago, IL, USA), where the analyses were completed. The descriptive statistics on the data comprised the mean, standard deviation, median, minimum, maximum, frequency and ratio values. The distribution of the variables was measured using the Kolmogorov-Smirnov test. The Wilcoxon test was used to analyze dependent quantitative data. The significance level was taken to be $p<0.05$. Receiver operating characteristic (ROC) curve analysis was used to determine cutoff values and calculate sensitivity and specificity.

RESULTS

A total of 188 upper extremities in 94 patients were included and 46 patients were excluded. Among the latter patients, the initial evaluations on 10 patients were found not to be compatible with UNE. Sixteen patients presented coexisting CTS, two patients had histories of operations to treat UNE, four patients presented polyneuropathy, two patients had entrapment neuropathy in Guyon's canal and seven patients had bilateral UNE. The F waves in five patients had low persistence, probably because of severe conduction block and axonal injury.

Among the 94 patients, 25 were male (26.6%) and 69 were female (73.4%). The mean age was 41.4±12.9 years (range 16–84 years) and the median age was 39.5 years.

The mean median-nerve distal onset latency, motor conduction velocity (MCV), mean ulnar-nerve distal onset latency and mean ulnar-nerve forearm MCV in the affected arms were not statistically different from these parameters in healthy arms (p=0.520, p=0.825, p=0.062 and p=0.159, respectively). However, the mean ulnar-nerve across-elbow MCV in the affected arms was significantly slower than the velocity in the healthy arms (56.2±12.6 vs. 59.9±7.7 m/s) (p=0.003). The mean ulnar-nerve F-min latencies were significantly longer in the affected arms (23.1±2.8 vs. 22.3±2.3 milliseconds, respectively) ($p<0.001$). The mean median-nerve F-min latencies were not statistically different between pairs of arms (21.6±1.4 vs. 21.4±1.4 milliseconds, respectively) (p=0.124) (Table 1).

Fifty-one patients were electrophysiologically diagnosed as presenting UNE (54.2%). The affected arms of these patients were compared with healthy arms. The mean ulnar-nerve F-wave minimum latency was significantly longer than in the healthy arms (26.6±3.0 vs. 24.5±2.8 milliseconds, respectively) (p=0.006). The mean ulnar-nerve across-elbow MCV in the affected arms was significantly slower (35.3±6.2 vs. 51.7±7.8 m/s) ($p<0.001$) and the mean ulnar-nerve distal onset latency was significantly longer in arms that had been diagnosed UNE-positive (2.7±0.6 vs. 2.5±0.4 milliseconds) (p=0.006). The electrophysiological data on UNE-positive patients, in comparison with the healthy arms, is presented in Table 2.

Lastly, the patients who were symptomatic but had normal nerve conduction were evaluated separately. Only the mean ulnar F-min latency was significantly longer in this group, compared with the healthy arms (22.0±1.6 vs. 21.6±1.6 milliseconds, respectively) ($p<0.001$) (Table 3). With a cutoff point of 2.24 milliseconds for symptomatic to asymptomatic ulnar-nerve F-min latency, the sensitivity was 81% and the specificity was 82% for detection of UNE.

Table 1. Distribution of nerve conduction evaluation results between the symptomatic and healthy arms of all participants.

	Min-Max	Median	Mean±SD	p-value*
Ulnar-nerve distal latency, milliseconds				
Symptomatic arm	1.6–4.6	2.2	2.3±0.4	0.062[w]
Healthy arm	1.6–3.6	2.2	2.2±0.3	
Ulnar-nerve forearm MCV, m/s				
Symptomatic arm	45.3–71.9	63.5	62.0±6.1	0.159[w]
Healthy arm	47.2–75.8	63.5	62.6±6.0	
Ulnar-nerve across-elbow MCV, m/s				
Symptomatic arm	26.1–76.9	61.1	56.2±12.6	0.003[w]
Healthy arm	40.0–76.7	60.8	59.9±7.7	
Median-nerve min. F-wave latency, milliseconds				
Symptomatic arm	20.0–27.9	21.3	21.6±1.4	0.124[w]
Healthy arm	20.0–28.7	20.9	21.4±1.4	
Ulnar-nerve min. F-wave latency, milliseconds				
Symptomatic arm	20.1–34.3	22.1	23.1±2.8	<0.001[w]
Healthy arm	20.0–33.8	21.7	22.3±2.3	

[w]Wilcoxon test; *p<0.05; MCV: motor conduction velocity; SD: standard deviation.

Table 2. Electrophysiological data on ulnar nerve entrapment -positive patients

UNE (+)	Min-Max	Median	Mean±SD	p-value*
Ulnar-nerve distal latency, milliseconds				
Symptomatic arm	2.0–4.6	2.6	2.7±0.6	0.006[w]
Healthy arm	1.8–3.6	2.4	2.5±0.4	
Ulnar-nerve forearm MCV, m/s				
Symptomatic arm	45.3–65.9	55.4	54.9±5.8	0.092[w]
Healthy arm	47.2–67.6	55.0	56.7±6.4	
Ulnar-nerve across-elbow MCV, m/s				
Symptomatic arm	26.1–54.0	35.7	35.3±6.2	0.000[w]
Healthy arm	40.0–70.0	50.3	51.7±7.8	
Median-nerve min. F-wave latency, milliseconds				
Symptomatic arm	22.1–27.9	22.1	22.4±2.1	0.852[w]
Healthy arm	20.3–28.7	22.0	22.3±1.9	
Ulnar-nerve min. F-wave latency, milliseconds				
Symptomatic arm	22.3–34.3	26.3	26.6±3.0	0.006[w]
Healthy arm	20.0–33.8	24.3	24.5±2.8	

[w]Wilcoxon test; * p<0.05; UNE: ulnar nerve entrapment; MCV: motor conduction velocity; SD: standard deviation.

Table 3. Electrophysiological data on ulnar nerve entrapment negative patients.

UNE (-)	Min-Max	Median	Mean±SD	p-value*
Ulnar-nerve distal latency, milliseconds				
Symptomatic arm	1.6–3.3	2.1	2.2±0.3	0.736[w]
Healthy arm	1.6–2.9	2.2	2.2±0.3	
Ulnar-nerve forearm MCV, m/s				
Symptomatic arm	47.6–71.9	65.1	64.1±4.5	0.614[w]
Healthy arm	53.7–75.8	64.1	64.3±4.7	
Ulnar-nerve cross-elbow MCV, m/s				
Symptomatic arm	46.5–76.9	63.2	62.2±5.5	0.940[w]
Healthy arm	49.9–76.7	62.5	62.2±5.9	
Median-nerve min. F-wave latency, milliseconds				
Symptomatic arm	20.0–24.7	21.4	21.5±1.0	0.081[w]
Healthy arm	20.0–24.8	21.2	21.2±1.1	
Ulnar-nerve min. F-wave latency, milliseconds				
Symptomatic arm	20.1–28.9	21.6	22.0±1.6	<0.001[w]
Healthy arm	20.0–27.2	21.3	21.6±1.6	

[w]Wilcoxon test, *p<0.05; UNE: ulnar nerve entrapment; MCV: motor conduction velocity; SD: standard deviation.

Additionally, the cutoff point for ulnar MCV across the elbow was detected as 56.75 m/s with a sensitivity of 76.2% and specificity of 76.7% (Figure 1).

DISCUSSION

Our study revealed that the mean ulnar-nerve F-wave minimum latency was significantly longer both in the UNE-positive group and in the symptomatic-only group, in comparison with the healthy arms of these patients.

Although ulnar nerve compression at the elbow can be diagnosed clinically, electrophysiological measurements are highly recommended for confirming the diagnosis. Even for the most experienced examiners, electrodiagnostic evaluation of UNE is frequently challenging and complex[11]. Fractioned measurement of the ulnar-nerve conduction velocity with stimulation at the wrist, distally and proximally to the cubital tunnel, examination of the motor action potential of the ADM muscle and sensory evaluations on the ulnar nerve are standard techniques in practical examination[11,13]. The ulnar sensory responses in UNE patients in previous studies have ranged from zero abnormal distal findings to 51 to 55% abnormal sensory findings across the elbow[14,15]. Beekman et al. revealed that the ulnar sensory amplitude was absent below the elbow in 17 cases and absent above the elbow in another 11 cases, out of 55 cases. A sensory conduction velocity of <46 m/s was found in 15 cases[15]. Therefore, sensory analyses do not contribute much to the sensitivity of the electrodiagnosis of UNE.

Demonstration of the slowing of ulnar-nerve across-elbow MCV is one of the most reliable and easy methods[13]. However, careful adjustment and standardization of the elbow angle is necessary in order to use the normative values for laboratories[16]. In this study, our examination technique was compatible with what has been reported in the literature[11,16]. The most reliable method for diagnosing UNE seems to be the short-segment ulnar motor nerve conduction test (inching test)[12,14]. The ulnar nerve is stimulated from distal to proximal in 10 mm or 20 mm steps in this method. Therefore, we used this technique on the elbows on all the symptomatic sides.

Conflicting results regarding the role of late responses in upper-extremity entrapment neuropathy have been presented in the literature[10,17,18,19,20]. While some authors have believed that F-wave studies play no role in diagnosing focal lesions[17], other authors have emphasized the role of late responses[8,10,20]. The mean ulnar nerve F-min latency was significantly longer in UNE-suspected arms than in healthy arms among the participants in our study. While ulnar motor and sensory nerve conductions were normal in 43 cases, F-min latency was still longer in this symptomatic group than in the healthy arms of the patients. These results suggest that F responses may be sensitive and useful measurements even

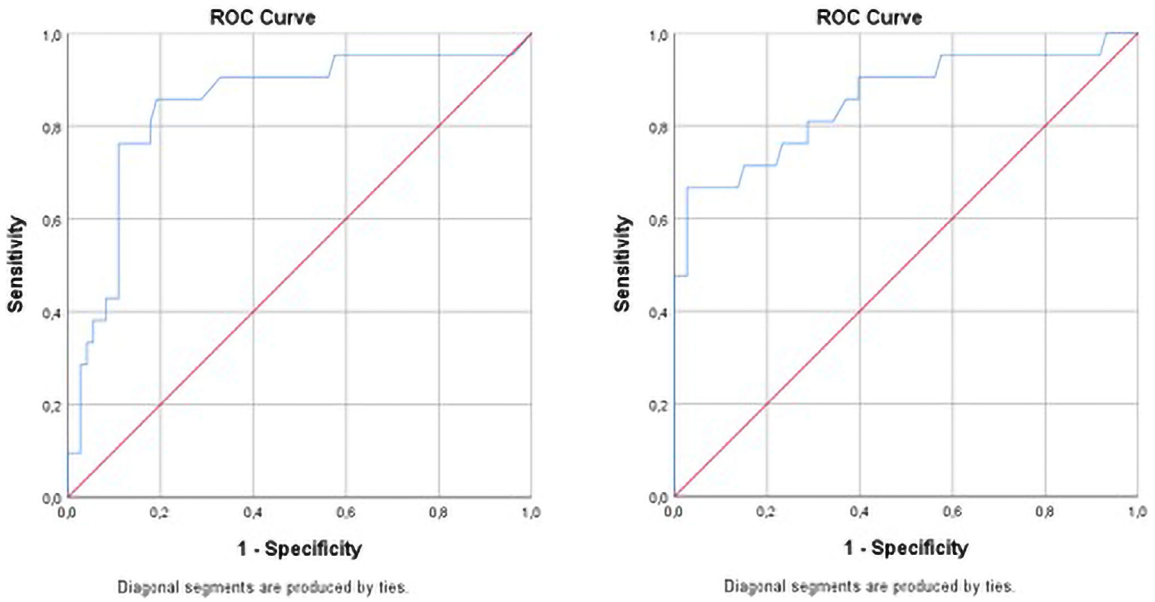

Figure 1. Receiver operating characteristic (ROC) curve analysis on ulnar F-wave latencies and ulnar-nerve across-elbow motor conduction velocity. (A) ROC curve analysis on ulnar F-wave latencies; area under curve: 0.84; 95% confidence interval (95%CI) 0.74–0.95; p=0.000; cutoff value: 2.24 (sensitivity: 81%, specificity: 82%). (B) ROC curve analysis on ulnar-nerve across-elbow motor conduction velocity; area under curve: 0.86; 95%CI 0.74–0.95; p<0.001; cutoff value: 56.75 (sensitivity: 76.2%, specificity: 76.7%).

in early UNE cases, with a careful differential diagnosis. In a previous study conducted by Alemdar using a smaller patient group but similar design[10], the results were compatible with those of our study and F-wave latency difference was also suggested as a sensitive measurement in making the diagnosis of ulnar nerve entrapment. In a previous study by Weber et al., F-min latency was the F-wave parameter that was most often abnormal in CTS but not for UNE. In contrast, they showed that F waves were more sensitive for UNE than for carpal tunnel syndrome and that the F wave parameter that was most often abnormal in UNE was mean F-wave latency[20]. Although F wave abnormalities can be used as a tool for suspecting UNE in electrodiagnostic analyses, their use does not allow the lesion site in the ulnar nerve to be located, including the elbow site. F wave abnormalities thus cannot be used as the only electrodiagnostic abnormality. Nevertheless, the amount of data in the literature remains very limited. We therefore believe that our study can help in reaching greater precision in diagnosing UNE.

Another issue that needs to be discussed with regard to our study is that it was very unusual that the inching test across the elbow, which has high sensitivity, did not find any abnormality in 43 of the 94 symptomatic patients. However, F responses showed abnormalities even if they were on long pathways. Transcutaneous nerve conduction velocity may not be accurately measured when a nerve is surrounded by muscle. Even so, this is a potential limitation of the present study and further studies are needed in order to compare the inching method and F wave abnormalities.

The abnormal F-wave measurement criterion is based on the normal range obtained from healthy subjects in many centers. However, there is an important limitation regarding the utility of reference values relating to patients' physical characteristics. It is difficult to exactly locate the point for postcondylar groove distal stimulation (elbow stimulation), especially in obese patients and in the presence of strongly developed muscles in the lower arm[21,22,23]. Other limitations relate to age, height and body temperature. We used the F-min values of the contralateral extremities of the same patient as control values, to avoid this interference.

The most frequent form of anomalous communication is one in which a number of nerve fibers supplying ulnar-innervated muscles cross over from the median to the ulnar nerve in the forearm. Such a communication, which has been named Martin-Gruber anastomosis, occurs in 27% of the subjects in unselected populations[24]. This is another important limitation of F waves, since it provides an alternative pathway for motor fibers of the ulnar nerve that avoids the entrapment site. In this context, F-min latencies are normal despite severe reduction of MCV across the elbow. Therefore, we excluded cases of this anastomosis through nerve conduction analyses on all participants.

Our study had some limitations. The examiner was not blinded to the diagnosis of UNE. Therefore, F-wave marker placement was a potential bias in some cases. Evaluation of F-wave maximum latency, chronodispersion or tachydispersion could be more sensitive in detecting UNE. Other neurological tests, such as sympathetic skin

response and quantitative sensory testing, were not carried out to investigate autonomic neuropathies. Conversely, the relatively high number of patients, standardization of the technique and sensitive selection of participants in order to avoid misdiagnosis were strong design points of our study. Therefore, patients with other conditions that may cause ulnar F-wave abnormalities (e.g. radiculopathy, plexopathy and polyneuropathy) were not included in our study, which thus allowed us to derive a pure study group involving UNE patients solely.

In conclusion, our study confirmed the utility of F-min latency measurements in making the electrodiagnosis of UNE. Early detection of ulnar-nerve entrapment neuropathy through electrophysiological assessments like minimum F-wave latency difference would help in making early diagnoses, to provide better treatment options.

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