

Needle electromyography in carpal tunnel syndrome: is it valuable or predictable?

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Received 15 June 2015

Accepted 24 December 2015

Egyptian Rheumatology & Rehabilitation
2016, 43:41–46

Context

Needle electromyography (EMG) examination is not crucial in establishing the diagnosis of carpal tunnel syndrome (CTS). However, the presence of axonal loss in needle EMG helps clinicians determine a treatment strategy such as surgery.

Aim of the work

The aim of this study was to investigate whether needle EMG in CTS patients is essentially needed or could be predicted using other nerve conduction study (NCS) parameters.

Materials and methods

This study included 100 patients with clinical and NCS-proven CTS, as well as 50 age-matched and sex-matched controls. All individuals were evaluated using electrodiagnostic techniques, including median distal latency, compound muscle action potential (CMAP), forearm motor nerve conduction velocity, median peak latency, sensory nerve action potentials, and sensory nerve conduction velocity. All CTS patients underwent EMG examination of the abductor pollicis brevis muscle, and the presence or absence of spontaneous EMG activity was recorded.

Results

Comparison of the NCS parameters between CTS patients with and without spontaneous EMG activity revealed that the main determinant parameters for spontaneous activity were CMAPs, sensory nerve action potentials, and forearm motor nerve conduction velocities. However, logistic regression analysis showed that CMAP was the most powerful predictor of the presence of spontaneous activity ($P = 0.000$, odds ratio = 12.154).

Conclusion

It can be concluded that median nerve CMAP amplitudes are the most powerful predictors of the occurrence of spontaneous EMG activity. However, EMG examination is still valuable in some CTS patients and NCS cannot completely replace needle EMG examination in these patients.

Keywords:

carpal tunnel syndrome, needle electromyography, spontaneous activity

Egypt Rheumatol Rehabil 43:41–46

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1110-161X

Introduction

Carpal tunnel syndrome (CTS) is the most commonly studied focal neuropathy [1,2]. It accounts for 90% of all entrapment neuropathies [3,4]. In general, nerve conduction studies (NCS) are more valuable compared with needle electromyography (EMG) in the diagnosis of CTS, because the underlying pathophysiology is mainly focal demyelination [1]. In CTS, both axonal degeneration and conduction block (CB) can cause weakness, in addition to electrophysiological findings such as impaired voluntary recruitment of motor units as well as low amplitude (even absent) compound muscle action potential (CMAP) and sensory nerve action potential (SNAP) [5,6].

Needle EMG of the abductor pollicis brevis (APB) muscle is considered optional by the practice parameters suggested by American Association of Electrodiagnostic Medicine (AAEM) [7–9]. However, needle EMG is often helpful in further characterizing the neuropathic insult in CTS, especially when the CMAP amplitude is reduced, because this can be a

consequence of either distal demyelination or axonal degeneration [1]. In addition, needle examination is important for identifying proximal lesions such as cervical radiculopathy or more proximal median nerve entrapment [10]. Thus, the decision whether or not to perform needle EMG in patients with CTS is not agreed upon universally [9,11,12].

Authors seeking to identify patients with 'severe' CTS have used a CMAP amplitude less than 2.0 mV [13], an absent median SNAP [14], or the presence of denervation potentials in the thenar eminence on needle EMG [15]. However, needle EMG of the APB muscle is a particularly uncomfortable procedure. Therefore, if the presence of axonal loss could be predicted from other NCS parameters then the patient would be

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spared from this uncomfortable procedure, with only a minimal loss of diagnostic information [10,16]. This study attempts to determine whether NCS parameters could predict the presence of denervation potentials in needle EMG examination.

Aim of the work

The aim of this study was to investigate whether needle EMG examination in CTS patients is essentially needed or the presence of spontaneous EMG activity can be predicted using parameters of NCS.

Materials and methods

The study included 100 patients with clinically proven and NCS-proven CTS, as well as 50 age-matched and sex-matched normal controls, to determine the cutoff points of normal values for electrophysiological parameters. Electrophysiological study was performed using Neuropack 2 EMG apparatus from Nihon Kohden (Japan). Temperature of the room was adjusted for standardized results. NCS were performed for the studied participants according to the AAEM criteria [12].

NCS provided proof of median neuropathy at the wrist on the basis of one or more of the following standard electrophysiological criteria: (a) a prolonged median distal latency (DL) to the APB compared with the control group, and (b) a prolonged antidromic sensory peak latency (PL) to the second digit compared with the control group. Patients were excluded if the clinical or electrophysiological data from their upper extremities suggested other peripheral neuropathy, such as an entrapment ulnar nerve neuropathy across the elbow, mononeuropathy multiplex, polyneuropathy, or cervical radiculopathy.

Electrophysiological studies

Motor nerve conduction studies

Recording electrodes used were surface electrodes, 7 mm in diameter. Stimulation was carried out using bipolar stimulator. The setting was adjusted at a sweep speed of 5 ms/division, sensitivity of 2–5 mV/division, and stimulation with a pulse duration of 0.2–0.5 ms, as well as a stimulation frequency of 1 Hz. Filter was set at low cut 20 Hz and high cut 3 kHz. Current in the range of 30–50 mA was used to achieve supramaximal stimulation.

Median motor study was performed by recording CMAPs from the APB muscle, with G1 placed over the muscle belly and G2 placed over the distal tendinous insertion. The median nerve was stimulated at the wrist 8 cm proximal to G1 and at the elbow. A ground

electrode was placed on the dorsum of the hand. For supramaximal responses, DL, CMAP amplitude (peak to peak), and forearm motor nerve conduction velocity (FMCV) were measured.

All CTS patients underwent EMG examination of the ABP muscle, and the presence or absence of spontaneous EMG activities was recorded.

Sensory nerve conduction study

Recording electrodes were the same as that for the motor study. The setting was adjusted at a sweep speed of 2 ms/division, sensitivity of 5–20 μ V/division, and stimulation with a pulse duration of 0.2 ms, as well as a stimulation frequency of 1 Hz. Filter was set at low cut 20 Hz and high cut 5 kHz. A current in the range of 5–20 mA was used to achieve supramaximal stimulation with an average of 20 stimulations or more.

Median SNAPs were determined by means of antidromic stimulation at the wrist and recording from the index finger 14 cm distally with the active recording electrodes placed over the proximal phalanx (G1) and the reference electrode placed 3 cm distally (G2). The placement of the ground electrode was the same as that for the motor study. Supramaximal responses were obtained, and PL, SNAP amplitude (peak to peak), and sensory nerve conduction velocity across the wrist were measured.

Ethical considerations

The nature of the present study was explained to all patients. Verbal and written consent was obtained from all patients and controls. Research protocol was approved by the Ethical Committee of Faculty of Medicine, Alexandria University.

Appropriate statistical analysis

Statistical analyses were performed using IBM SPSS statistics for windows, (version 20, Armonk, NY: IBM Corp.). Latencies and conduction velocities of the unobtainable responses were considered as missing values (were excluded from the number of cases), whereas amplitudes of the unobtainable responses were considered as zero. The statistical significance level was set at *P*-value less than 0.05. Descriptive statistics, including means, SDs, and median, were calculated for each nerve conduction parameter. For normally distributed variables, abnormal values were defined as the rounded mean \pm 2 SD, as calculated for the controls. As regards abnormally distributed variables, for variable abnormality determined by the normal lower limit the 25th percentile was used as the cutoff point, whereas for variable abnormality determined by the normal upper limit the 75th percentile was used as the cutoff point.

The patients were then divided into two groups based on the findings of spontaneous needle EMG activity in their APB muscle: a group with and another group without such activity. The raw data for each parameter were compared between the two patient groups using Student's *t*-test for normally distributed variables and using the Mann–Whitney test for abnormally distributed variables. Subsequently, using the cutoff values from the control group, normal and abnormal results (including unobtainable responses) for the different parameters of the NCS were compared between the two patient groups using the χ^2 -test. When more than 20% of the cells have expected count less than 5, correction for χ^2 was conducted using Fisher's exact test. A binary logistic regression was then applied to determine which of the parameters from the NCS could significantly predict spontaneous activity on EMG. Finally, receiver operating characteristic curve was applied to determine the sensitivity and specificity of selected cutoff points or criterion values in discriminating between the two groups of patients.

Results

The study included 100 clinically and electrophysiologically proven CTS patients (85 female

and 15 males; mean age 45.96 ± 12.14 years; range 23–74 years), as well as 50 age-matched and sex-matched controls (42 female and eight male; mean age 43.02 ± 7.53 years; range 26–67 years). There was no statistically significant difference between the patient and the control group with regard to age ($P = 0.119$) or sex ($P = 0.873$).

Comparison between the two CTS patient groups (with and without spontaneous activity) revealed that patients with spontaneous activity were significantly older compared with those without spontaneous activity ($P = 0.009$) and had statistically significantly longer disease duration compared with those without spontaneous activity ($P = 0.01$) (Table 1). The DLs of CTS patients with spontaneous activity were significantly longer compared with those of patients without spontaneous activity ($P = 0.01$). The CMAPs and SNAPs of the CTS patients with spontaneous activity were significantly lower compared with those without spontaneous activity ($P = 0.000$). The FMCVs of CTS patients with spontaneous activity were significantly slower than that of patients without spontaneous activity ($P = 0.001$). There was no statistically significant difference between the two CTS groups with regard to PLs and sensory nerve conduction velocity (Table 1).

Table 1 Comparison between carpal tunnel syndrome patients without spontaneous activity and those with spontaneous activity on electromyographic examination with regard to age, diseases duration, and electrophysiologic parameters

Parameters	CTS without spontaneous activity	CTS with spontaneous activity	Test statistics	P-value
Age (years)				
Mean (SD)	43.27 (10.08)	49.67 (13.79)	<i>t</i> -Test=-2.679	0.009*
Median	43.5000 (<i>n</i> =58)	53.000 (<i>n</i> =42)		
Disease duration (years)				
Mean (SD)	1.33 (1.12)	3.2634 (2.87)	Mann–Whitney test=1629.0	0.01*
Median	1.000 (<i>n</i> =58)	3.000 (<i>n</i> =42)		
DL (ms)				
Mean (SD)	5.35 (1.40)	7.21 (3.60)	Mann–Whitney test=1199.0	0.01*
Median	5.0000 (<i>n</i> =58)	5.5000 (<i>n</i> =31)		
CMAP (mV)				
Mean (SD)	13.16 (6.38)	4.45 (6.16)	Mann–Whitney test=358.5	0.000*
Median	12.0000 (<i>n</i> =58)	0.9000 (<i>n</i> =42)		
FMCV (m/s)				
Mean (SD)	52.22 (4.35)	47.85 (6.76)	<i>t</i> -Test=3.429	0.001*
Median	52.000 (<i>n</i> =58)	49.6000 (<i>n</i> =22)		
PL (ms)				
Mean (SD)	4.64 (0.55)	5.18 (0.80)	<i>t</i> -Test=10.828	0.068
Median	4.500 (<i>n</i> =47)	5.2000 (<i>n</i> =10)		
SNAP (μ V)				
Mean (SD)	19.51 (16.60)	5.95 (13.74)	Mann–Whitney test=485.0	0.000*
Median	16.700 (<i>n</i> =58)	0000 (<i>n</i> =42)		
SNCV (m/s)				
Mean (SD)	37.38 (5.79)	36.00 (7.09)	<i>t</i> -Test=0.658	0.513
Median	38 (<i>n</i> =47)	35 (<i>n</i> =10)		

CMAP, compound muscle action potential; CTS, carpal tunnel syndrome; DL, distal latency; FMCV, forearm median motor conduction; PL, peak sensory latency; SNAP, sensory nerve action potential; SNCV, sensory nerve conduction velocity; *Statistical significance at $P < 0.05$.

On the basis of cutoff values of the control group (Table 2), parameters of the NCS were classified as normal or abnormal, where unobtainable responses were considered abnormal results. Comparison between the two CTS patient groups with regard to normal and abnormal results revealed a statistically significant difference between the two groups with regard to CMAPs ($P = 0.000$), SNAPs ($P = 0.000$), FMCVs ($P = 0.001$), and PL ($P = 0.038$) (Table 3).

Comparison of the NCS parameters between the two CTS patient groups, both quantitatively and qualitatively, revealed that the main determinant parameters for spontaneous activity were CMAPs, SNAPs, and FMCVs. Thus, binary logistic regression analysis was conducted. Regression analysis showed that CMAP was the most powerful predictor of the presence or absence of spontaneous activity during EMG examination ($P = 0.000$, odds ratio = 12.154) (Table 4).

Table 2 Cutoff values for the electrophysiological parameters of the control group

Parameters	Control ($n = 50$)	Cutoff value
DL (ms)		
Mean (SD)	3.74 (0.35)	4.44
Median	3.8000	
CMAP (mV)		
Mean (SD)	15.13 (3.72)	7.70
Median	13.70	
FMCV (m/s)		
Mean (SD)	53.12 (3.35)	46.41
Median	54.30	
PL (ms)		
Mean (SD)	3.52 (0.30)	4.13
Median	3.50	
SNAP (μ V)		
Mean (SD)	26.84 (20.07)	17.50
Median	23.15	
SNCV (m/s)		
Mean (SD)	54.08 (5.35)	43.38
Median	53.00	

CMAP, compound muscle action potential; DL, distal latency; FMCV, forearm median motor conduction; PL, peak sensory latency; SNAP, sensory nerve action potential; SNCV, sensory nerve conduction velocity.

Table 3 Comparison between carpal tunnel syndrome patients with and without spontaneous activity on electromyographic examination with regard to electrophysiologic parameters

Parameter	CTS without spontaneous activity [n (%)]	CTS with spontaneous activity [n (%)]	χ^2 -test	P value
DL (ms) (abnormal)	47 (56)	37 (44)	0.544	0.641
CMAP (mV) (abnormal)	7 (19)	30 (81)	36.82	0.000*
FMCV (m/s) (abnormal)	6 (19)	26 (81)	29.76	0.000*
PL (ms) (abnormal)	52 (55)	42 (45)	Fisher exact	0.038*
SNAP (μ V) (abnormal)	31 (46)	36 (54)	11.47	0.001*
SNCV (m/s) (abnormal)	52 (56)	41 (44)	2.37	0.123

CMAP, compound muscle action potential; CTS, carpal tunnel syndrome; DL, distal latency; FMCV, forearm median motor conduction; PL, peak sensory latency; SNAP, sensory nerve action potential; SNCV, sensory nerve conduction velocity; *Statistical significance at $P < 0.05$.

Using receiver operating characteristic curve, it was found that, if median nerve CMAP amplitude was 5.3 mV or less, the sensitivity of this CMAP amplitude in the detection of EMG spontaneous activity was 95% or greater, and when the median nerve CMAP amplitude was higher than the lower limit normal value (7.7 mV), the specificity of this CMAP amplitude in excluding the presence of spontaneous EMG activity was about 80%.

Discussion

CTS is the most frequent compressive focal mononeuropathy seen in clinical practice. Its incidence varies in different studies, affecting ~3–6% of adults in the general population [17–19]. NCS are increasingly used for the diagnosis and severity assessment with a high degree of sensitivity and specificity [20].

Needle EMG can detect the presence of membrane instability by recording denervation potentials, such as fibrillation potentials and positive sharp waves, and altered motor unit morphology. With severe CTS, electrodiagnostic evidence of axonal loss of motor nerves and subsequent motor unit reorganization can be seen in the APB muscle [1]. Determining the presence of axonal degeneration and ongoing denervation in the APB is important for clinical treatment decisions in CTS patients [21]. In the current study, 42% of the patients had spontaneous activity. This was higher compared with the results reported by Werner and Albers [10], who found that 22% of patients with CTS had spontaneous activity. This difference might be related to the degree of severity of CTS in the studied group of patients. The current study showed that CTS patients with spontaneous EMG activity were older and had longer disease duration compared with those without. This is in accordance with the results of Werner and Albers [10], who found that CTS patients with an abnormal EMG examination tended to be older.

The current work demonstrated that patients with spontaneous EMG activity have smaller median

Table 4 Comparison between carpal tunnel syndrome patients with or without spontaneous activity on electromyographic examination with regard to the determinant electrophysiologic parameters using logistic regression analysis

Parameter	Spontaneous activity				
	B-value	P-value	Odds ratio	95% CI	
				Lower	Upper
CMAP (mV)	2.498	0.000*	12.154	3.09	47.71
FMCV (ms)	1.361	0.064	3.901	0.926	16.44
SNAP (μ V)	-0.310	0.681	0.258	0.17	3.22

CI, confidence interval; CMAP, compound muscle action potential; FMCV, forearm median motor conduction; SNAP, sensory nerve action potential.

CMAP and SNAP amplitudes, more prolonged latencies, and slower FMCV compared with those without spontaneous activity. However, logistic regression analysis showed that abnormal CMAP amplitude is the best parameter associated with the presence of spontaneous activity. These results are similar to those reported by Chang *et al.* [16], who revealed that CMAPs had a more powerful association with spontaneous activity than did SNAPs or other NCS parameters. Contrary to our results, Werner and Albers [10] found that SNAPs were more sensitive compared with CMAPs in documenting axonal loss. As needle EMG actually reflects motor fiber abnormalities, it is reasonable to predict spontaneous activity based upon motor responses rather than sensory responses [22].

In the present study, it was found that, at median CMAP amplitude less than or equal to 5.3 mV, sensitivity of the CMAP amplitude in the detection of EMG spontaneous activity was 95% or greater, and when the median CMAP amplitude was higher than the lower limit normal value (7.7 mV), the specificity of the CMAP amplitude in excluding the presence of spontaneous EMG activity was about 80%. Accordingly, a drop of the CMAP by 80% of the lower limit normal is strongly associated with the detection of spontaneous EMG activity. These results are in accordance with those of Chang *et al.* [16], who reported that, depending on the CMAP amplitude, spontaneous activity could be predicted, and found that a decrease of ~60% in CMAP amplitude below the lower normal limit is highly associated with spontaneous EMG activity in CTS patients. However, contrary to our results, Werner and Albers [10] reported that the sensitivity of a single parameter with a defined threshold in predicting an abnormal EMG examination ranged from 57 to 68%, but the specificity was poor, ranging from 58 to 61%. Accordingly, they concluded that NCS are poorly predictive of abnormal EMG findings on an individual basis.

It is to be emphasized that CB is a typical manifestation of focal demyelination in CTS, which may be misinterpreted as axonal degeneration because of the low CMAP amplitude [23]. In the present study, palmar conduction study, for the detection of CB, was not performed. This was based on the findings of Chang *et al.* [16], who analyzed CTS patients with and without CB and found that CMAP amplitude of the APB is still the most powerful predictor of the occurrence of spontaneous activity in both groups.

According to our results, CMAP amplitudes less than 5.3 mV are strongly associated with spontaneous activity, whereas CMAP amplitudes between 5.3 mV and the lower normal limit 7.7 mV are recommended for performance of EMG examination for detecting spontaneous activity. Despite these recommendations, needle EMG is still an important test in CTS patients, especially in those with an atypical CTS presentation and when a more proximal nerve entrapment is present. EMG study is still the gold standard for detecting spontaneous activity in CTS patients because the absence of CMAP is not always suggestive of axonotmesis (as it might be due to severe demyelination with temporal dispersion and CB) and a relatively preserved CMAP amplitude does not exclude presence of some axonal degeneration [16]. It can be concluded that EMG examination is valuable in some CTS patients and NCS cannot completely replace needle EMG examination in these patients.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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