MJMR, Vol. 34, No. 3, 2023, pages (11-18).

Open Access
ISSN:2682-4558

Research Article

Neurophysiological evaluation of patients with carpal tunnel syndrome using different diagnostic methods

Muhammad Mumdouh Ismail[1], Nermin Aly Hamdy[1], Mohamed Abdelfatah Yehia[1], Rasha Nady Saleh[1], Tasneem Mohamed Desouky[1] and Mohamed Abdelkader[1]
[1]Neuropsychaitry Department, Faculty of Medicine, Minia University, Minia, Egypt

DOI: 10.21608/mjmr.2023.211598.1397

Abstract
Background: Carpal Tunnel Syndrome (CTS) is the most common form of median nerve entrapment, and represents about 90% of all entrapment neuropathies. Diagnosis of CTS depends mainly on clinical evaluation and nerve conduction studies. This study aims at studying sensitivities of different conventional and other modified neurophysiological methods in the diagnosis of carpal tunnel syndrome. **Methods:** One hundred and nine hands of 83 patients with clinical presentation of CTS have been included in this study in the period between August, 2022 and February, 2023. Hands were classified clinically as mild to moderate or severe according to the modified criteria of the Italian CTS Study Group. Conventional techniques used were assessment of the median nerve distal motor latency at wrist and assessment of the median nerve sensory conduction velocity at index. We used also 2 motor and 6 sensory modified techniques. **Results:** Collectively, modified nonconventional techniques - especially the sensory ones - showed higher sensitivities than those of conventional techniques. Differences were more obvious in patients with mild to moderate clinical presentation. The most sensitive methods were methods measuring differences between median and ulnar sensory latencies. **Conclusion:** Sensory modified techniques were the most helpful in diagnosing CTS especially in patients with early clinical presentation.

Keywords: CTS; Neurophysiological; Diagnosis

Introduction
Carpal Tunnel Syndrome (CTS) is the most common form of median nerve entrapment.(1) It represents about 90% of all entrapment neuropathies.(2) Diagnosis of CTS depends mainly on clinical evaluation and nerve conduction studies. Prolonged distal sensory and motor latencies, and reduced sensory and motor conduction velocities of median nerve around wrist have been accepted as diagnostic criteria for CTS.(3) This study aims at studying sensitivities of different conventional and other modified neurophysiological methods in the diagnosis of carpal tunnel syndrome.

Patients and Methods
One hundred and nine hands of 83 patients with clinical presentation of CTS – whether unilateral or bilateral – have been included in this study in the period between August, 2022 and February, 2023. Patients have been recruited from the neurology outpatient clinic in Minia University Hospital. All patients were subjected to detailed history taking and meticulous neurological examination, and patients with clinical presentation that can be attributed to any other illness other than CTS were excluded. Hands were classified clinically as mild to moderate or severe according to the

modified criteria of the Italian CTS Study Group.[4] Mild to moderate, include asymptomatic patients (Grade 0), patients with nocturnal paraesthesia (Grade I) and patients with nocturnal and diurnal paraesthesia (Grade II). Severe, include patients with sensory loss (Grade III) and patients with atrophy and/or weakness of median innervated thenar muscles (Grade IV).

Neurophysiological examination of all patients was done in the neurophysiology unit at Minia University Hospital. We used Neuropack MEB-2300 6 channel EMG/EP measuring system; Nihon Kohden Corporation, Tokyo, Japan.

Conventional methods used were:
Assessment of median nerve distal motor latency (DML) at wrist, values greater than 4.2 ms were considered diagnostic. All hands were examined by this technique.

Assessment of median nerve sensory conduction velocity (SCV) at index, values less than 44 m/s were considered diagnostic. Ninety one hands were examined by this technique.
Other modified methods used were:

Determining differences between median nerve motor latencies at palm and wrist, examined in 80 hands. Differences above 2.15 ms were considered diagnostic.

Determining differences between median and ulnar nerve distal motor latencies at wrist, examined in 68 hands. Differences above 1.4 ms were considered diagnostic.

Determining median nerve SCV at the middle finger, examined in 105 hands. Values less than 44 m/s were considered diagnostic.
Determining the differences between sensory latencies (SL) of median nerve at index and ulnar nerve at little finger, examined in 85 hands. Values above 0.4 ms were considered diagnostic.

Determining differences between SL of median nerve at middle finger and ulnar nerve at little finger, examined in 105 hands. Values above 0.4 ms were considered diagnostic.

Determining differences between SL of median and ulnar nerves at ring finger, examined in 74 hands. Values above 0.4 ms were considered diagnostic.
Determining median nerve SL at the palm by orthodromic technique, examined in 68 hands. Values above 1.85ms were considered diagnostic.

Determining the differences between SL of median nerve and ulnar nerve at palm by orthodromic techniques, examined in 42 cases. Values above 0.4ms were considered diagnostic.
Cut off values for conventional and modified techniques followed values reported by *Kimura,* (2013).[5,6]

Statistical Analysis
The collected data were coded and statistically analyzed using IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp; 2011. Descriptive statistics were done for categorical data by number and percentage, while they were done for numerical data by mean, standard deviation and minimum and maximum of the range. Chi square test was used for qualitative data between groups if the number per cell was more than 5 and Fisher exact test if the number per cell was less than 5. The level of significance was taken at (P value ≤ 0.05).

Ethical Approval
Research has been conducted after approval of the Institutional Review Board of Faculty of Medicine, Minia University (Approval No. 651/2023). All patients signed an informed consent before the examination clarifying advantages and disadvantages of the study.

Results
One hundred and nine hands of 83 patients with clinical presentation of CTS have been included in this study in the period between August, 2022 and February, 2023. Age ranged between 16 and 65 years with a mean of 36.6 ± 21.34 years old. Female hands represented 93.5%. According to the modified criteria of the Italian CTS Study Group, 44 hands (40.36 %) were clinically classified as grade I, 29 hands (26.60%) were of grade II, 25 hands (22.93%) were of grade III and 11 hands (10.09%) were of grade IV.

The comparison between the sensitivities of assessment of the difference between median nerve motor latencies at palm and wrist and conventional methods (assessment of the median nerve DML and the SCV of median nerve at index) showed no significant difference.

Other results could be seen clearly in tables below (Tables 1, 2, 3, 4, 5, 6 and 7).

Table (1): Comparison between the sensitivities of assessment of the difference between median and ulnar distal motor latencies at wrist, median nerve DML and SCV of median nerve at index

Result	Median and Ulnar DML Wrist Diff.	Median DML Wrist	P value	Median SCV Index	P value
In the total no. of patients	36 / 68 (52.94 %)	41/ 109 (37.61 %)	0.045*	43 / 91 (47.25 %)	0.478
In patients with grade I	1/33 (3.03 %)	0 / 44 (0 %)	0.427	0 / 40 (0 %)	0.452
In patients with grade II	10/10 (100 %)	5 / 29 (17.24%)	< 0.001**	8 / 15 (53.3 %)	0.020*
In patients with grade (I+II)	11/43 (25.58%)	5 / 73 (6.84 %)	0.010*	8 / 55 (14.54 %)	0.170
In patients with grade III	16/16 (100 %)	25 / 25 (100 %)	1	24 / 25 (96 %)	1
In patients with grade IV	9/9 (100 %)	11 / 11 (100 %)	1	11 / 11 (100 %)	1
In patients with grade (III+IV)	25/25 (100 %)	36 / 36 (100 %)	1	35 / 36 (97.22%)	1

DML: distal motor latency; SCV: sensory conduction velocity

Table (2): Comparison between the sensitivities of assessment of the median nerve DML and SCV of median nerve at middle finger

Result	Median DML Wrist	Median SCV Middle Finger	P value
In the total no. of patients	41 / 109 (37.61 %)	53 / 105 (50.47%)	0.058
In patients with grade I	0 / 44 (0 %)	0/44 (0 %)	1
In patients with grade II	5 / 29 (17.24%)	21/29 (72.41%)	< 0.001**
In patients with grade (I+II)	5 / 73 (6.84 %)	21/73 (28.76 %)	< 0.001**
In patients with grade III	25 / 25 (100 %)	22/22 (100 %)	1
In patients with grade IV	11 / 11 (100 %)	10/10 (100 %)	1
In patients with grade (III+IV)	36 / 36 (100 %)	32/32 (100 %)	1

DML: distal motor latency; SCV: sensory conduction velocity

Table (3): Comparison between the sensitivities of assessment of the median nerve DML and: the differences between SL of median nerve at index and ulnar nerve at little finger, the differences between SL of median nerve at middle finger and ulnar nerve at little finger and the difference between SL of median and ulnar nerves at ring finger

Result	Median DML Wrist	Median Index and Ulnar Little Finger SL Diff.	P value	Median Middle Finger and Ulnar Little Finger SL Diff.	P value	Median and Ulnar Ring Finger SL Diff.	P value
In the total no. of patients	41 / 109 (37.61%)	81 / 91 (89.01%)	<0.001**	99 / 105 (94.28 %)	<0.001**	52 / 74 (70.27 %)	<0.001**
In patients with grade I	0 / 44 (0 %)	31 / 40 77.50%	<0.001**	39 / 44 (88.63 %)	<0.001**	18 / 34 (52.94 %)	<0.001**
In patients with grade II	5 / 29 (17.24%)	14 / 15 93.33%	<0.001**	28 / 29 (96.55 %)	<0.001**	10 / 16 (62.50 %)	0.002**
In patients with grade (I+II)	5 / 73 (6.84 %)	45 / 55 81.81%	<0.001**	67 / 73 (91.78 %)	<0.001**	28 / 50 (56 %)	<0.001**
In patients with grade III	25 / 25 (100%)	25 / 25 (100 %)	1	22 / 22 (100 %)	1	15 / 15 (100 %)	1
In patients with grade IV	11 / 11 (100%)	11 / 11 (100 %)	1	10 / 10 (100 %)	1	9 / 9 (100 %)	1
In patients with grade (III+IV)	36 / 36 (100%)	35 / 35 (100 %)	1	32 / 32 (100 %)	1	24 / 24 (100 %)	1

DML: distal motor latency; SL: sensory latency

Table 4: Comparison between the sensitivities of assessment of the median nerve DML and median nerve SL at the palm by orthodromic technique

Result	Median DML Wrist	Median Palm SL Ortho	P value
In the total no. of patients	41 / 109 (37.61 %)	34/ 68 (50%)	0.105
In patients with grade I	0 / 44 (0 %)	2 / 29 (6.89 %)	0.155
In patients with grade II	5 / 29 (17.24 %)	7 / 13 (53.84 %)	0.015*
In patients with grade (I+II)	5 / 73 (6.84 %)	9 / 42 (21.42 %)	0.021*
In patients with grade III	25 / 25 (100 %)	17 / 18 (94.44 %)	0.419
In patients with grade IV	11 / 11 (100 %)	8 / 8 (100 %)	1
In patients with grade (III+IV)	36 / 36 (100 %)	25 / 26 (96.15 %)	0.419

DML: distal motor latency; SL: sensory latency

Table (5): Comparison between the sensitivities of assessment differences between SL of median nerve and ulnar nerve at palm by orthodromic techniques and median nerve DML, SCV of median nerve at index

Result	Median andUlnar Palm SL Diff. Ortho	Median DML Wrist	P value	Median SCV Index	P value
In the total no. of patients	21 / 42 (50 %)	41/ 109 (37.61 %)	0.166	43 / 91 (47.25 %)	0.768
In patients with grade I	3 / 22 (13.63 %)	0 / 44 (0 %)	0.034*	0 / 40 (0 %)	0.041*
In patients with grade II	2 / 3 (66.66 %)	5 / 29 (17.24 %)	0.113	8 / 15 (53.3 %)	1
In patients with grade (I+II)	5 / 25 (20 %)	5 / 73 (6.84 %)	0.061	8 / 55 (14.54 %)	0.540
In patients with grade III	10 / 11 (90.90 %)	25 / 25 (100 %)	0.306	24 / 25 (96 %)	0.524
In patients with grade IV	6 / 6 (100 %)	11 / 11 (100 %)	1	11 / 11 (100 %)	1
In patients with grade (III+IV)	16 / 17 (94.11 %)	36 / 36 (100 %)	1	35 / 36 (97.22 %)	0.543

SL: sensory latency; DML: distal motor latency; SCV: sensory conduction velocity

Table (6): Comparison between the sensitivities of assessment of the SCV of median nerve at index and: the differences between SL of median nerve at index and ulnar nerve at little finger, the differences between SL of median nerve at middle finger and ulnar nerve at little finger and the difference between SL of median and ulnar nerves at ring finger

Result	Median SCV Index	Median Index and Ulnar Little Finger SL Diff.	P value	Median Middle Finger and Ulnar Little Finger SL Diff.	P value	Median and Ulnar Ring Finger SL Diff.	P value
In the total no. of patients	43 / 91 (47.25 %)	81 / 91 (89.01%)	<0.001**	99 / 105 (94.28 %)	<0.001**	52 / 74 (70.27 %)	0.003**
In patients with grade I	0 / 40 (0 %)	31 / 40 77.50%	<0.001**	39 / 44 (88.63 %)	<0.001**	18 / 34 (52.94 %)	< 0.001**
In patients with grade II	8 / 15 (53.3 %)	14 / 15 93.33%	0.035*	28 / 29 (96.55 %)	0.001**	10 / 16 (62.50 %)	0.605
In patients with grade (I+II)	8 / 55 (14.54 %)	45 / 55 81.81%	<0.001**	67 / 73 (91.78 %)	<0.001**	28 / 50 (56 %)	< 0.001**
In patients with grade III	24 / 25 (96 %)	25 / 25 (100 %)	1	22 / 22 (100 %)	1	15 / 15 (100 %)	1
In patients with grade IV	11 / 11 (100 %)	11 / 11 (100 %)	1	10 / 10 (100 %)	1	9 / 9 (100 %)	1
In patients with grade (III+IV)	35/ 36 (97.22%)	35 / 35 (100 %)	1	32 / 32 (100 %)	1	24 / 24 (100 %)	1

SCV: sensory conduction velocity; SL: sensory latency

Table (7): Comparison between the three most sensitive techniques used in our study

Result	Median Index and Ulnar Little Finger SL Diff. (1)	Median Middle Finger and Ulnar Little Finger SL Diff. (2)	Median and Ulnar Ring Finger SL Diff. (3)	P value		
In patients with grade, I	31/40 (77.5 %)	39/44 (88.63 %)	18/34 (52.94%)	0.001**		
				(1)and(2)	(1)and(3)	(2)and(3)
				0.171	0.026*	<0.001**
In patients with grade II	14/15 (93.33%)	28/29 (96.55 %)	10/16 (62.5%)	0.004**		
				(1)and(2)	(1)and(3)	(2)and(3)
				1	0.083	0.005**
In patients with grade III	25/25 (100 %)	22/22 (100 %)	15/15 (100 %)	1		
				(1)and(2)	(1)and(3)	(2)and(3)
				1	1	1
In patients with grade IV	11/11 (100 %)	10/10 (100 %)	9/9 (100 %)	1		
				(1)and(2)	(1)and(3)	(2)and(3)
				1	1	1
In patients with grade (I+II)	45/55 (81.81%)	67/73 (91.78 %)	28/50 (56%)	< 0.001**		
				(1)and(2)	(1)and(3)	(2)and(3)
				0.092	0.004**	<0.001**
In patients with grade (III+IV)	35/35 (100 %)	32/32 (100 %)	24/24 (100 %)	1		
				(1)and(2)	(1)and(3)	(2)and(3)
				1	1	1
In the total no. of patients	81 / 91 (89.01 %)	99 / 105 (94.28 %)	52 / 74 (70.27 %)	< 0.001**		
				(1)and(2)	(1)and(3)	(2)and(3)
				0.177	0.003**	<0.001**

SL: sensory latency

Discussion

The eight modified non-conventional techniques performed were chosen carefully to be easily applicable and of high probable sensitivity. It was difficult to apply all conventional and other modified techniques to all hands included in this study uniformly because it was painful and could not be afforded by most of patients, so there was variability in number of hands examined by each technique.

Regarding the two non-conventional motor techniques chosen in this study (differences between median nerve motor latencies at palm and wrist, and differences between median and ulnar nerve distal motor latencies at wrist), we thought they may add significant early diagnostic value, as it was reported that motor and sensory axons showed comparable incidences of abnormalities in patients with CTS. Ginanneschi et al., (2006) reported that CTS patients with selective involvement of sensory conduction in conventional studies show abnormalities of motor axon recruitment induced by submaximal stimulus intensities.[7]

Also, Rao and Maruthi, (2015) concluded that the motor conduction studies (including the median nerve motor latency at wrist and differences between median nerve motor latencies at palm and wrist) can be equally sensitive to sensory nerve conduction studies, and are no more difficult.[8]

Also we postulated that assessment of the median nerve sensory conduction velocity at middle finger may add more sensitive diagnostic value than that at index, as Uncini et al., (1989); and Terzis et al., (1998) concluded that recording from the thumb or middle finger or the lateral half of the ring finger often reveals abnormalities not detectable from the index finger.[9,10] The relative sparing of the sensory branch to index might be explained by studying the anatomy of median nerve within the carpal tunnel. Compression of median nerve is usually most severe distally in the carpal tunnel, just proximal to its division into motor and sensory branches. At that level, nerve fibers giving rise to the branches to index lie most posteriorly with the least direct compressive and ischemic effects. [11]

According to our results, the most sensitive techniques used in our study were: 1) the differences between SL of median nerve at index and ulnar nerve at little finger 2) the differences between SL of median nerve at middle finger and ulnar nerve at little finger 3) the difference between SL of median and ulnar nerves at ring finger. That was in agreement with Astroshiand et al., (2003) who concluded that among the different motor and sensory nerve conduction tests they used, measurement of median-ulnar sensory latency difference had the highest diagnostic accuracy in patients with CTS.[12]

Technique 1 and 2 were significantly more sensitive than technique 3 especially in clinically mild to moderate patients. Differences were more obvious and showed higher significance with technique 2. But with the direct comparison between technique 1 and 2 differences were not statistically significant (Table 7). The superiority of technique 2 could be explained by the relative sparing of the index sensory branch in patients with CTS as discussed above, [9,10,11] and the relatively higher sensitivity of sensory conduction studies to digit three. Aydin et al., (2004) reported that the 1st digit showed the highest frequency of decreased conduction velocity. [13] Lauritzen et al., (1991); Padua and colleagues, (1997) reported that there were no significant differences in the sensitivities of median nerve SCV at the 1st and 3rd digits in their studies.[14,15]

Conclusions

Modified nonconventional neurophysiological diagnostic methods have higher sensitivities than those of conventional techniques, especially the sensory ones. They are especially needed in patients with mild to moderate clinical presentation. The most sensitive are methods measuring differences between median and ulnar sensory latencies. Assessment of difference between sensory latencies of median nerve at middle finger and ulnar nerve at little finger seems to have the highest diagnostic sensitivity according to our results.

In patients with clinical findings suggesting carpal tunnel syndrome, it is recommended to do at first conventional electro diagnostic techniques to confirm the diagnosis. These conventional techniques are the assessment of median nerve distal motor latency at wrist and the sensory conduction velocity at index. It is better to assess the sensory conduction velocity at middle finger than at index. If these techniques were diagnostic, so no need for additional modified techniques. However, if they were not diagnostic – especially in patients with mild to moderate clinical presentation – assessment of difference between sensory latencies of median nerve at middle finger and ulnar nerve at little finger will confirm the diagnosis in most of cases with the highest sensitivity and the least effort.

References

1. Pfeffer GB, Gelberman RH, Boyes JH, Rydevik B. The history of carpal tunnel syndrome. J Hand Surg Br1988;13(1):28-34.
2. Aroori S, Spence RA. (2008) Carpal tunnel syndrome. Ulster Medical J. 2008;77(1): 6–17.
3. Mathew SP, Jonathan P, Wasim SK, Nicholas JG. Is there Light at the End of the Tunnel? Controversies in the Diagnosis and Management of Carpal Tunnel Syndrome. Hand. 2004;5(4): 354-360.
4. Padua L, Padua R, LoMonaco M, Aprile I, Tonali P. Multiperspective assessment of carpal tunnel syndrome. A multicenter study. Neurology. 1999;53: 1654-1659.
5. Kimura J. Assessment of individual nerves. In: Kimura J editor. Electrodiagnosis in

diseases of nerve and muscle: Principles and practice, 4thed. New York: Oxford university press. 2013; p. 99-146.
6. Kimura J. Mononeuropathies and entrapment syndromes. In: Kimura J editor. Electrodiagnosis in diseases of nerve and muscle: Principles and practice, 4th ed. New York: Oxford university press; 2013; p. 756-806.
7. Ginanneschi F, Mondelli M, Dominici F, Rossi A. Changes in motor axon recruitment in the median nerve in mild carpal tunnel syndrome. Clin Neurophysiol. 2006;117: 2467–2472.
8. Rao CR, Maruthi W. Study of Median Motor versus Sensory Conduction Studies in the Diagnosis of Carpal Tunnel Syndrome. Indian journal of applied research medical science. 2015;5(10): 2249-555X, 382-387.
9. Uncini A, Lange DJ, Solomon M, Soliven B, Meer J, Lovelace RE. Ring finger testing in carpal tunnel syndrome: A comparative study of diagnostic utility. Muscle Nerve. 1989;12: 735–741.
10. Terzis S, Paschalis C, Metallinos IC. Early diagnosis of carpal tunnel syndrome: Comparison of sensory conduction studies of four fingers. Muscle Nerve1998;21: 1543–5.
11. Macdonell RA, Schwartz MS, Swash M. Carpal tunnel syndrome: Which finger should be tested? An analysis of sensory conduction in digital branches of the median nerve. Muscle Nerve. 1990; 13: 601–6.
12. Atroshi I, Gummesson C, Johnsson R, Ornstein E. Diagnostic properties of nerve conduction tests in population-based carpal tunnel syndrome. BMC Musculoskelet Disord. 2003; 4:9.
13. Aydin G, Keles I, Demir SO, Baysal AI. Sensitivity of median sensory nerve conduction tests in digital branches for the diagnosis of carpal tunnel syndrome. Am J Phys Med Rehabil. 2004; 83: 17–21.
14. Lauritzen M, Liguori R, Trojaborg W. Orthodromic sensory conduction along the ring finger in normal subjects and in patients with a carpal tunnel syndrome. Electroencephalogr Clin Neurophysiol. 1991 81: 18–23.
15. Padua L, LoMonaco M, Gregori B, Valente EM, Padua R, Tonali P. (1997) Neuro-physiological classification and sensitivity in 500 carpal tunnel syndrome hands. Acta Neurol Scand. 1997;96: 211–217.