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Validity of current electrodiagnostic techniques in the diagnosis of carpal tunnel syndrome

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Abstract

Background: Determining the validity of current median sensory nerve conduction techniques for diagnosis of carpal tunnel syndrome (CTS).

Methods: Eighty five patients with clinical diagnosis of CTS were compared with the same number of healthy people. The validity of electrodiagnostic tests were compared in a case-control manner. These electrodiagnostic techniques included long-segment, short-segment, 2-segment and relative slowing studies; as well as disto-proximal ratio. Receiver Operating Characteristic (ROC) curve employed for comparison, determining the optimal cut-off points for each test. Validity was evaluated with likelihood ratio.

Results: Likelihood ratio (LHR) for Radial-median sensory latency difference was ∞, while LHR for ulnar-median sensory latency difference was 16.9. Sensitivity of Two-segment method was 98.8% and mixed palm-wrist median Nerve Conduction Velocity (NCV) study showed a sensitivity and specificity of 97.6%, 83.5% respectively**.**

Conclusions: Radial-median latency difference study (optimal cut-off point ≥0.5) and study of wrist-segment NCV (optimal cut-off point <50.45) were the most valuable techniques in diagnosis of CTS, respectively. Median-ulnar latency difference study and disto-proximal ratio study had more diagnostic implication than long and short (mixed) segment technique in this regard.

Keywords: Carpal Tunnel Syndrome, Electrodiagnosis, ROC curve.

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Introduction

Carpal Tunnel Syndrome (CTS) is the most frequent entrapment neuropathy (1,2) affecting the upper extremity with an estimated prevalence of 2.7% (3,4). In 1993, the American Association of Electrodiagnostic Medicine (AAEM) reported the sensitivities of electrodiagnostic studies ranging from 49% to 84% and specificities≥ 95% in diagnosis of CTS (3,5).

Two years earlier in 1991, the Quality Assurance Committee of AAEM had performed an exhaustive critical analysis of the CTS electrodiagnostic results and concluded the median sensory nerve conduction studies (NCS) are more sensitive than median motor NCSs. Short-segment median wrist-palm sensory or mixed NCSs were more sensitive than long-segment wrist-digit sensory or mixed NCSs in this report, as well (6).

In some studies, determining the sensory NCV across the palm-wrist segment has been introduced as the most sensitive diagnostic procedure for CTS with a sensitivity ranging from 98.5% to 99% (7,8). However, radial-median and/or median-ulnar sensory distal latency differences have been

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reported as the most accurate diagnostic tests in other studies (9,10). Likewise, there is still an ongoing debate on the most appropriate finger for studying the median NCS (7).

Evidently, there is not a consensus about the sensitivity and specificity of different techniques in diagnosis of CTS.

In this study, we evaluated the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and likelihood ratio (LHR) of current electrodiagnostic studies in CTS.

Methods

All the patients referred to our electrodiagnosis center from May 2009 to April 2010 were selected in a manner of convenience. Based on the following formula:

$$TP+FN=Z_{\alpha}^{\times}\ (SN\ (1-SN)/W^2)$$

Where "TP" stands for true positive, "FN" stands for false negative, SN shows sensitivity and "W" represents the accuracy. To show the 89% sensitivity (7, 8), with 5% type I error and 7% accuracy in estimation, a sample size of 77 cases with disease condition (CTS+) was needed.

Finally, eighty five patients out of 115 cases attended with symptoms indicating CTS (as the case group) were selected, to fulfill the calculated sample size.

The patients were compared with the same number of healthy people without any complain in the upper limb (As the control group) after informing them and filling the consent form. They were evaluated in a cases-control study approved by ethical committee in the university.

Clinical symptoms and signs were considered as gold standard. Patients with at least two symptoms and/or one symptom and one sign of CTS considered as the case group; with the following:

1- Symptoms including hand numbness, tingling, paresthesia or nocturnal pain in the median nerve distribution area (11) which were lasted for at least 3 months.

2- Signs including Tinel's sign or positive Phalen's test (12, 13) weakness especially abduction of digit 1 and the sensory deficit (pin prick or light touch) in the median territory. The exclusion criteria were an ulnar motor nerve distal latency >3.7 ms, an ulnar sensory nerve amplitude < 12 µv, absence of median sensory nerve action potential (SNAP), a positive history of diabetes mellitus, thyroid, renal or connective tissue disease, previous history of median nerve releasing surgery or any proximal entrapment in median nerve distribution (confirmed with inching technique if there was any doubt) and presence of clinical or electrodiagnostic findings suggestive of radiculopathy of the upper extremity. Electromyography of at least extensor digitorum and pronator teres muscles used for rolling-out any probable radiculopathy.

All the electrodiagnostic studies were performed using dual-channel Medelec Synergy instrument in a blind manner by another physiatrist. Skin temperature maintained at > 32° C. Recorders of sensory potentials were set as follows: Sweep speed: 10 ms, sensitivity: 20 µv/div, pulse duration: 100-200 µs, filter: 20-3000Hz, constant current with active and reference electrode distance of 4 cm. Electrodiagnostic studies performed in both the case and the control groups as following:

* *Long-segment studies* (antidromic median wrist-digit sensory NCV without subtraction): Antidromic NCV from 10 cm in the wrist-digit 1 segment and from 14 cm in the wrist-digit 2 ,3 and 4segments (14,15).

Recording electrode were placed 1-2 cm distal to metacarpophalangeal (MCP) joints. Latencies were measured from the onset of recorded sensory wave. Distance divided by onset latency yielded the velocity.

* *Short-segment studies* (orthodromic median palm-wrist mixed sensory NCV without subtraction): Stimulation of median nerve was carried out in the palm between 2nd and 3rd metacarpi, 8 cm away from recording electrode on the wrist. Amplitude, latency and velocity calculated in the same

way as in the long-segment studies (16,17).

* *Two-segment studies* (median wrist sensory NCV with subtraction): Median nerve was stimulated in two different points on the wrist and the palm 7 cm apart (7cm-14cm technique). Recording electrode placed on digit 3, 1-2 cm distal to MCP joint. Amplitude, latency and velocity were calculated in the same way as in the long-segment studies (18,19).

* *Relative slowing studies* (antidromic radial-median and median-ulnar sensory distal latency differences from digits 1 and 4): Antidromic radial sensory nerve conduction latency measured 10 cm from digit 1. The difference between radial sensory nerve conduction latency and median sensory nerve conduction latency was calculated in wrist-digit 1 segment. Difference between ulnar sensory nerve conduction latency (with standard 14 cm distance) and median sensory nerve latency was also calculated in wrist-digit 4 segment, as well. Peak latencies were considered in this technique. Meanwhile, the ulnar SNAP was also recorded from 5th digit, aiming to roll out any neuropathy (20- 22).

* *Disto-proximal ratio studies*: Antidromic NCV in the palm-digit 3 divided by orthodromic NCV in the palm-wrist segment yielded this ratio (3).

Data analysis

Receiver operating characteristic (ROC) curve was used for comparing the results of the aformentioned techniques in both case and control groups. Accordingly, optimal cutoff point was calculated for each technique for diagnosis of CTS. The cut-off points considered for radial-median and ulnar-median latency differences from digit 1 and 4 were 0.4 and 0.5, respectively.

Results

Eighty five patients out of primary 115 cases referred to our electrodiagnosis center with probable CTS ultimately considered as a case group consisted of; 13 males and 72 females, with the mean age of 42.8±9.4 years. These patients compared with 85 healthy age and sex matched people, 18 males and 67 females, with the mean age of 41.5±9.5 years.

Results of different techniques are summarized in Table 1. As illustrated, each technique had statistically significant diagnostic values for detecting CTS.

Figure 1and 2 express the ROC diagrams of different techniques. The higher the AUC, the greater was the accuracy of the measurement. Therefore, two-segment values had the highest accuracy rate for diagnosis of CTS.

Table 1. Comparison of different techniques for diagnosis of carpal tunnel syndrome

technique		Optimal cut-off	sensitivity	specificity	PPV	NPV	LHR
two-segment		≤50.4	97.6%	96.5%	96.5%	97.6%	27.8
relative slowing	M-U LD	0.4<	100%	94.1%	94.4%	100%	16.9
	R-M LD	0.5<	85.9%	100%	100%	87.9%	∞
median long-segment	W-D 1 NCV	≤46.6	98.8%	80%	83.1%	98.5%	4.9
	W-D 2 NCV	≤57.5	98.8%	37.6%	61.3%	96.9%	1.5
	W-D 3 NCV	≤54.3	97.6%	42.4%	62.8%	94.7%	1.6
	W-D 4 NCV	≤52.2	97.6%	67.1%	74.7%	96.6%	2.9
median short-segment NCV		≤50.8	97.6%	83.5%	85.5%	97.3%	5.9
disto-proximal ratio		1<	100%	92.9%	93.4%	100%	14

LHR: likelihood ratio, M-U LD: median-ulnar latency difference, NCV: nerve conduction velocity, NPV: negative predictive value, PPV: positive predictive value, R-M LD: radial-median latency difference, W-D: wrist-digit

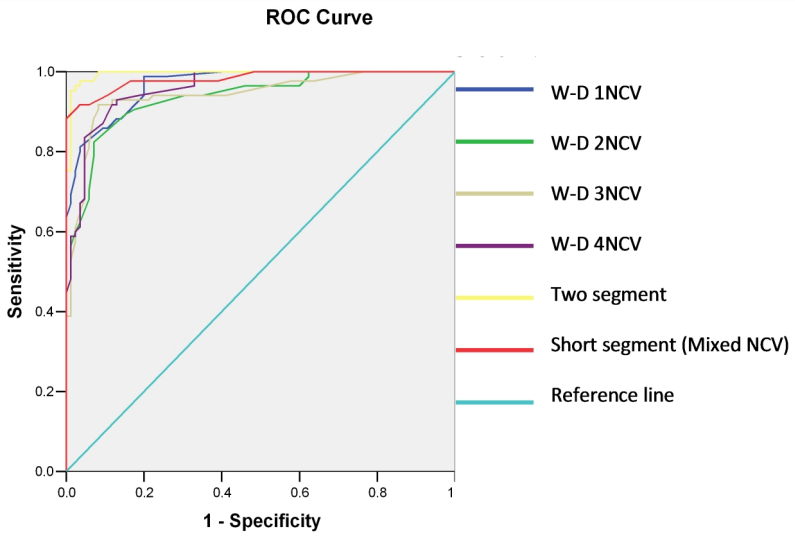

Fig.1. ROC curves of long segment, short segment and two segment techniques

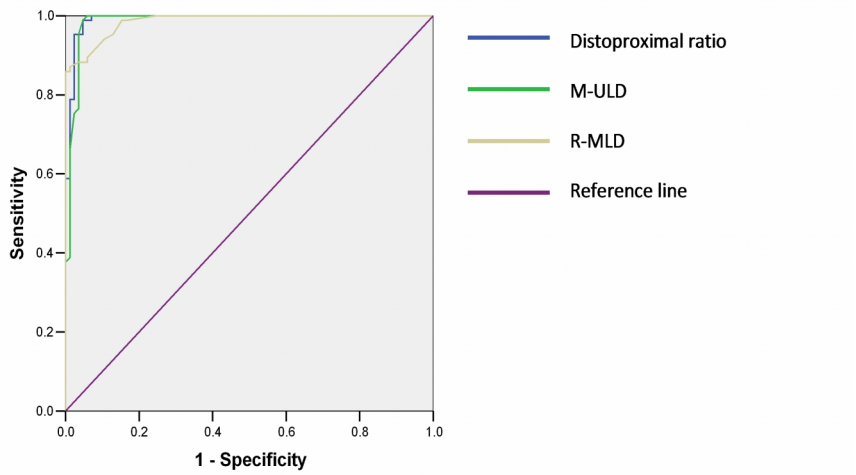

Fig. 2. ROC curves of Distoproximal ratio, Median-Ulnar and Radial-Median latency difference techniques

In order to compare the AUC of different techniques with that of two segment technique, LR test was performed and the results are presented in Table 2. Due to type I error inflation in multiple comparisons, Bonferonni correction was used to adjust the p-values. As it is shown, the highest AUC belonged to two-segment (AUC= 0.995) and disto-proximal ratio (AUC= 0.991), respectively. On the other hand, the lowest accuracy rates were observed in two median long-segment measurements as follow: W-D 2 NCV with the AUC of 0.936 and W-D 3 NCV with the AUC of 0.943. Whne compared with two-segment values as the standard measurement, the Bonferroni corrected LR test showed that disto-proximal ratio (P=NS), median short-segment NCV (p=0.593), relative slowing M-U LD and R-M LD (P=NS) are not significantly different from the two-segment values. While, median long-segment measurements had either borderline (W-D1 NCV, p=0.069) or significantly lower accuracies (W-D 2 NCV, p=0.0026; W-D 3 NCV, p=0.0080; W-D 4 NCV, p=0.0091) compared with two-segment values.

Discussion

Increasing understanding about CTS makes it possible to have electrodiagnosis of these patients in their earlier stages of the disease. In this group, up to 40% of the patients with typical symptoms yet may have no electrodiagnostic evidence of CTS (3).

There is also a debate about the most appropriate technique for evaluating median

nerve conduction (7). In our study, LHR, as the validity of a diagnostic test, was higher in the wrist-digit 1 segment studies (LHR=4.94). Digits 4, 3 and 2 took position in a descending order in this regard (LHR was 2.97, 1.69 and 1.58 respectively). Our results are in conformity with Aydin's (7) and Demirci's studies (8) which report a higher sensitivity for digit 1. Sharma et al (3) did not evaluate the sensitivity of different digits for diagnosis of CTS. However, they compared wrist-digit 1 median sensory NCV study with the disto-proximal ratio technique. With a cut-off point of ≤ 45.9. sensitivity and specificity of the first technique were higher (89.5% and 98.6%, respectively).

Lew et al (24) reported a low sensitivity (33.46%) for the long-segment studies in the wrist-digit 1, 2, 3 and 4 segments. The authors concluded that the inclusion and exclusion criteria could have caused low sensitivity in this study. On the other hand, it should be noticed that only mild cases with CTS were evaluated in this study.

In our study, as well as Aydin's report (7), there was a lower diagnostic value in the wrist-digit 2 segment with significantly lower than two-segment technique (P=0.0026). This may be due to specific anatomy of median nerve in carpal tunnel. It has been shown earlier that distal compression on median nerve, just proximal to its branching point into sensory and motor fibers is more vigorous. In this point, fibers innervating digits 1 and 3 and medial part of digit 4 are placed beneath the wrist transverse ligament in antro-lateral and antro-medial portions, respectively; whereas, fibers innervating digit 2 are in the most posterior portion. Thus there will be milder compression and ischemia consequently (7).

In the current study, mixed palm-wrist median NCV study showed a sensitivity and specificity of 97.6%, 83.5% and a relatively low LHR (5.9) for diagnosis of CTS. Lew et al (24) compared short-segment technique (median mixed palm-wrist NCV), long-segment technique (wrist-digit) and two-segment study (including 7 cm-14 cm technique). The first technique turned out to be the most sensitive method. This study had some disadvantages, such as lacking the LHR.

In the mixed median NCV study, normal conducting nature in motor fibers may conceal minor abnormalities in the sensory component. This would justify our results considering lower LHR of mixed median NCV comparing two-segment method, in which only sensory fibers were examined. On the other hand, alongside movement of median and ulnar nerves in the wrist may have caused a volume conduction effect; i.e. ulnar nerve response to a wrong stimulation would compensate a median nerve conducting abnormality (23).

The second valuable technique in our study was the two-segment study (median wrist-palm sensory NCV). Aydin et al (7) reported a predominance of two-segment over long-segment studies (orthodromic methods employed; sensitivity of 98.5% vs. 82.88%). This study confirms our results in this regard. Albeit application of an orthodromic method may shed some doubt on its validity, because it would not ensure a sheer stimulation of the sensory nerve fibers in the palm.

Demirci et al (8) also concluded the same without a LHR. Two-segment method was the most sensitive technique in this study (sensitivity of 98.8%). Of relative slowing techniques, radial-median latency difference was more sensitive than median-ulnar latency difference (sensitivity of 94.1% vs. 84.7%). Among long-segment techniques, NCV in the wrist-digit 1 was more sensitive.

In two-segment technique, it is possible to calculate two important conduction velocities by subtracting latency of the palm stimulation (7 cm) from latency of the wrist: NCV in carpal tunnel and NCV in palm-digit segment. It is of important value because this method can accurately determine the involved segment of median nerve, particularly in the early stages of the disease.

Pathology of CTS is confined to carpal tunnel and 2-4 cm distally, especially during the onset of the disease. Nerve conduction study in long distances including proximal and distal segments may show no abnormality, because an almost normal distal segment could prevent detection of any little abnormality in proximal segment (7,23). Otherwise, using just a long distance for nerve conduction study (14 cm) may yield a false abnormality due to an underlying neuropathy in distal segments other than in the carpal tunnel itself. Another advantage of two-segment study is ability to compare median sensory nerve amplitude by stimulation of the wrist and palm as well as assessing any probability of conduction block (23).

Uncini et al (24) reported that comparing median to ulnar latencies from digit 4 was the most sensitive method to make the diagnosis of CTS. Because digit 4 has dual innervation, median and ulnar sensory latencies can be determined over identical distances. Lauritzen et al (25) concluded that testing the sensory conduction along the ring finger is useful in about 74% of patients with CTS . Uncini et al (26) reported that difference between median and ulnar sensory latencies from digit 4 stimulation in the most sensitive method among first palmar or second lumbrical and interossei muscles stimulations. Bodofsky et al (27) concluded the median sensory latency was the most sensitive parameter. Moreover the median sensory-ulnar motor latency difference was the criteria of choice (cut-off value of 0.8 ms).

Our study showed a significant predominance of the radial-median sensory latency difference on the ulnar-median sensory latency difference in relatively slow techniques (LHR=∞ vs. 16.9). However, this difference was not statistically significant (P=NS). Demirci et al (8) reported a similar result and Chang et al (9) have proposed these two techniques were the best diagnostic method for CTS. Also Pease et al (22) reported the median-radial latency difference in digit 1 was a sensitive indicator of mild CTS that can be measured quickly with a minimum of discomfort.

In our study the diagnostic value of disto-proximal technique was lower than that in two-segment and relatively slow techniques and higher than short and long segment studies. However, the results of LHR test showed that the difference in the AUC of disto-proximal technique was not significantly different from two-segment values (P=NS).

Sharma (3) reported that the wrist-digit 1 median sensory NCV study was superior to disto-proximal ratio technique. In this study, the LHR for disto-proximal ratio technique was higher than ours (23.8 vs. 14.08). This may be due to a higher cut-off point in Sharma's series (1.2 vs. 1). We selected a cut-off point with the highest sensitivity to diminish the rate of false negative results and also, earlier diagnosis of CTS. This was already recommended by electrodiagnostic reference (23).

Conclusion

In this study, radial-median latency difference study (optimal cut-off point >0.5) and wrist segment NCV study by 2-segment technique (optimal cut-off point <50.45) were the most valuable techniques in diagnosis of CTS, respectively. Median-ulnar latency difference study and disto-proximal ratio study had greater diagnostic implications than long and short (mixed) segment techniques in this regard.

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