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Application of Median-Ulnar F-Wave Latency Difference for the Diagnosis of Carpal Tunnel Syndrome

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ABSTRACT

Background and Objective: Carpal tunnel syndrome (CTS) is the most common entrapment neuropathy in which the median nerve is compressed in the wrist area while it passes through it, and its early diagnosis will improve the overall outcome and reduce morbidity. Electrodiagnostic testing is the most commonly used techniques to diagnose it but no consensus is reached about which test is the most useful. This research was conducted to evaluate the sensitivity and specificity of the difference in F-wave conduction velocity below and above carpal tunnel for the diagnosis of CTS.

Methods: This case-control study included 240 patients clinically diagnosed with CTS with negative nerve conduction test, and these tests included the F-wave conduction velocity of median nerve by stimulating the nerve at two sites, one at mid-palm and the other at the wrist (6 cm proximal to mid-palm stimulation site). After that, distance from stimulating sites to the area between C7 vertebral spine was obtained and the resulting two conduction velocities were compared.

Findings: The difference in F-wave conduction velocity across the wrist was 4.9±1.6 m/s in patients with CTS while it was 2±0.1 m/s in healthy control subjects, with statistically significant differences ($p<0.05$). Also, the study found that at difference of 3 m/s between wrist and mid-palm stimulation, the sensitivity for diagnosing CTS was 90% and specificity was 100%.

Conclusion: The results of this study showed that F-wave conduction velocity of median nerve difference across the wrist is a new technique to test median nerve in CTS and it is highly sensitive and specific.

Keywords: *Median Nerve, Nerve Conduction Studies, Wrist Injuries, Carpal Tunnel Syndrome.*

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Introduction

Compression of median nerve at the wrist as CTS is the most common entrapment neuropathy (1), with estimated prevalence of 1.5% to 5.8% in the general population. Higher prevalence rates are seen in women than men and in specific groups like hand workers (2). The classical symptoms of CTS are numbness, paresthesia/pain, or sensory-motor deficit in the distribution of median nerve in the hand. In addition to that, patients might experience pain or disuse that affect the forearm and may be the whole limb (3). Other clinical findings include reduced or excessive sweating, edema and cyanosis due to autonomic dysfunction which was reported in 12–55% of the affected hands (4).

The CTS diagnosis is usually suspected depending on characteristic clinical features and supported by electromyographic (EMG) studies, mainly nerve conduction study (5). Accurate and early diagnosis of the disease is important in instituting treatment and preventing possible morbidity and complications. At the present time, electrodiagnostic study (EDX) is considered the gold standard test for the diagnosis of patients with clinical picture suggestive of the disease (6, 7). Electromyographic examination can provide useful information about the severity of median nerve entrapment and then help in choosing the therapeutic strategy (7). In CTS, the EDX studies allows for localization of the entrapment site by finding focal slowing or focal demyelination of median nerve at the wrist; it also provides information about prognosis by quantifying the degree of axonal loss depending on the amplitude of sensory/motor potentials. To date, the EDX studies is the only found test that evaluate nerve fiber function non-invasively in normal and pathological conditions (8).

There are multiple EDX studies that aid in the diagnosis of CTS with variable sensitivity and specificity. The standard NCS tests is digit-to-wrist median nerve sensory conduction velocity (SCV) and wrist-to-APB median nerve distal motor latency (DML) has a sensitivity of 50-80% (8, 9) and when we add the more sensitive comparison tests which use comparison between the median nerve to nearby ulnar or radial nerves that does not pass under the transverse carpal ligament or segmental, this will enhance the overall sensitivity of the NCS for median nerve up to 95% (10) and specificity to 97% (10, 11). F-wave is a late response evoked due to antidromic activation of anterior horn cells. Accordingly, F-wave is useful is assessing the whole nerve, with special emphasis on proximal nerve segments which is not assessed by routine nerve conduction studies. They have moderate sensitivity and specificity in the diagnosis of CTS (73% and 64%, respectively) (12). The current research objective is to evaluate the sensitivity and specificity of the difference in F-wave conduction velocity below and above carpal tunnel for diagnosis of CTS.

Methods

The current case control research was conducted from January 2018 to December 2020. It included 240 CTS patients with the ethical code of Babylon University BU12-2-2020, who were diagnosed by an experienced neurologist or orthopedic based on the classical signs and symptoms of median nerve entrapment at the carpal tunnel including pain, and paresthesia with/without weakness affecting the lateral 3 digits, and finding positive Phalen`s and Tinel`s signs. The diagnosis based on clinical background show normal electrodiagnostic assessment including NCS of median and ulnar nerves and electromyography of median innervated muscles. All patients have no other neurological diseases like cervical radiculopathy, cervical plexopathy and no medical disease like diabetes mellitus or endocrine diseases. Patients are matched to 240 normal healthy volunteers by age, gender and geographical distribution, and oral consent was obtained from them.

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Electrophysiological testing: Median nerves sensory, motor and F-wave responses was recorded in patient and control. Temperature was measured and kept around 32-35 ℃, the testing was done using Nihon Kohden machine 2010 (figure 1).

Median motor study along with F-wave minimum latency was done recording at the abductor pollicis brevis (ABP) muscle and stimulating both at the wrist 5 cm proximal to active electrode and at the elbow, while sensory study was done recording from the index finger and stimulating at the wrist 11-13 cm proximal to active electrode (8). All stimulations were supramaximal with proper placement of recording and stimulating electrodes.

F-wave conduction velocity was tested at two stimulating sites while the recording electrode was at the APB, the first stimulation site was at the mid-palm, about 5 cm distal and medial to the active electrode and the second stimulating site was at the wrist 11 cm proximal to mid-palm stimulation site (figure 2). The distance was measured from these two sites to the area between C7 vertebral spine and T1 vertebra. The obtained distance is doubled to obtain conduction velocity of F-wave, since F-wave is obtained when the stimulation travels antidromically toward spinal cord and back again to the recording site. A minimum of 10 F-wave responses was recorded and the mean F-wave latency was measured (equation 1).

$$\text{F - wave} = \frac{\text{Distance (m)}}{\text{Mean F – wave latency (s)}} \quad (1)$$

The F-wave velocity will be measured and the difference between them is used for comparison.

The results of the study were imported to a computer program, Statistical package for Social Science (SPSS 20 for windows; SPSS Inc,). The obtained data were analyzed by several tests according to their type. T-test was used to compare between numeric variables, ROC curve is utilized to enhance the sensitivity and specificity of the analysis (9). P-wave less than 0.5 was considered as significant findings.



Figure 1. Nihon Kohden Nerve conduction study machine

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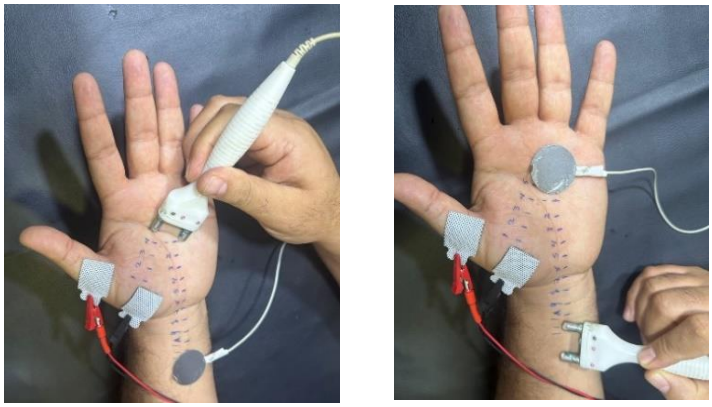


Figure 2. Sites of stimulation of F-wave at the mid-palm and at the wrist while recording from abductor policies brevis

Results

Demographic data: The demographic information of the population is summarized in table 1, where most of the cases were women and in the middle age and the symptoms were almost short (in mean 5 months).
Nerve conduction research parameters: The findings of motor and sensory nerve conduction study of median nerve are shown in tables 2 and 3 in which there is statistically significant differences between patients and control groups.

Table 1. Population demographic information

Variable	Patient	Control
Age (years) (Mean±SD)	36±10	30±10
Sex (number)		
Male	39	55
Female	200	200

Table 2. Nerve conduction study of median nerve motor fibers for both tested groups

Variables	Mean±SD	p-value
Latency (ms)		
Patient	3.4±0.5	0.00
Control	2.6±0.2	
Amplitude (mv)		
Patient	9.8±2.1	0.00
Control	7.5±2	
Conduction Velocity (CV) (m/s)		
Patient	58±6	0.00
Control	58±6	

Table 3. Nerve conduction study of median nerve sensory fibers for both tested groups

Variables	Mean±SD	p-value
Latency (µs)		
Patient	2.4±0.4	0.00
Control	2±0.04	
Amplitude (µv)		
Patient	36±18	0.00
Control	57±16	

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F-wave conduction velocity at wrist stimulation shows significant difference between patients and control group as shown in table 4. The difference in F-wave conduction velocity across the wrist show highly significant difference between both tested groups. In addition, it shows high sensitivity and specificity in the diagnosis of CTS. These results are shown in table 5. ROC curve shown in figure 3 and is used to calculate the sensitivity and specificity of conduction velocity difference across the wrist.

Table 4. Conduction velocity of F-wave of median nerves compared between patients and controls

Variable	Mean±SD	p-value
F-wave conduction velocity (m/s)		
Patient	48±15	0.04
Control	44±12	

Table 5. The results difference in conduction velocity of F-wave across carpal tunnel in patients and control

	Patient Mean±SD	Control Mean±SD	p-value	Sensitivity	Specificity
Conduction velocity difference (3m/s)	4.9±1.6	2±0.1	0.00	90%	100%

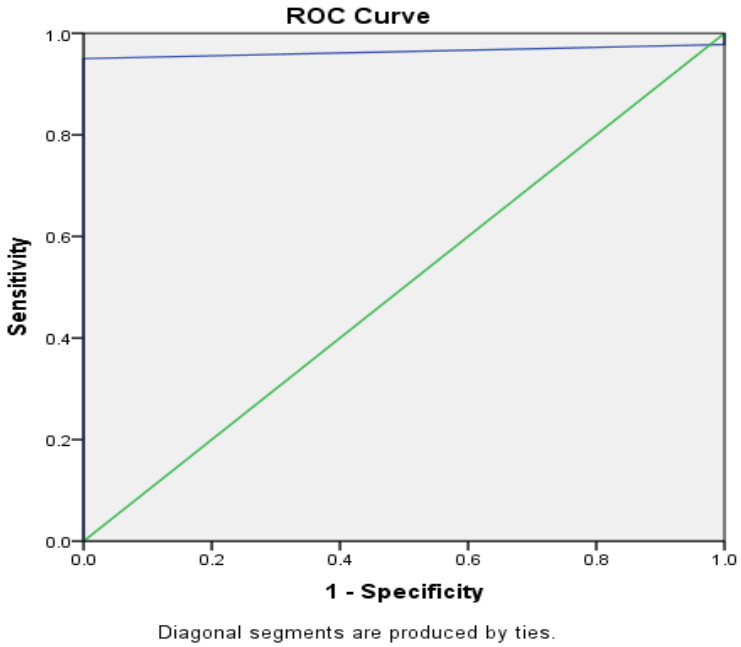


Figure 3. ROC curve

Discussion

There are multiple electrodiagnostic tests developed to diagnose CTS. However, there is no general agreement between authors and researchers regarding which test is the most sensitive. There is a generally consensus that the testing of median sensory fibers is more sensitive than testing motor nerve fibers. Accordingly, few studies have been done about the value of motor studies in diagnosing CTS; and no

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agreement has been reached to propose the most appropriate motor conduction test. The current study explored the diagnostic value of F-wave conduction index using the difference in the conduction velocity of F-wave recorded by 2 stimulation sites, one at the mid-palm and the other at the wrist (across carpal tunnel). The result of this study indicate that CTS can be diagnosed using new comparison methods depending on the difference in F-wave conduction velocity between mid-palm and wrist stimulation while recording in the abductor policies brevis. It is in agreement with the results of (10), which approved the Median–ulnar F-wave latency difference efficacy in obese cases by moderate and mild CTS. The results demonstrated that at 3 m/s difference in F-wave conduction velocity between mid-palm and wrist stimulation, the sensitivity was 90% and the specificity was 100%, which is confirmed in (11), which shows that the F-wave research is related to BMI, which should be considered in the unified cases.

In this research, we used F-wave parameter to diagnose CTS and show high sensitivity and specificity. Previous studies showed the absolute value of minimal F-wave latency and compared it to normal control and found that the sensitivity was 50-70 % (12, 13); other studies investigated the difference of F-wave latency between median nerve and ulnar nerve and name it as F-wave inversion and found that it has slightly higher sensitivity (60-89%) and specificity (80-90%) compared to testing F-wave alone (14).

Our new technique is more useful than F-wave inversion because it avoids the disadvantage of coexisting ulnar neuropathy which might affect the recording in F-wave inversion. F-wave is easily tested and is considered as part of routine and standard tests of CTS diagnosis, and if we add new recording site (at mid-palm), we will get higher accuracy in the diagnosis. To understand the reason for this difference in F-wave conduction velocity between mid-palm and wrist, we have to recall the physiology of F-wave.

When motor nerve is stimulated, it will be conducted in two directions, antidromic toward spinal cord and orthodromic toward neuromuscular junction (13, 15). When stimulating at the mid-palm, the resulting current needs to cross the demyelination focus of median nerve at the wrist twice, first while the current moves toward spinal cord and the other time when the current travels back to the recording electrode. So, the effect of the demyelinating focus at the carpal tunnel will be doubled. This is not the case in wrist stimulation, in which the first current will go to spinal cord without passing through the demyelinating focus and only the second current will pass through it, so the effect of demyelination may be diluted, especially in F-wave the signal will travel for long distance between the recording and stimulating electrode.

According to that, on mid-palm stimulation, the relative slowing of conduction of CMAP while moving through the nerve below the carpal ligament will be augmented causing much recorded delay in conduction velocity, while the case is not true regarding the wrist stimulation. On the other hand, according to the physiology of F-wave, each F-wave represent firing of small population of neurons (about 5-10%), so any pathology that preferentially affects limited group of nerve fibers will be easily manifested as slowing of F-wave response (13).

This new test is useful and can be considered as one of the highly sensitive comparison tests that is used to diagnose CTS. It is especially important when there is co-existing neuropathy that limits the use of comparison with ulnar or radial nerves. On the other hand, it is easier to do than the inching method. In conclusion, F-wave conduction velocity difference across carpal tunnel is a new technique to test median nerve in CTS and it has high sensitivity and specificity and since it is routinely done in assessing median nerve in CTS patient, it can be added as one of the commonly performed comparative tests of CTS diagnosis.

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