DIAGNOSTIC VALUE OF MEDIAN NERVE CONDUCTION VELOCITY ACROSS WRIST AMONG PATIENTS WITH SUSPECTED CARPAL TUNNEL SYNDROME

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Abstract

Background: Carpal Tunnel Syndrome (CTS) is the most prevalent type of compressive neuropathy. At present, electrodiagnosis is considered the gold standard in diagnosing CTS. However, no clear cutoff point has been established regarding the diagnostic value of the median nerve conduction velocity, across the carpal tunnel area, among patients with CTS.

Objectives: This study aimed to determine the cutoff point for patients' median nerve conduction velocity (NCV), to diagnose CTS among suspected patients, which is determined using electrical stimulations conducted across the carpal tunnel area. The present study also aimed to determine the diagnostic value of the median nerve conduction velocity across the carpal tunnel area, compared with the standard method.

Methods: This cross-sectional study was conducted among 56 participants (106 wrists) suspected of CTS. Motor and sensory NCV across the carpal tunnel was investigated to yield diagnostic value of CTS compared with the standard technique.

Results: The optimal cutoff point in diagnosing CTS using the wrist to midpalm conduction velocity, was ≤ 40 m/s (with a sensitivity of 87.04% and specificity of 87.18%) for the sensory nerve conduction study, and ≤ 35 m/s (with a sensitivity of 88.06% and specificity of 89.74%) for the motor nerve conduction study.

Conclusion: Our study determined that the optimal cutoff conduction velocities for CTS diagnosis, using the wrist-to-midpalm electrical stimulation method, was ≤40 m/s for the sensory nerve, and ≤35 m/s for the motor nerve.

Keywords: Carpal tunnel syndrome, Median nerve, Nerve conduction velocity
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Introduction

The median nerve compression causes Carpal Tunnel Syndrome (CTS) as it passes through the carpal tunnel and constitutes the most prevalent type of focal nerve entrapment among patients. To elaborate, CTS causes pain, numbness and tingling in the hands and affects the patient's daily functioning.[1-3]

Given the negative effects of CTS, accurate and efficient diagnosis is important for research and clinical practice, and in turn, patient recovery. The Nerve Conduction Study (NCS) method has been considered the gold standard for diagnosing CTS. [4]

In the current standard method, electrical stimulation is applied at the wrist and the elbow.[5-7] However, a major problem with this kind of application is the slowing of conduction between the wrist and the elbow, possibly caused by other abnormalities proximal to the level of the wrist.[8] Losing large fast-conducting myelinated nerve fibers could also result in slower nerve conduction velocity and delayed distal latency. Therefore, prolongation of the distal latency does not suggest focal demyelination. [9]

In this study, we used segmental measurements of velocity across the lesion, which is helpful in distinguishing CTS from other forms of peripheral neuropathy. [1, 10-11] Our method has the advantage of showing the exact site of the lesion.[12] Despite its advantages, the method we suggested is not yet considered the standard practice; segmental motor conduction studies such as wrist to mid-palm nerve conduction velocity are still considered an optional technique by the American Association of Neuromuscular & Electrodiagnostic Medicine (AANEM).[6, 13] Thus, a clear cutoff point has yet to be established regarding the diagnostic value of the median nerve conduction velocity, across the carpal tunnel area among patients with CTS.

Therefore, the primary aim of this research was to determine the cutoff point for patients' median nerve velocity, to accurately diagnose possible patients with CTS, determined using electrical stimulations conducted across the carpal tunnel area. In addition to the cutoff point, the present study aimed to find the diagnostic value of the median nerve conduction velocity across the carpal tunnel area, compared with the standard method.

Methods

This cross-sectional study was conducted among 56 outpatients (106 wrists) at the Department of Rehabilitation Medicine, Phramongkutklao Hospital. The study's protocol was approved by the Institutional Review Board, the Royal Thai Army Department (IRBRTA 1348/2562). All participants consented to participate in the study. The data were collected between December 2019 and August 2020. Eligibility criteria included Thai adults 18 years or older displaying one or more of the following primary symptoms in median nerve distribution: numbness, pain or tingling. We excluded participants who had (1) received treatment by local corticosteroid injection or surgical release for CTS before enrollment, (2) other neurologic diseases such as polyneuropathy, cervical radiculopathy or other neuropathy of the upper extremities and (3) anatomical anastomosis such as Martin Gruber anastomosis and Riche–Cannieu anastomosis.

Demographic data of all participants were collected. A single physiatrist, with over ten years' experience, managed the wrist-to-mid palm nerve conduction study among all participants. On the same day, all participants received the standard nerve conduction study to diagnose CTS, carried out by a physiatrist with at least two years' experience in NCS and supervised by an experienced physiatrist. The methods of both practices are elaborated below.

Wrist to mid-palm nerve conduction velocity study

All participants received palmar stimulation. Midpalm stimulation for the sensory nerve was stimulated between the 2nd and 3rd metacarpal bones and recorded from the 2nd digit. The motor nerve was recorded from the abductor pollicis brevis muscle. The stimulation site was at the proximal thenar crest with the cathode pointed to the abductor pollicis brevis muscle.[4, 14] The electromyographer moved the stimulation probe finely to elicit the maximum potential (**Figure 1).** Distances were gauged using a tape measure from cathode to cathode. Motor and sensory nerve conduction velocity was calculated by dividing the distance between stimulation sites (wrist and midpalm) by the latency difference. An electromyographer with ten years' experience in EDx stimulated the midpalm in all cases.

Routine nerve conduction study

Confirmation of CTS was achieved in the routine NCS study including (1) median motor study recording the abductor pollicis brevis, stimulating the wrist and antecubital fossa; (2) ulnar motor study recording abductor digiti minimi, stimulating the wrist and elbow; (3) median sensory response, recording digit 2 or 3, stimulating the wrist and (4) ulnar sensory response, recording digit 5, stimulating the wrist. (8) Additionally, bilateral studies were conducted. The results were classified in four groups; normal, mild, moderate and severe, based on the following recommendation of Stevens.[15]

Mild: prolonged distal sensory latency ± SNAP amplitude below the lower limit of normal

Moderate: abnormal median sensory latency as above and prolonged median motor distal latency

Severe: Prolonged median motor and sensory distal latencies, with either an absent SNAP or low amplitude or absent thenar CMAP

When median studies were equivocal, sensory indexes were combined to maximize sensitivity to detect CTS.

Based on the AANEM reference value[6]; prolonged distal median sensory more than 4.0 m/s., prolonged distal median motor latency more than 4.5 m/s., decreased onset-to-peak SNAP amplitude of median sensory nerve potential below 11 µV and decreased CMAP amplitude of the median motor nerve potential below 4.1 mV, all considered as abnormal.

Statistical Analysis

A Receiver Operating Characteristic (ROC) curve was plotted to compare the standard NCS results and the wrist-to-midpalm stimulation technique to determine the optimal cutoff point of median nerve conduction velocity across

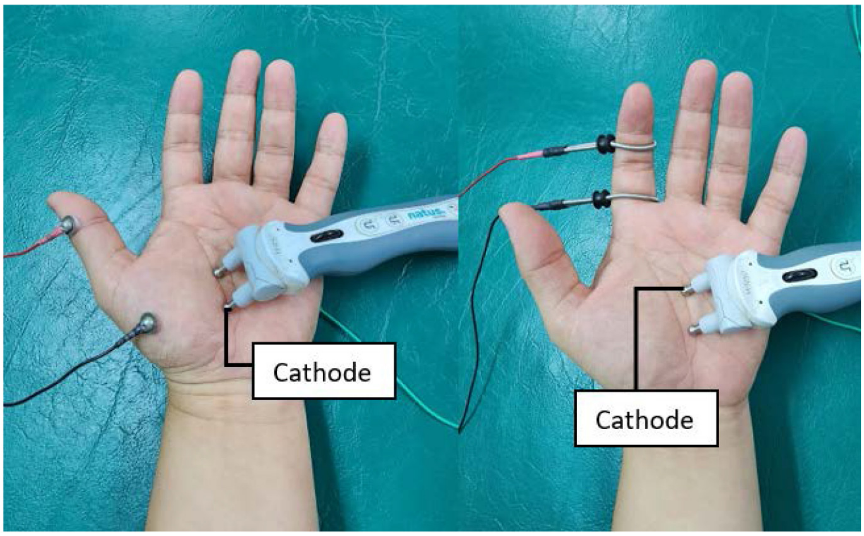

Figure 1. Midpalm stimulation site; left for motor and right for sensory stimulation. Electromyographer will move the probe to determine the highest amplitude. Distances are measured from cathode to cathode.

the wrist among patients with CTS. Then the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), positive likelihood ratio(+LR) and negative likelihood ratio(-LR) were calculated. Statistical analyses were performed using STATA, Version 13.0.

Results

We assessed 56 participants (112 wrists) with suspected CTS for eligibility and then excluded 6 wrists due to their history of steroid injection and wrist surgery. Thus, we calculated our results from 56 participants (106 wrists). Participants included 47 females and 9 males, with a mean age of 54.11±11.44 years, as shown in **Table 1.** Of the 56 participants, the majority were right hand dominant (91%). The 106 wrists included in the analysis were classified as follows: 40 (37.74%) were documented as normal, 16 (15.09%) as mild, 37 (34.90%) as moderate and 13 (12.26%) as severe CTS. The mean (±SD) median nerve conduction velocity across the carpal tunnel in wrists with and without CTS is summarized in **Table 2**.

Table 1. Demographic data of enrolled participants

	N (56)
Age	54.1±11.4
Height (cm)	158.2±8.0
BMI	24.4±3.8
Sex	
female	47 (83.9)
Duration of symptoms(month)(106 hands)	9.9±10.4

Displayed as mean±SD and number (percent)

Table 2. Values of median nerve conduction velocity (mean±SD) across the carpal tunnel in wrists with and without CTS, categorized by severity of the CTS.

	Normal (m/s) N=40 wrists	Mild (m/s) N=16 wrists	Moderate (m/s) N=37 wrists	Severe (m/s) N=13 wrists
Sensory NCV	48.56±7.79	38.09±5.43	29.01±7.55	No response
Motor NCV	45.12±12.63	34.74.5±6.57	24.77±7.56	15.09±5.78

Median sensory nerve conduction velocity

The mean (±SD) median sensory nerve conduction velocity across the carpal tunnel was 48.56±7.79 m/s in wrists without and 31.61±8.09 m/s in wrists with CTS, with means of 38.09±5.43 m/s in mild and 29.01±7.55 m/s in moderate CTS. The sensory nerve action potential was absent in severe CTS.

Median motor nerve conduction velocity

The mean (±SD) of median motor nerve conduction velocity across the carpal tunnel was 45.12±12.63 m/s in wrists without and 24.98±9.50 m/s in wrists with CTS, with a mean of 34.74.5±6.57 m/s in mild, 24.77±7.56 m/s in moderate and 15.09±5.78 m/s in severe CTS.

The ROC curves to determine the cutoff points were also drawn. Compared with the current standard method, our study determined that the optimal cutoff point in diagnosing CTS, using the wrist-to-midpalm conduction velocity method, was ≤40 m/s (with a sensitivity of 87.04% and specificity of 87.18%) for the sensory nerve, and ≤35 m/s (with a sensitivity of 88.06% and specificity of 89.74%) for the motor nerve. The area under the ROC curve was 0.939 (95% CI, 0.0869-0.978) for the sensory nerve (**Fig. 2** left) and 0.912 (95%CI, 0.841 to 0.958) for the motor nerve (**Figure 2** right). Notably; however, a lower nerve conduction velocity value would be more effective in ruling in CTS. Similarly, a higher value would also hold excellent power to rule out CTS, as shown in **Table 3**.

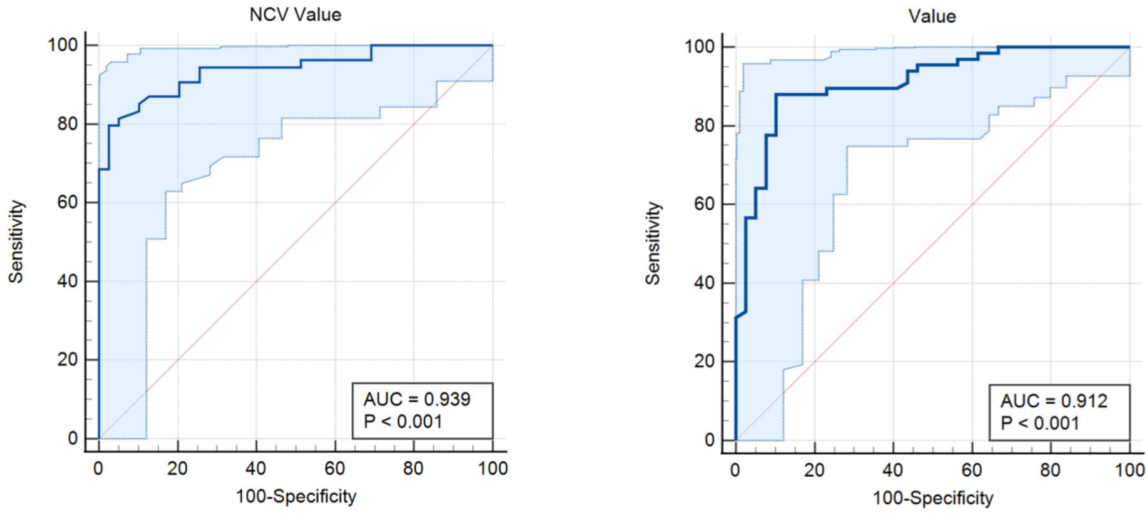

Figure 2. Receiver operator characteristic (ROC) curves with area under the curve of nerve conduction velocity across the carpal tunnel area, to diagnose CTS among patients; left for sensory NCV and right for motor NCV.

Table 3. Diagnostic properties of each different cutoff value

	NCV for cutoff points (m/s)	Sensitivity (95%CI)	Specificity (95%CI)	PPV	NPV	+ LR	- LR
Sensory N=93 hands	≤ 37.25	81.48(68.6-90.7)	94.87(82.7-99.4)	95.7	78.7		
	≤ 38.78	85.19(72.9-93.4)	89.74(75.8-97.1)	92.0	81.4		
	≤ 40.00	87.04(75.1-94.6)	87.18(72.6-95.7)	90.4	82.9	5.29	0.12
	≤ 41.84	90.74(79.7-96.9)	79.49(63.5-90.7)	86.0	86.4		
	≤ 42.74	94.44(84.6-98.8)	74.36(57.9-87.0)	83.6	90.6		
Motor N=106 hands	≤ 27.78	64.18(51.5-75.5)	94.87(82.7-99.4)	95.6	60.7		
	≤ 31.50	77.61(65.8-86.9)	92.31(79.1-98.4)	94.5	70.6		
	≤ 35.00	88.06(77.8-94.7)	89.74(75.8-97.1)	93.7	81.4	5.03	0.08
	≤ 37.20	89.55(79.7-95.7)	76.92(60.7-88.9)	87.0	81.1		
	≤ 40.00	91.04(81.5-96.6)	56.41(39.6-72.2)	78.2	78.6		

NCV, nerve conduction velocity; PPV, positive predictive value; NPV, negative predictive value.; +LR, positive likelihood ratio; -LR, negative likelihood ratio.

Discussion

According to the AANEM, the reference value for median motor nerve conduction velocity among adults is 49 m/s at a-ll ages.[6] However, a strong relationship between conduction velocity and nerve fiber diameter has been reported in the literature. Recent studies have documented that the diameter of the peripheral motor nerve gradually decreases until it reaches the target muscle.[16] The mentioned reference value might be inaccurate in the distal segment.

The present research studied, for the first time, the optimal cutoff point of the wrist to midpalm median nerve conduction velocity in diagnosing CTS. The results of this study indicated that the optimal cutoff point was ≤40 m/s (with a sensitivity of 87.04% and specificity of 87.18%) for the sensory nerve and ≤35 m/s (with a sensitivity of 88.06% and specificity of 89.74%) for the motor nerve. These values can be useful in diagnosing CTS because no clear cutoff point of this technique has been studied until now.

Our results revealed that the mean (±SD) median nerve conduction velocity across the carpal tunnel was 45.12±12.63 m/s among normal subjects for the motor nerve and 48.56±7.79 m/s for the sensory nerve. Our results were similar to a related study by Jun Kimura[4] reporting that the motor and sensory nerve conduction velocity was slow when less than 41 m/s and 44 m/s, respectively, in the wrist-to-palm segment.

Additionally, our results suggested a tendency existed for decreasing values of the mean (±SD) median nerve conduction velocity across the carpal tunnel area with increasing severities of CTS among patients, as shown in **Table 1**. These findings may be used to determine the cutoff values in future studies, to more clearly define the categories of patients with CTS by severity.

This study encountered limitations. Firstly, although NCS has been considered the gold standard, no universally accepted reference standard has been established to diagnose CTS.[17] Secondly, skin temperature was not monitored during the study. However, all participants were warmed with a hydrocollator pack before NCS testing. Variations in hand temperature could affect the results of nerve conduction velocity; thus, future studies should control this factor.[18] Next, height significantly correlated to nerve conduction velocity.[19] Therefore, these values may be invalid among patients who are taller and shorter than average individuals. In addition, our reference values might not be generalized to the advanced age group. Finally, this method was the surface measurement which couldn't reflect the actual nerve length.

Unfortunately, the midpalm conduction velocities yielded sensitivity and specificity between 87 and 89% compared with the standard procedure. It couldn't replace the standard NCS. Considering the positive likelihood ratio of motor and sensory nerve conduction velocities at 35m/s and 40 m/s, respectively, 5.03 and 5.29 indicated a moderate effect for CTS diagnosis, given a positive result, respectively. However, the negative likelihood ratio was 0.08 for motor and 0.12 for sensory nerve conduction velocity. These values indicated a moderate to strong effect to exclude CTS when the result was negative. Thus, we recommend using sensory and motor NCV across the wrist as screening tools.

Conclusion

This study determined that the optimal cutoff point to diagnose CTS, using the wrist-to-midpalm electrical stimulation method, was ≤40 m/s for the sensory nerve and ≤35 m/s for the motor nerve.

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