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Sensitivity and specificity of terminal latency index and residual latency in the diagnosis of carpal tunnel syndrome

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Abstract. – *Objectives:* **Traditionally, nerve conduction study (NCS) are used to diagnose carpal tunnel syndrome (CTS). However, no NCS has the sufficient sensitivity or specificity values to diagnose CTS by itself. Median terminal latency index (mTLI) and median residual latency (mRL) are parameters that calculated to identify abnormalities in distal segments of the median motor nerve. There are few studies on mTLI and mRL in the diagnosis of CTS. The objective of this study was to examine the sensitivity and specificity of mTLI and mRL together with NCS in the diagnosis of CTS.**

Patients and Methods and Results: **The diagnostic sensitivity of mTLI and mRL were calculated and compared with the conventional NCS. Sensitivity values of electrophysiological findings were as follows: median distal sensory latency (mDSL) 91.5%, fourth finger median-ulnar sensory (M4-U4) latency difference 91.5%, mTLI 90.1%, median sensory nerve conduction velocity (mSNCV) 87.4%, and median motor distal latency (mMDL) 68.6%. Specificity values of electrophysiological findings in those with carpal tunnel syndrome were mSNCV 98.6%, mMNCV (median motor nerve conduction velocity) 98.6%, median motor wrist muscle action potential amplitude 98.6%, median sensory nerve action potential amplitude 97.4%, mSDL 97.3% and M4-U4 (fourtm finger median-ulnar sensory peak latency difference) latency difference 97.3%. In all CTS patients with long mMDL values, mTLI was found to be lower, however in 22 CTS patients (22.6%) with normal mMDL, mTLI was also found to be lower. Compared with mMDL, the sensitivity of mTLI in the diagnosis of CTS was found to be higher but its specificity was lower. No differences were found in the sensitivity and specificity of mRL and mMDL. The electrophysiological findings with the highest sensitivity and specificity in diagnosing CTS among conventional NCS were mSDL, M4-U4 peak latency difference and mSNCV.**

Conclusions: **It was concluded that mTLI and mSDL can complete each other in the detection of abnormalities of sensory and motor fibres in the diagnosis of CTS.**

Key Words:

Carpal tunnel syndrome, Electromyography, Diagnosis, Specificity, Sensitivity.

Introduction

Carpal tunnel syndrome (CTS) occurs as the result of compression of the median nerve in the carpal tunnel of the wrist, and is most commonly seen as an entrapment neuropathy, especially in women[1]. It is possible to make a diagnosis with symptoms and findings, but the clinical findings almost always need to be confirmed by electrophysiological examinations[2]. Conventional nerve conduction studies (NCS) are used for the diagnosis of CTS, but none of the electrophysiological tests on its own has sufficient sensitivity and specificity for the diagnosis of CTS. The most commonly preferred traditional electrophysiological methods in the diagnosis of CTS are median sensory nerve conduction, median motor distal latency, comparison of median and ulnar nerve sensory conduction, and comparison of fourth finger median-ulnar peak latency[3]. Terminal latency index (TLI) and residual latency (RL), calculated from distal motor latency, distal distance and proximal motor conduction velocities, are electrophysiological parameters used to identify abnormalities in the distal segment of the motor nerve[2,4]. Although, it has been reported that TLI gives additional information to conventional electrophysiological studies in mildly affected motor nerves, there are few studies on the sensi-

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tivity and specificity of TLI and RL in the diagnosis of CTS[2,5-9].

The objective of this study was to examine the sensitivity and specificity of TLI and RL along with conventional NCS in the diagnosis of CTS.

Patients and Methods

This prospective study was carried out on 102 hands of 57 patients referred with suspected CTS and with a three-month history of complaints of pain and numbness in the upper extremities. Patients were not included in the study that had a diagnosis of polyneuropathy due to diabetes mellitus or other reasons had, who underwent surgery or local steroid injections for CTS. Clinical diagnostic parameters were recorded, and demonstrated in Table I[2,10]. The number and duration of clinical symptoms were recorded.

Electrophysiological studies were carried out according to the CTS diagnostic criteria of the American Academy of Electrodiagnostic Medicine using a 4-channel EMG machine (Nihon Kohden, 2005 model, Neuropack, Tokio Japan) in the traditional way[11]. Recordings were made at normal room temperature (24-26°C) and a skin temperature of over 30°C, with surface stimulator and recording electrodes. Stimuli were given for 0.1-0.2 ms supramaximally by bipolar surface electrodes. A sensory NCS ring, and for motor NCS surface felt bipolar recording electrodes, were used. Electrophysiological examination was conducted on the ulnar and median nerves of both hands of the control group and only on the symptomatic hands of the CTS patients. Sensory nerve action potentials were obtained antidromically. In NCS, median and ulnar sensory initial latency, amplitude and conduction velocities, and median and ulnar motor latencies, amplitude and conduction velocities were determined for both hands. Recorded parameters comprised median motor distal latency (mMDL), median motor nerve conduction velocity (mMNCV), median distal wrist muscle action potential amplitude (mBKAPa), median motor terminal latency index (mMTLI), median sensory distal latency (mSDL), median sensory nerve conduction velocity (mSNCV), median sensory nerve amplitude (mSNAPa), fourth finger median-ulnar sensory (M4-U4) peak latency difference, and median motor residual latency (mRL).

Table I. Frequency of detected clinical diagnostic parameters for the diagnosis of carpal tunnel syndrome (CTS) in upper extremities of our patients.

Clinical diagnostic parameters	CTS group (n = 102) n (%)
Paresthesia in the hand	95 (93.1)
Symptoms provoked by repeated or continuous movement of the hand or arm	94 (92.2)
Pain in the hand and arm	94 (92.2)
Symptoms occurring at the dermatome of the median nerve	93 (91.2)
Symptoms provoked by sleep	92 (90.2)
Symptoms reduced by changing hand position	91 (89.2)
Symptoms reduced by shaking the hand	82 (80.4)
Positive Tinel or Phalen test	65 (61.7)
Loss of sensation at the dermatome of the median nerve	36 (35.3)
Atrophy and/or weakness of the thenar muscle	16 (15.7)

N = number of hand.

mMTLI was calculated as distal distance over mMCNV multiplied by mMDL mMTL[1] = distal distance/mMNCV × mMDL.

mRL was found by the formula MRL = mMDL (ms) — [mMTL[1] = distal distance (mm)/mMNCV (m/s)][2,6].

Distal distance was measured as the distance between the place of distal stimulation on the wrist and the middle of the recording electrode. Our laboratory obtained normal values by the same technique from parameters recorded prospectively from the 76 hands of 38 healthy controls. Abnormal values were found from the average values of these parameters recorded from the controls according to a standard deviation of ±2. According to a standard deviation of 2, CTS was accepted as mSDL ≥2.83 ms, mSNCV ≤48.2 m/s, and mMDL ≥3.84 ms.

BKAP latency and amplitude for the median nerve were recorded from the abductor pollicis brevis muscle, and for the ulnar nerve from the adductor digiti minimi. mMDL was determined from the length of time from the beginning of the stimulus artifact to the beginning of BKAP. In BKAP recordings, the distance between the stimulator and recording electrodes was maintained

at an average of 6 cm. mSDL was determined from the length of time from the beginning of the stimulus artifact to the beginning of SNAP. In SNAP recordings, the distance between wrist stimulation points for stimulation of both the median and ulnar nerves and the recording electrodes on the second, fourth and fifth fingers were 14 cm.

Statistical Analysis

The Statistical Package for Social Sciences (SPSS) 11.5 for Windows (Chicago, IL, USA) was used to calculate the average values and standard deviation (SD) of the electrophysiological data from both groups. The average NCS values of the control and CTS groups were compared by independent Student's t-test. Assessment of nominal data was compared by chi-square test. In order to determine the diagnostic validity of mTLI and mRL as an addition to traditional NCS, sensitivity was calculated as [true positive / (true positive + false negative)], specificity as [true negative/(true negative + false positive)], positive predictive value as [true positive/(true positive + false positive)], and negative predictive value as [true negative/(true negative + false negative)]. Nerve conduction in CTS patients was correlated with age and number and duration of symptoms by Pearson correlation analysis. The McNemar test was used to test the differences between the diagnostic sensitivity of the various electrophysiological tests, and the degree of conformity between the methods was determined using kappa statistics. *p* value less than 0.05 accepted as statistically significant.

Results

A total of 57 patients with CTS (54 women, 3 men) and 38 healthy controls (36 women, 2 men) were investigated after taking anamnesis and performing neurological and electrophysiological examinations. Fourty-five CTS cases (78.9%) were diagnosed as bilateral CTS, 8 (14%) in the right hand, and 4 (7%) in the left hand, so that recordings were made from a total of 102 hands. Seventy-six upper extremities of healthy subjects were investigated as controls. No significant difference was found between the mean ages of the CTS (46.6±12.4 years, age range 25-71 years) and the control groups (45.3±10.9 years, age range 22-66 years) ($p>0.05$). There was also no significant difference in the male/female ratios of the two groups (CTS group, M/F:3/54.; control group, M/F:2/36 ($p>0.05$). Table I shows the frequency of clinical diagnostic parameters in the CTS patients. Table II shows the results of the electrophysiological examination of 102 upper extremities from the CTS group and 76 upper extremities from the control group. In the CTS group, mMDL, mSDL, and M4-U4 interpeak latency difference median residual latency were found to be significantly higher compared with the control group ($p<0.001$ for each parameter) (Table II). A positive relationship was found between age and mRL in the CTS group (r = 0.308, $p = 0.001$). Table III shows the sensitivity, specificity, positive predictive value and negative predictive value of electrophysiological diagnostic tests for the CTS patients. The mRL values of 63.7% CTS patients were found to be longer than

Table II. Comparison of electrophysiological findings between studied upper extremitites of patients and control groups.

	CTS (n = 102)	Controls (n = 76)	*p*
mSNCV (m/s)	41.17 ± 5.86	59.01 ± 5.38	< 0.001
mSDL (ms)	3.47 ± 0.54	2.39 ± 0.22	< 0.001
mMDL (ms)	4.23 ± 0.91	2.94 ± 0.45	< 0.001
mMNCV (m/s)	54.2 ± 6.2	59.6 ± 4.9	< 0.001
mBKAPa (mV)	8.77 ± 3.04	12.63 ± 4.13	< 0.001
M4-U4 peak latency difference (ms)	1.46 ± 1.0	0.15 ± 0.12	< 0.001
mSNAPa (μV)	20.1 ± 11.35	51.5 ± 25.6	< 0.001
mTLI (ms)	0.24 ± 0.07	0.31 ± 0.05	< 0.001
mRL (ms)	3.27 ± 0.91	2.06 ± 0.45	< 0.001

mSDL: median sensory distal latency; mSNCV: median sensory nerve conduction velocity; mSNAPa: median sensory nerve action potential amplitude; mMDL: median motor distal latency; M4-U4: fourth finger median-ulnar sensory peak latency difference; mMNCV: median motor nerve conduction velocity; mMTLI: median motor terminal latency index; mRL: median motor residual latency; CTS: carpal tunnel symdrome, n= number of hands.

Table III. Sensitivity, specificity, and positive predictive value (PPV) and negative predictive value (NPV) of the various electrophysiological diagnostic tests in CTS patients.

	Abnormality criteria	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
mSDL (ms)	> 2.83	91.5	97.3	98	90
M4-U4 latency difference (ms)	> 0.4	91.5	97.3	98	86
mTLI (ms)	< 0.30	90.1	53.9	72	80
mSNCV (m/s)	< 48.2	87.4	98.6	98	86
mMDL (ns)	> 3.84	68.6	94.7	94	69
mRL (ms)	> 2.96	63.7	94.7	94	66
mSNAPa (μV)	< 20	42.1	97.4	96	65
mMNCV (m/s)	< 50	15.6	98.6	94	46
mBKAPa (mV)	< 5	8.8	98.6	90	45

mSDL: median sensory distal latency; mSNCV: median sensory nerve conduction velocity; mSNAPa: median sensory nerve action potential amplitude; mMDL: median motor distal latency; M4-U4: fourth finger median-ulnar sensory peak latency difference; mMNCV: median motor nerve conduction velocity; mBKAPa: median motor wrist muscle action potential amplitude; mMTLI: median motor terminal latency index; mRL: median motor residual latency; CTS: carpal tunnel syndrome.

normal value. The mMDL of 68.6% CTS patients found to be longer than normal value. Tables IV and V show the abnormal values determined by the traditional NCS and mRL and mMTL. The most sensitive electrophysiological findings in CTS patients, in order of sensitivity, were mSDL (91.5%9), M4-U4 latency difference (91.5%), mTLI (90.1%), mSNCV (87.4%) and mMDL (68.6%). The most specific electrophysiological findings in CTS patients were mSNCV (98.6%), mMNCV (98.6%), mBKAPa (98.6%), mSNAPa (97.4%), mSDL (97.3%) and M4-U4 latency difference (97.3%). In all patients with long mMDL, mTLI was found to has low sensitivity. In nine (8.8%) of CTS patients with reduced mSNCV, mTLI was found as normal, but in 12 patients (11.8%) where mSNCV was within normal limits, low mTLi was recorded. In eight extremities (7.8%) in the CTS group with extended mSDL, mTLI was normal, while in seven extremities (6.9%) in which mSDL was normal, mTLI was found to be low. In three CTS

Table IV. Median motor terminal latency index (mTLI) in patients with carpal tunnel syndrome in relation to other nerve conduction tests.

		mTLI n (%)	
		Normal	Low
mSNCV	Normal	1 (1)	12 (11.8)
	Reduced	9 (8.8)	80 (78.4)
mMDL	Normal	10 (9.6)	22 (21.6)
	Extended	0 (0.0)	70 (68.6)
mSDL	Normal	2 (1.9)	7 (6.9)
	Extended	8 (7.8)	85 (83.3)
mMNCV	Normal	4 (3.9)	82 (80.4)
	Reduced	6 (5.9)	10 (9.6)
mBKAPa	Normal	9 (8.8)	84 (82.4)
	Low	1 (1)	8 (7.8)
mSNAPa	Normal	5 (4.9)	38 (37.3)
	Low	5 (4.9)	54 (52.9)

n = Number of hands.

Table V. Median motor residual latency (mRL) in CTS patients in relation to other nerve conduction tests.

		mTLI n (%)	
		Normal	High
mSNCV	Normal	10 (9.6)	3 (2.9)
	Extended	27 (26.5)	62 (60.8)
mMDL	Normal	31 (30.4)	1 (1.0)
	Extended	6 (5.9)	64 (62.7)
mSDL	Normal	6 (5.9)	3 (2.9)
	Extended	31 (30.4)	62 (60.8)
mMNCV	Normal	29 (28.4)	57 (55.9)
	Extended	8 (7.8)	8 (7.8)
mBKAPa	Normal	35 (34.3)	58 (56.9)
	Extended	2 (1.9)	7 (6.9)
mSNAPa	Normal	21 (20.6)	22 (21.6)
	Extended	16 (15.7)	43 (42.2)

n = Number of hands.

Table VI. Conformity statistics for electrophysiological methods.

	Mc Nemar			
	Chi-square	*p*	Kappa	*p*
mSNCV-mTLI	28.26	0.000	0.362	0.000
mMDL-mRL	151.54	0.000	0.919	0.000
mSDL-mRL	60.99	0.000	0.559	0.000
mSDL-mTLI	33.70	0.000	0.404	0.000
mMNCV-mTLI	1.34	0.188	0.034	0.247
mSNCV-mRL	70.35	0.000	0.609	0.000
mMDL-mTLI	51.65	0.000	0.448	0.000
mMSCV-mRL	0.574	0.306	0.040	0.448

patients (2.9%) where mSNCV was normal, mRL was found to be extended, but in 27 patients (26.5%) with normal mSNCV, mRL was found as normal. In six patients (5.9%) with normal mMDL, mRL was normal, and in one patient with normal mMDL (1.0%), mRL was extended. Comparison of sensitivity rates of all NCS tests were examined with McNemar test and non-random compatibility Kappa test. The non-random compatibility values of the results of all comparisons apart from mMNCV-mTLI and mMNCV-mRL matching were found to be statistically significant (Table VI).

Discussion

The diagnosis of CTS is made on the basis of the findings of clinical and electrophysiological findings[3,4]. The commonest clinical complaints and findings of CTS in our patients were paresthesia in the region of the median nerve, numbness made worse by repetitive hand movements, pain in the hand and arm, disappearance of symptoms with a change in position, positive Tinel or Phalen findings, and atrophy of the thenar muscle[2,9].

This study was done in order to investigate the value of mTLI and mRL as an addition to traditional NCS for patients with CTS using clinical parameters. Electrophysiological tests are usually used to aid in the diagnosis of CTS. However, no single procedure or group of procedures has demonstrated adequate sensitivity. The American Association of Electrodiagnostic Medicine practice parameters for electrodiagnostic studies in CTS has reported the sensitivities of the conventional tests as 49% to 84%, with specificities of 95% or greater. These include the mMDL, sensory conductions to second or fourth fingers or thumb, and mixed-nerve palmar studies[12,13]. Additional tests such as mTLI and mRL have also been devised in an attempt to establish more sensitive methods[2]. The mTLI decreases as the conduction time increases across the carpal tunnel due to motor nerve demyelination[2,4,5]. mTLI is a calculation method intended to increase the diagnostic sensitivity of mMDL[2]. Table VII shows the normal and average standard values of mTLI found in previous studies[2,4-7,14,15]. In these studies, values of mTLI varying between below 0.31 and below 0.36 were accepted as abnormal. We calculated the values from averages obtained from the healthy controls and two standard deviations in our laboratories, and counted below 0.30 mTLI as abnormal. This finding was lower than those of previous studies[2,5-7,14,15]. Reasons for this may be local reasons such as heat, different NCS

Table VII. Results of previous studies: normative data for mTLI.

Studies	Normal mTLI	mTLI (mean ± SD)
Kuntzer[6]	≥ 0.34	0.427 ± 0.043
Simovic and Weinberg[2]	≥ 0.34	0.43 ± 0.04
Lissens et al.[7]	≥ 0.34	0.428 ± 0.038
Karata et al.[5]	≥ 0.34	0.42 ± 0.036
Aygul et al.[15]	> 0.33	0.41 ± 0.038
Bae and Kim[4]	≥ 0.36	0.37 ± 0.03
Lupu et al.[14]	≥ 0.31	0.32 ± 0.04
Current study	> 0.30	0.31 ± 0.05

techniques or the use of different EMG machines. mRL is found by dividing median motor distal distance by median motor nerve conduction velocity[2,5].

Conflicting results have been obtained from both mTLI and mRL in terms of sensitivity in CTS diagnosis. Some researchers maintain that these two parameters show a significant degree of sensitivity in the diagnosis of CTS[2,9]. It was reported from one study[8] that mTLI did not increase diagnostic sensitivity. In another study[5], it was proposed that both TLI and RL were sensitive indicators of the obstruction of motor nerves. However, Kuntzer[6] emphasized that although both methods had high sensitivity, their specificity was low. Simovic and Weinberg, in two studies[2,9], one retrospective and one prospective, maintained that the diagnostic sensitivity of mTLI was as high as NCS, and even that it was the only electrophysiological abnormality in some patients. Similarly, Karata et al[5]. emphasized that median mixed nerve conduction velocity and mTLI were the most sensitive diagnostic indicators. These varying results may be related to differing study groups or the use of different techniques. In the present investigation, NCS sensitivity in the diagnosis of CTS was found to be, in order, mSDL, M4-U4 peak latency difference, mTLI, mSNCV, mMDL and mRL. Our presented results support the idea that in the diagnosis of CTS the examination of median sensory NCS sensitivity is more sensitive than median motor NCS. Among median motor NCS, the sensitivity of mTLI in CTS diagnosis was higher than that of mBKAP amplitude and mSNCV. The diagnostic sensitivity of mTLI was similar to that of mSDL, M4-U4 peak latency difference and mSNCV. At the same time, in some CTS patients with normal mSDL and mSNCV, low mTLI was established as the only finding. Although the sensitivity of mTLI in CTS diagnosis was high, its specificity was very low (53.9%) relative to traditional NCS.

Electrophysiological findings in order of specificity in CTS diagnosis were mSNCV, mMNCV, mBKAPa, mSNAPa, mSDL, M4-U4 latency difference, mMDL, mRL, and mTLI. Diagnostic sensitivity of mRL was found to be lower than that of mSDL, M4-U4 peak latency difference, mTLI, MSNCV, and mMDL. However, the specificity of mRL in CTS diagnosis was as high as that of traditional NCS. The NCS parameters with the highest positive predictive value in CTS patients were mSDL, M4-U4 latency difference, mSNCV, and mSNAPa.

The NCSs with the highest negative predictive value in CTS patients were, in order, mSDL, M4-U4 latency difference, MSNCV, and mTLI. Positive and negative predictive values of mTLI and mRL in CTS diagnosis had not been examined in previous studies[2,5,9,15]. In the present work, the positive predictive value of mTLI in CTS patients was 72%, and its negative predictive value was 80%. The positive predictive value of mRL in CTS patients was 94% and its negative predictive value was 66%.

In conclusion, the sensitivity of mTLI in CTS diagnosis is higher than that of mMDL, but its specificity is lower. The sensitivity and specificity of mRL and mMDL are similar. mRL is not superior to traditional NCS. Among traditional NCS, the most sensitive methods were found to be mSDL, M4-U4 peak latency difference, and mSNCV. Although the sensitivity in CTS diagnosis of mTLI was similar to that of mSDL and mSNCV, it was more sensitive than mMDL. For this reason, mTLI can show the effect on median nerve motor fibres in mild CTS cases. In some cases, although median sensory NCSs are normal, abnormality in mTLI may be a guide in CTS diagnosis. mTLI and mSDL complement each other with regard to the identification of pathology in sensory and motor nerves. The relatively small number of patients in our investigation means that our findings need to be confirmed in future clinical studies.

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