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The Electrodiagnosis of Carpal Tunnel Syndrome – comparison of the sensitivities of various nerve conduction tests

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Abstract

Nerve conduction studies were carried out on 81 hands in 48 patients diagnosed clinically to have carpal tunnel syndrome to evaluate the sensitivities of thirteen predefined electro-physiological parameters. Normal values were established from 40 normal control subjects. Abnormal values were control mean ± 2 standard deviation. For median : ulnar sensory amplitude ratio, abnormal value was < 1. The most sensitive tests were the median mid-palm to wrist versus mid-palm to 2nd digit mixed nerve sensory latency difference (76.5%) and the median versus ulnar mid-palm to wrist mixed nerve latency difference (75.3%). The least sensitive parameters were the median versus ulnar sensory amplitude ratios (39.5%) and the median wrist - 2nd digit to forearm sensory nerve conduction velocity ratio (29.6%). 34.6% of hands were normal for the median distal motor latency. Of these, 46.4% were positive for the two most sensitive tests above. When considering all tests together, only 6 (7.4%) of hands were negative. Tests that measure latencies for shorter distances across the carpal tunnel are more sensitive. Comparative studies further enhance the sensitivity. Combination of several test parameters result in higher diagnostic yield overall.

Key words: carpal tunnel syndrome, nerve conduction studies, sensitivity, palm stimulation, comparative tests

INTRODUCTION

Carpal tunnel syndrome is the combination of symptoms and signs resulting from compression of the median nerve as it passes through the bony carpal canal, from the forearm to the palm. The absence of a gold standard for its diagnosis has led to the development of various clinical diagnostic criteria [1-4] as well as several laboratory methods of diagnosis viz. electrophysiological tests, quantitative sensory tests [5] as well as imaging of the carpal tunnel.[6]

Electrophysiological tests are the most commonly used methods in providing objective diagnosis. Carpal tunnel syndrome is probably the most common entrapment neuropathy referred to the neurophysiology laboratory. Much has been reported about the various nerve conduction studies diagnostic of carpal tunnel syndrome which in essence demonstrates slowing of sensory and/or motor conduction across the carpal tunnel. The American Association of Electrodiagnostic Medicine (AAEM) provided an extensive review of previously reported literature and set out recommendations regarding evaluation of electrodiagnostic studies in carpal tunnel syndrome. [1] In general, the review found that sensory conduction studies were more sensitive than motor studies, and sensory or mixed nerve studies which evaluate median nerve conduction over shorter distances across the carpal tunnel and comparative studies with the ipsilateral ulnar and/or radial nerve were most sensitive.

In a busy neurophysiology laboratory providing service to a general hospital as well as other surrounding hospitals, it is often not possible to perform exhaustive nerve conduction studies to confirm the diagnosis of carpal tunnel syndrome. Hand surgeons, on other hand tend to rely on a positive nerve conduction result before deciding on carpal tunnel release surgery for their patients.[7-9] Nerve conduction procedures should therefore be relatively easy and quick to perform and yet afford a reasonable accuracy in diagnosis.

The aim of this prospective study was therefore to evaluate several commonly used nerve conduction tests (sensory and motor), chosen for ease of performance, in a patient population defined clinically to have carpal tunnel syndrome. We report on the sensitivity and specificity of various selected parameters

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and compare it with previously reported series of patients.

MATERIALS AND METHODS

Subjects: Patients were referred to the Neurodiagnostic Laboratory, Department of Neurology, Tan Tock Seng Hospital for nerve conduction studies to confirm or exclude carpal tunnel syndrome. They were evaluated clinically by the investigating neurologist and were recruited if they had numbness or tingling of fingers and hands with one of the following viz. nocturnal symptoms, reproduction of symptoms with wrist flexion (Phalen's sign), tapping of the wrist (Tinel's sign) or objective signs of sensory deficit within the median nerve distribution or weakness and/or wasting of the median-innervated muscles. Patients with clinical or electrophysiological evidence of underlying peripheral neuropathy were not included. Control subjects were recruited from volunteers among the hospital staff to establish reference values for this study. None had symptoms or signs of carpal tunnel syndrome or peripheral nerve disease.

Nerve conduction studies were performed on a Medelec Sapphire electromyography machine. A surface stimulator or ring stimulating electrodes placed at the interphalangeal joints were used to provide supramaximal stimulation while surface or ring electrodes were used for recording. Studies were carried out in an open room and in our tropical climate there was no necessity to warm the hands to keep the temperature above 32° Celsius. A standardised nerve conduction protocol was carried out in all patients and controls. The tests carried out were as follows :-

Motor conduction studies

Median nerve: The median nerve was stimulated supramaximally at the wrist and the compound muscle action potential (CMAP) was recorded over the abductor pollicis brevis.[10, 11] A fixed conduction distance of 6.5 cm was used. The median distal motor latency (DML) and motor nerve conduction velocity (MNCV) were recorded. Two indices, the residual motor latency (RML) and the terminal latency index (TLI) were calculated to correct the median distal motor latency for variations in the median nerve motor forearm velocity using formulae previously described [12, 13] :-

Residual Motor Latency =
DML – (10 × D/MNCV)
Terminal Latency Index =
10 × D/(MNCV × DML)

where DML = distal motor latency
D = conduction distance
MNCV = motor nerve conduction velocity in the forearm.

Lumbrical and interossei recording: The method described by Preston and Logigian [14] was used. The active recording electrode was placed lateral to the midpoint of the 3rd metacarpal, recording over the second lumbrical (median) and interossei (ulnar) muscles, while the median and ulnar nerves were stimulated over the wrist at identical distances from the recording electrode. The difference between the second lumbrical and interossei latencies (2L-INT DIFF) was calculated.

Sensory/mixed nerve conduction studies

Digit to wrist studies: The median nerve was stimulated orthodromically using ring electrodes placed over the interphalangeal joints of the 2nd digit and the sensory nerve action potential (SNAP) recorded over the median nerve at the wrist. The distal sensory onset latency (DSOL) and the distal sensory peak latency (DSPL) and the median sensory nerve action potential (SNAP) amplitudes were recorded. The ulnar nerve was similarly stimulated orthodromically with the stimulating ring electrodes over the 5th digit and SNAP recorded over the wrist. A fixed conduction distance was used for both median and ulnar nerve recordings. The ratio of median SNAP amplitude to ulnar SNAP amplitude was calculated.[15]

Other comparative studies

For comparison with the ulnar and radial nerves of the same hand, orthodromic sensory nerve conduction studies were carried out from the 4th digit to the wrist and from the thumb to the wrist. These are variations of previously reported studies.[10, 16-18] For median-ulnar comparison, ring electrodes were used to stimulate the 4th digit and recordings made simultaneously at the wrist over the median and ulnar nerves. For median-radial comparison, the thumb was stimulated and recordings likewise made over the wrist. The conduction distances were kept equal. The following were calculated :-

(1) The difference between median and ulnar sensory onset latencies from digit to wrist on fourth digit stimulation.
(2) The difference between median and radial sensory onset latencies from digit to wrist while stimulating at the thumb.

Wrist to forearm sensory nerve conduction velocity ratio: The median nerve was stimulated antidromically at the wrist and elbow and recording made over the 2nd digit. The ratio of the velocity across the 'distal' (wrist to 2nd digit) segment to the 'proximal' (forearm) segment was calculated.[19]

Palmar stimulation studies: An adaptation of the techniques described by Jackson and Clifford[10] and Kimura [11] was used. The median nerve was stimulated in the palm between the 2nd and 3rd metacarpal heads, recording over the median nerve at the wrist, as well as simultaneous recording over the 2nd digit (using ring electrodes). Conduction distances between palm and wrist and palm and the 2nd digit were kept identical. The mixed nerve sensory onset latency from mid-palm to wrist and mid-palm to the 2nd digit was recorded. The difference between the two latencies was calculated.

Palmar stimulation of the ulnar nerve between the 4th and 5th metacarpal heads was also carried out, recording over the ulnar nerve at the wrist.[10] The conduction distance was kept identical to that of the median palmar stimulation test for each particular hand. The mixed nerve sensory onset latency for the ulnar nerve on palmar stimulation was measured and the median versus ulnar mid-palm to wrist mixed nerve sensory latency difference was calculated.[10, 20]

Criteria for abnormality: Descriptive statistics i.e. mean, minimum, maximum and standard deviation were applied to each nerve conduction parameter. Criteria for abnormality were control mean ± 2 standard deviation (SD) for all parameters except for median to ulnar sensory amplitude ratio. Sensory amplitude values did not follow a normal distribution; therefore the above criteria could not be used. The criterion for abnormality was a median : ulnar sensory amplitude ratio of less than one, based on a previous report by Loong and Seah.[15]

Sensitivity and specificity of a parameter were calculated as indices of test accuracy.[21] Sensitivity of a parameter is the proportion of carpal tunnel syndrome patients who had abnormal values for that particular test. Specificity is the proportion of normal control subjects who were normal for that particular test. Comparison between different percentages of sensitivity was performed using the chi-square test.

RESULTS

Forty eight patients with a total of 81 symptomatic hands with clinically defined carpal tunnel syndrome were recruited. 33 (68.75%) patients had bilateral and 15 (31.25%) had unilateral carpal tunnel syndrome. There were 36 (75%) females and 12 (25%) males. Their ages ranged from 20 to 70 years (mean 47.6 years). 41 were Chinese, 3 Malay, 2 Indian and 2 other races. 40 control subjects were studied. 25 (62.5%) were females and 15 (37.5%) were males. Their ages ranged from 22 to 60 years (mean 44.4 years).

Tables 1 and 2 show the sensitivity and

TABLE 1: Sensitivity and specificity of motor parameters

Test Parameter	Reference values (mean, SD*)	Sensitivity (%)	Specificity (%)
median distal motor latency (DML) (abnormal value = mean + 2SD)	3.49 msec, 0.37 (> 4.23 msec)	65.4	97.5
2nd lumbrical-interossei latency difference (abnormal value = mean + 2SD)	0.06 msec, 0.14 (> 0.34 msec)	66.7	100
median residual motor latency (RML) (abnormal value = mean + 2SD)	2.39, 0.33 (> 3.05)	64.2	97.5
median terminal latency index (TLI) (abnormal value = mean - 2SD)	0.32, 0.03 (< 0.26)	50.6	97.5

* standard deviation

TABLE 2: Sensitivity and specificity of sensory / mixed nerve parameters

Test Parameter	Reference values (mean, SD*)	Sensitivity (%)	Specificity (%)
median 2nd digit to wrist distal onset latency (DSOL) (abnormal value = mean + 2SD)	2.69 msec, 0.30 (> 3.29 msec)	64.2	95
median 2nd digit to wrist distal peak latency (DSPL) (abnormal value = mean + 2SD)	3.35 msec, 0.35 (> 4.05 msec)	63	97.5
median palm to wrist mixed nerve latency (abnormal value = mean + 2SD)	1.49 msec, 0.18 (>1.85 msec)	69	97.5
median vs. ulnar palm to wrist latency difference (abnormal value = mean + 2SD)	0.02 msec, 0.15 (> 0.32 msec)	75.3	97.5
median palm to wrist vs. palm to 2nd digit latency difference (abnormal value = mean + 2SD)	0.03 msec, 0.14 (> 0.31 msec)	76.5	97.5
median vs. ulnar 4th digit to wrist latency difference (abnormal value = mean + 2SD)	0.08 msec, 0.27 (> 0.62 msec)	55.6	100
median vs. radial thumb to wrist distal latency difference (abnormal value = mean + 2SD)	0.09 msec, 0.20 (> 0.49 msec)	69.1	97.5
median : ulnar sensory action potential amplitude ratio (abnormal value = < 1.0)	2.29 (< 1.0)	39.5	92.5
median wrist : forearm sensory conduction velocity ratio (abnormal value = mean - 2SD)	0.89, 0.11 (< 0.67)	29.6	97.5

* standard deviation

specificity of the various motor and sensory parameters as well as the reference values (from the control group) and the criteria for abnormality. Table 3 shows the comparison of sensitivities of the various test parameters in descending order. 4 hands were abnormal for all test parameters. 6 hands were normal for all tests i.e. the overall false negative rate was 7.4%.

The most sensitive test was the median mixed nerve sensory latency difference between mid-palm to wrist versus mid-palm to 2nd digit where 62 hands (76.5%) showed a latency difference of more than 0.31 milliseconds. Median versus ulnar mid-palm to wrist mixed nerve latency difference was abnormal (> 0.32 milliseconds) in 61 hands (75.3%). Other tests which compared median nerve parameters with the other nerves in the hand also afforded good sensitivity. The median-radial thumb to wrist sensory latency difference had a sensitivity of 69.1% while the second lumbrical - interossei motor latency difference was 66.7%. The median-ulnar 4th digit to wrist latency difference was less sensitive at 55.6%.

The *classical* tests for the diagnosis of carpal tunnel syndrome were generally less sensitive - median distal motor latency was abnormal (> 4.23 milliseconds) in 53 hands (65.4%) and median distal sensory onset latency abnormal (> 3.29 milliseconds) in 52 hands (64.2%). The residual motor latency (RML) and the terminal latency index (TLI) did not enhance the sensitivity of median distal motor latency. In

TABLE 3: Comparison of sensitivities of parameters in descending order

Test Parameter	Sensitivity (%)
median palm to wrist vs. palm to 2nd digit sensory latency difference	76.5
median vs. ulnar palm to wrist mixed nerve latency difference	75.3
median vs. radial thumb to wrist sensory latency difference	69.1
median palm to wrist mixed nerve latency	69
2nd lumbrical - interossei motor latency difference	66.7
median distal motor latency (DML) (wrist to abductor pollicis brevis)	65.4
median sensory distal onset latency	64.2
median residual motor latency (RML)	64.2
median sensory distal peak latency	63
median vs. ulnar 4th digit to wrist sensory latency difference	55.6
median motor terminal latency index (TLI)	50.6
median vs. ulnar sensory amplitude ratio	39.5
median wrist : forearm sensory conduction velocity ratio	29.6

fact only one patient with normal distal motor latency had an abnormal residual latency while none had abnormal terminal latency index. The least sensitive tests were the median versus ulnar sensory amplitude ratio (abnormal in 32 hands or 39.5%) and the ratio of the median nerve sensory conduction velocity across the wrist to that across the forearm (abnormal in 24 hands or 29.6%). The specificity of all parameters were 97.5% or greater except the median distal sensory onset latency and median-ulnar sensory amplitude ratio which had a specificity of 95% and 92.5% respectively.

Comparing the most sensitive tests to the median distal motor latency (DML), which is usually the most commonly used parameter, showed that only the mid-palm to wrist versus mid-palm to 2nd digit latency difference was significantly more sensitive, 76.5% versus 65.4% ($\chi^2 = 4.42$, 1 d. f., $p = 0.035$). Median versus ulnar mid-palm to wrist mixed nerve latency difference was not significantly so, 75.3% versus 65.4% ($\chi^2 = 3.49$, 1 d. f., $p = 0.062$). Other comparative studies were not significantly more sensitive compared to the median distal motor latency.

Twenty eight hands (34.6%) had mild carpal tunnel syndrome which we defined empirically as having normal median distal motor latency. In this group, the most sensitive tests were again the median palm to wrist versus palm to 2nd digit latency difference and the median versus ulnar nerve palm to wrist latency difference - abnormal in 13 of 28 (46.4%) hands in both tests followed by median-radial thumb to wrist sensory latency difference in 12 of 28 (42.9%) hands.

DISCUSSION

The median distal motor latency and the median sensory latency/velocity measurements have been the most basic electrodiagnostic test for carpal tunnel syndrome.[1,10,20,22,23] However these cannot confirm mild to moderate cases, their sensitivities ranging from 60% to 74% for distal motor latency and 49% to 66% for sensory peak latency.[1] In our study the sensitivities were 65.4% and 63% respectively. Further, more sensitive tests are required to provide an objective diagnosis.

In this study, the most sensitive parameters were the median mid-palm to wrist versus mid-palm to 2nd digit sensory latency difference and the median versus ulnar mid-palm to wrist latency difference, at 76.5% and 75.3% respectively. This agrees with previous reports which demonstrate that electrophysiological studies across the palm to wrist segment may reveal more abnormalities[1,20,24,25], compared to conventional studies between the digit and wrist. Measurement of the shorter mid-palm to wrist segment is more sensitive as it removes the

"dilutional" effect of normal conduction in the median nerve segment distal to the carpal tunnel (i.e. palm to digit segment) seen in routine orthodromic or antidromic sensory conduction tests between wrist and digit. Measurement of even shorter segments such as in the *centimetric test* where sequential stimulation of the median nerve is carried out at 1 cm intervals across the carpal tunnel is probably more sensitive.[11,17,26.27] This technique however, is time-consuming and technically more difficult, making it unfeasible for routine studies.

Comparative studies with unaffected segments or other nerves in the same hand have long been shown to improve test sensitivity.[1,10,14-16,28,29] The sensitivity of the mid-palm to wrist mixed nerve latency test was 69%. This was further enhanced when comparing the latency across the affected segment with an unaffected segment of the median nerve (i.e. palm to 2nd digit) or with a similar segment of the ulnar nerve. We found that the mid-palm to 2nd digit versus mid-palm to wrist latency difference was a significantly more sensitive test when compared to the median distal motor latency. Sensory nerve conduction has been shown to be faster from digit to palm than between palm and wrist in patients with carpal tunnel syndrome[24,30], and this appears to be a useful parameter especially in cases of mild carpal tunnel syndrome. A similar evaluation of the ratio of the sensory nerve conduction velocity (SNCV) from the third digit to mid-palm and from mid-palm to wrist has been suggested to be an extremely sensitive parameter.[30] Palm to wrist latency studies were more sensitive when compared with the ipsilateral ulnar nerve then when evaluated alone, as previously reported.[1,10,20] We evaluated the second palmar branch. It has however, been shown in a recent report, that evaluating the third palmar branch may be a better parameter, possibly because medially located fibres may be more susceptible to damage.[31]

Other comparative studies i.e. median versus radial nerve thumb to wrist sensory latency difference and lumbrical-interossei latency difference also afforded greater sensitivity in our study compared to *classical* tests. The exception was the median versus ulnar ring finger to wrist sensory latency difference. This parameter was less sensitive compared to median distal motor latency in this study. Other studies which have proposed that this parameter is highly sensitive[17,18,28,29], again suggesting that the funicular topography of the median nerve is such that more medial fibres are more susceptible to anoxia and damage. Whether this is due to a technical differences or whether there are differences in our Asian patients as compared to the Caucasian patients of the other studies is uncertain.

Using the most sensitive test in our study alone, we would have a false negative rate of 23.5%. This can however be reduced further if several nerve conduction parameters are considered together - our overall false negative rate is 7.4%. Hence a combination of tests would be more appropriate than reliance on a single parameter.

The variation in the sensitivities of similar tests[1] carried out in different studies on carpal tunnel syndrome reflect the basic problem of assessing diagnostic tests in a condition in which the study population is defined by clinical criteria. Although there is no diagnostic 'gold standard' for carpal tunnel syndrome and nerve conduction studies do not afford 100% sensitivity, clinical symptoms and signs are much less reliable.[32] A diagnosis based on symptoms alone persisted in fewer cases than one based on electrodiagnostic abnormalities as well.[8] Highly sensitive electrophysiological tests remain the most objective means of confirming a diagnosis of carpal tunnel syndrome.

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