Original Article

A study of interpolation method in diagnosis of carpal tunnel syndrome

Alireza Ashraf[1,2], Abbas Daghaghzadeh[1,3], Mahshid Naseri[1,2], Aref Nasiri[1,2], Maryam Fakheri[1,2]

Department of [1]Physical Medicine and Rehabilitation, [2]Burn Research Center, [3]Geriatric Research Center, Shiraz University of Medical Sciences, Shiraz, Iran

Abstract

Context: The low correlation between the patients' signs and symptoms of carpal tunnel syndrome (CTS) and results of electrodiagnostic tests makes the diagnosis challenging in mild cases. Interpolation is a mathematical method for finding median nerve conduction velocity (NCV) exactly at carpal tunnel site. Therefore, it may be helpful in diagnosis of CTS in patients with equivocal test results. **Aim:** The aim of this study is to evaluate interpolation method as a CTS diagnostic test. **Settings and Design:** Patients with two or more clinical symptoms and signs of CTS in a median nerve territory with 3.5 ms ≤ distal median sensory latency <4.6 ms from those who came to our electrodiagnostic clinics and also, age matched healthy control subjects were recruited in the study. **Materials and Methods:** Median compound motor action potential and median sensory nerve action potential latencies were measured by a MEDLEC SYNERGY VIASIS electromyography and conduction velocities were calculated by both routine method and interpolation technique. **Statistical Analysis Used:** Chi-square and Student's *t*-test were used for comparing group differences. Cut-off points were calculated using receiver operating characteristic curve. **Results:** A sensitivity of 88%, specificity of 67%, positive predictive value (PPV) and negative predictive value (NPV) of 70.8% and 84.7% were obtained for median motor NCV and a sensitivity of 98.3%, specificity of 91.7%, PPV and NPV of 91.9% and 98.2% were obtained for median sensory NCV with interpolation technique. **Conclusions:** Median motor interpolation method is a good technique, but it has less sensitivity and specificity than median sensory interpolation method.

Key Words

Carpal tunnel syndrome, electrodiagnosis, interpolation, nerve conduction velocity

For correspondence:
Dr. Mahshid Naseri, Department of Physical Medicine and Rehabilitation, Shahid Faghihi Hospital, Shiraz University of Medical Sciences, Shiraz, Iran. E-mail: naseri_m@sums.ac.ir

Ann Indian Acad Neurol 2013;16:623-6

Introduction

Carpal tunnel syndrome (CTS) is the most common entrapment neuropathy affecting the median nerve in the wrist. Clinicians usually use electrodiagnostic tests to confirm their impression according to signs and symptoms. Several techniques have been established as standard methods for detecting early CTS. American Association of Neuromuscular and Electrodiagnostic Medicine and American Academy of Neurology proposed a rating system to evaluate diagnostic techniques. They have rated distal sensory latency and transcarpal conduction study including median wrist-palm-sensory conduction time, median wrist-palm-mixed nerve conduction time and the difference between the median and ulnar wrist-palm-mixed nerve conduction time as high, reflecting a high degree of clinical certainty of these methods.[1,2]

Access this article online	
Quick Response Code:	Website: www.annalsofian.org
	DOI: 10.4103/0972-2327.120495

Although median sensory conductions generally seem to be more sensitive than motor conductions, some studies have found a good sensitivity for median terminal latency ratio and wrist-palm motor conduction velocity even more than sensory techniques.[3,4] The motor latency difference between the second lumbrical muscle and second interosseous muscle is another valuable study for CTS diagnosis.[5,6]

The low correlation between the patients' signs and symptoms and electrodiagnostic tests results in mild CTS cases makes this diagnosis challenging, even after using many other possible methods in addition to the above-mentioned techniques.[7-14] A relatively new assessment method is somatosensory evoked potential. Ilkhani *et al*., studied this test evaluating patients with mild idiopathic CTS symptoms and found its utility especially in those with normal nerve conduction velocity (NCV) results.[15] Median nerve conduction study evaluation after a provocative test (e.g., wrist flexion) may also be helpful for diagnosis of the mild CTS.[16]

Bodofski E-B introduced another new electrodiagnostic test for CTS; interpolation; a mathematical method used for the first time for finding median NCV exactly at carpal tunnel site. This technique omits the effects of nerve conduction velocities at other points along the nerve, which are necessarily involved in routine average velocity determination over the wrist-palm segment.[17] Later, Bahrami *et al*., studied median motor conduction velocity with this method and compared it with mid-palm antidromic sensory method for mild CTS diagnosis and obtained different results. They found less sensitivity and specificity for median motor interpolation technique than Bodofsky did. Furthermore, they concluded that mid-palm antidromic sensory technique has a significantly greater sensitivity and specificity than motor interpolation method.[18]

Polynomials interpolation technique actually was invented by Isaac Newton with wide use in engineering, physics and chemistry. The formula of polynomials interpolation applied to the conduction velocity is based on the assumption that acceleration is constant at any point of the nerve and that the NCV is reduced in a linear way along the nerve. This is previously studied and mentioned in the literature.[19] For median nerve study, there are three data points. Since one can fit n (x, y) data points together with a unique equation of degree (n-1), for our study the equation is degree two or a quadratic equation. The three data points for median motor nerve with stimulus at the wrist and elbow are the elbow latency and distance, wrist latency and distance and finally the terminal latency (1.1 ms and distance = 0).[17] The duration of time between cathodal current initiation and that necessary to achieve sodium activation with ensuing propagation is referred to as the latency of activation (utilization time) and has duration of approximately 0.1 ms.[20] In the point with distance = 0 (over recorder) for recording sensory nerve action potential (SNAP) this latency should be considered. For motor nerve action potential recording at such point, the time required to achieve neuromuscular transmission, which is approximately 1 ms also should be added to the latency of activation. Therefore, at the point with distance = 0 the motor action potential latency (motor terminal latency) is 1.1 ms.[20]

The specific formula for $n = 3$ is:

$$p(x) = y_0 + (x-x_0)\,(x, x_1) + (x-x_0)\,(x-x_1)\,(x_0, x_1, x_2)$$

where x_0, x_1, x_2 are the X values (latency) at the three data points; y_0, y_1, y_2 are the corresponding Y data points (distance of recorder) and the "divided differences".

$$(x_0,x_1) = (y_1-y_0)/(x_1-x_0),\ (x_1,x_2) = (y_2-y_1)/(x_2-x_1),\ \text{and}\ (x_0, x_1, x_2 = ((x_1, x_2)-(x_1,x_0))/\,(x_2-x_0)$$

This method is available on most major statistical programs and we just need to enter the three data points into a spreadsheet. The first derivative of this equation predicts the velocity at a given point along the nerve.[17]

To the best of our knowledge, this is the first study using this technique for median sensory nerve. We aimed to evaluate interpolation method for measuring both median motor and sensory nerve conduction velocities as a CTS diagnostic test.

Materials and Methods

Patients and healthy appearing control subjects were selected from those who came to our electrodiagnostic clinics between January 2009 and April 2010. We categorized the patients based on electrodiagnosis to three classes:

- Class I: 3.5 ms≤ distal median sensory latency (DMSL) <4.6 ms
- Class II: 4.6 ms≤ DMSL ≤ 5.5 ms
- Class III: 5.5< DMSL.

We included patients with two or more clinical symptoms and signs of CTS including numbness, tingling, clumsiness, weakness and nocturnal awakening in a median nerve territory that were categorized as Class I according to DMSL measurement from the middle finger. Patients with the history of diabetes mellitus or impaired glucose tolerance test, peripheral neuropathy, cervical radiculopathy and brachial plexopathy and also those in Class II or III (DMSL ≥ 4.6 ms) were excluded.

The controls were aged matched healthy appearing volunteers without signs and symptoms of CTS. After their initial evaluation with electrodiagnostic tests, the subjects with DMSL equal or more than 3.5 ms or distal median motor latency more than 4.2 ms were excluded (to exclude subjects with subclinical CTS). Finally, 60 cases and 58 controls remained in the study.

All subjects and controls gave written informed consent to participate in the study and research protocol was approved in the Ethics Committee of our University.

The tests were performed by a MEDLEC SYNERGY VIASIS electromyography with bar electrodes (two 6 mm felt tips with diameter pads 23 mm apart) as stimulators and recorders. Skin temperature during all studies was at least 31°C and all examinations were carried out in rooms with similar constant temperatures between 23°C and 25°C.

Median compound motor action potentials latencies were recorded at abductor pollicis brevis (APB) muscle belly (motor point) with stimulation at 8 cm proximal to it and also at the cubital fossa.

Median SNAPs latencies were recorded at the third finger (E1 electrode distal to the metacarpophalangeal joint) with stimulation 7 cm and also 14 cm proximal to the recorder at the palm and wrist. Wrist stimulation was applied exactly at the point 2 cm proximal to the distal wrist crease by moving the recorder more proximal or distal if it was necessary. Median sensory and motor conduction velocities were calculated dividing distances between proximal and distal stimulation sites by differences in the latencies.

For determining the median conduction velocity across the canal, we used interpolation technique. Median motor and sensory conduction velocities in a specific point for each hand were calculated by putting the measured distances and latencies in every above-mentioned techniques in the interpolation formula. The three data points for median sensory nerve with stimulus at the wrist and mid-palm are the wrist

latency and distance, mid-palm latency and distance and the terminal latency (0.1 ms) and distance (0 cm) over recorder.[20]

The specific point for estimating the median motor NCV was considered to be at the distance where 15% of the time was spent since stimulation at the wrist until recording at APB, according to Bodofski's study.[17] Bodofsky in his study suggested if 85% of time between wrist stimulation and recording point over APB subtracts from the total time, then we will have latency that means the time between wrist and a point exactly in carpal tunnel. In the other words, this time is 15% of the total latency. Based on this concept, this is actually 15% of the median motor latency at the wrist that determines the estimated velocity about 1.5 cm distal to the wrist stimulation site exactly in the carpal tunnel. For the median sensory nerve, we considered this point just at the middle of the distance between stimulation sites at the wrist and palm, which would be 3.5 cm distal to the stimulus at the wrist. Because the wrist stimulation site is 2 cm proximal to the distal wrist crease, the target point is clearly located in the carpal tunnel based on our anatomy knowledge.[21]

All data were analyzed using Statistical Package for the Social Sciences (SPSS) version 16. Descriptive statistics (means and standard deviations) were reported for each nerve conduction value. Chi-square and Student's *t*-test were used for comparing group differences. Cut-off points were calculated using receiver operating characteristic (ROC) curve.

Results

In the patient group, there were 60 hands, 25 (41.7%) from men and 35 (58.3%) from women. In the control group, among a total number of 58 hands, 37 (68.8%) were men's and 21 (36.2%) were women's.

The average median sensory nerve latency at the wrist was 3.93 ± 0.27 ms in the case and 3.16 ± 0.16 in the control group and the average median sensory nerve latency at mid-palm were 1.86 ± 0.16 ms in the case and 1.73 ± 0.12 ms in the control group.

The average median motor and sensory nerve conduction velocities in carpal tunnel with interpolation method were calculated and compared in the case and control groups and the difference between groups was significant ($P < 0.0001$, two sample *t*-test, Table 1).

The average median motor NCV in the forearm and average median transcarpal sensory NCV (with mid-palm antidromic sensory method) were also measured and the case and control groups' difference was significant ($P < 0.0001$, two sample *t*-test, Table 1).

The median motor NCV cut-off point between the case and control subjects was calculated 37.41 m/s and the median sensory NCV cut-off point was calculated 41.69 m/s in the interpolation method.

Using these cut-off points, a sensitivity of 88%, specificity of 67%, positive predictive value (PPV) and negative predictive value (NPV) of 70.8% and 84.7% were obtained for motor NCV and a sensitivity of 98.3%, specificity of 91.7%, PPV and NPV of 91.9% and 98.2% were obtained for sensory NCV.

Discussion

This study shows that interpolation not only improves motor techniques for diagnosis of mild CTS, as Bodofsky said, but also provides greater sensitivity and specificity for sensory conduction studies.

The average DMSL was 3.93 ms in the case group and 3.16 ms in the healthy controls. Comparing the average DMSL difference between the case and control groups in our study with Bahrami's study results (3.97 ms in cases and 3.1 ms in controls) and Bodofski's study results (5.1 ms in cases and 3.07 ms in healthy subjects) shows a greater difference in Bodofski's study. It can be explained by considering that we recruited only mild cases.

Statistical significance of the difference between motor velocity in the carpal tunnel of the case and control groups can question the belief that mild CTS involves the sensory fibers first. Motor fibers involvement occurs early in the course of the disease, but it can be very mild and difficult to be detected with conventional electrodiagnostic methods. This is in the same line with previous results.[17,18]

There is a greater difference in average median motor NCV in the carpal tunnel with interpolation method between cases and controls in Bodofski's study than the other two studies and so greater sensitivity, specificity, PPV and NPV of median motor NCV with interpolation method, which is due to lack of excluding more severe cases [Tables 2 and 3].[17,18]

Although Interpolation method for median motor NCV has high sensitivity and specificity for diagnosis of mild CTS, but due to Bahrami's study and our findings these are lower than antidromic sensory stimulation method at the wrist and mid-palm.

To the best of our knowledge, median sensory NCV by interpolation method was not calculated and studied as a diagnostic technique before. Bodofsky stated that it is not

Table 1: Average median nerve conduction velocity using different methods

NCV group	Motor (routine)	Sensory (routine)	Motor (across canal)	Sensory (across canal)
Control	56.58±5.95	49.58±6	42.02±4.59	45.82±2.42
Case	50.12±7.58	33.7±3.9	33.59±4.25	38.43±2.71

NCV=Nerve conduction velocity

Table 2: Average median motor NCV using interpolation method in three studies

Study group	Bodofski□s study	Bahrami□s study	Our study
Control	43.2	40.34	42.02
Case	32	34.73	35.59
Difference	11.2	5.63	6.43

NCV=Nerve conduction velocity

Table 3: Comparison of the median motor interpolation diagnostic technique in three studies

Study test characteristics	Bodofsky (%)	Bahramy (%)	Our study (%)
SEN	96.70	85.50	88
SPE	94.70	85	67
PPV	96.70	94.60	70.80
NPV	94.70	65.40	84.70

SEN=Sensitivity, SPE=Specificity, PPV=Positive predictive value, NPV=Negative predictive value, NCV=Nerve conduction velocity

Table 4: Comparison of the median sensory NCV measurement with interpolation technique and mid-palm antidromic sensory method

Method test characteristics	Interpolation (%)	Mid-palm antidromic (%)
SEN	98.30	91.60
SPE	91.70	89
PPV	91.90	87.30
NPV	98.20	91.40

SEN=Sensitivity, SPE=Specificity, PPV=Positive predictive value, NPV=Negative predictive value, NCV=Nerve conduction velocity

likely that a much higher sensitivity or specificity would be obtained with this technique. We studied it and found that it is very sensitive and specific in differentiation of mild cases of CTS from normal subjects [Table 4].

Study limitations

We know that CTS is more common in women. Although we matched cases and controls regarding the age, but they were not closely matched with regards to all demographic data such as gender.

Conclusion

In mild CTS, median motor nerve involvement is common, but it can be very limited and cases may remain undiagnosed with usual electrodiagnostic tests. According to our findings, median motor interpolation method is a good technique, but with less sensitivity and specificity than median sensory interpolation method for such cases. We suggest performing more well-designed studies to evaluate median sensory interpolation method to see whether it can be helpful in mild CTS diagnosis.

Acknowledgment

This study is a part of thesis of Abbas Daghaghzadeh (Grant no: 1552). Hence, we would like to thank Shiraz University of Medical Sciences for supporting the research.

References

1. Chang MH, Liao YC, Lee YC, Hsieh PF, Liu LH. Electrodiagnosis of carpal tunnel syndrome: Which transcarpal conduction technique is best? J Clin Neurophysiol 2009;26:366-71.
2. Chang MH, Liu LH, Lee YC, Wei SJ, Chiang HL, Hsieh PF. Comparison of sensitivity of transcarpal median motor conduction velocity and conventional conduction techniques in electrodiagnosis of carpal tunnel syndrome. Clin Neurophysiol 2006;117:984-91.
3. Lee KY, Lee YJ, Koh SH. Usefulness of the median terminal latency ratio in the diagnosis of carpal tunnel syndrome. Clin Neurophysiol 2009;120:765-9.
4. Chang MH, Wei SJ, Chiang HL, Wang HM, Hsieh PF, Huang SY. Comparison of motor conduction techniques in the diagnosis of carpal tunnel syndrome. Neurology 2002;58:1603-7.
5. Meena AK, Srinivasa Rao B, Sailaja S, Mallikarjuna M, Borgohain R. Second lumbrical and interossei latency difference in carpal tunnel syndrome. Clin Neurophysiol 2008;119:2789-94.
6. Banach M, Słowik A, Szczudlik A. The value of motor latency difference measurements between the second lumbrical muscle and second interosseous muscle in the diagnosis of carpal tunnel syndrome. Neurol Neurochir Pol 2002;36:657-67.
7. Perić Z, Sinanović O. Sensory-motor index is useful parameter in electroneurographical diagnosis of carpal tunnel syndrome. Bosn J Basic Med Sci 2006;6:23-7.
8. Uzar E, Tamam Y, Acar A, Yucel Y, Palanci Y, Cansever S, *et al.* Sensitivity and specificity of terminal latency index and residual latency in the diagnosis of carpal tunnel syndrome. Eur Rev Med Pharmacol Sci 2011;15:1078-84.
9. Sheu JJ, Yuan RY, Chiou HY, Hu CJ, Chen WT. Segmental study of the median nerve versus comparative tests in the diagnosis of mild carpal tunnel syndrome. Clin Neurophysiol 2006;117:1249-55.
10. Loong SC, Seah CS. Comparison of median and ulnar sensory nerve action potentials in the diagnosis of the carpal tunnel syndrome. J Neurol Neurosurg Psychiatry 1971;34:750-4.
11. Prakash KM, Fook-Chong S, Leoh TH, Dan YF, Nurjannah S, Tan YE, *et al.* Sensitivities of sensory nerve conduction study parameters in carpal tunnel syndrome. J Clin Neurophysiol 2006;23:565-7.
12. Schuhfried O, Vacariu G, Kopf A, Paternostro-Sluga T. Relative slowing of the median antidromic sensory nerve conduction velocity to the ring finger in screening for carpal tunnel syndrome. J Hand Surg Am 2004;29:947-52.
13. Demirci S, Sonel B. Comparison of sensory conduction techniques in the diagnosis of mild idiopathic carpal tunnel syndrome: Which finger, which test? Rheumatol Int 2004;24:217-20.
14. Scelsa SN, Herskovitz S, Bieri P, Berger AR. Median mixed and sensory nerve conduction studies in carpal tunnel syndrome. Electroencephalogr Clin Neurophysiol 1998;109:268-73.
15. Ilkhani M, Jahanbakhsh SM, Eghtesadi-Araghi P, Moayyeri A. Accuracy of somatosensory evoked potentials in diagnosis of mild idiopathic carpal tunnel syndrome. Clin Neurol Neurosurg 2005;108:40-4.
16. Emad MR, Najafi SH, Sepehrian MH. The effect of provocative tests on electrodiagnosis criteria in clinical carpal tunnel syndrome. J Electromyogr Kinesiol 2009;19:1061-3.
17. Bodofsky EB. Diagnosing mild carpal tunnel syndrome with interpolation. Electromyogr Clin Neurophysiol 2004;44:379-83.
18. Bahrami MH, Rayegani SM, Nouri F. Study of interpolation method in diagnosis of carpal tunnel syndrome and comparison with midpalm antideromic sensory method. Electromyogr Clin Neurophysiol 2009;49:259-62.
19. Bodofsky EB. A mathematical model for peripheral nerve conduction velocity. Electromyogr Clin Neurophysiol 2003;43:223-9.
20. Dumitru D, Amato AA, Zwarts M. Electrodiagnostic Medicine, 2nd ed. Philadelphia: Hanley and Belfus, Inc; 2002. p. 176-7.
21. Standring S. Wrist and hand. In: Standring S, editor. Gray's Anatomy: The Anatomical Basis of Clinical Practice, 40th ed. New York: Churchill Livingstone; 2008. p. 878-9.

How to cite this article: Ashraf A, Daghaghzadeh A, Naseri M, Nasiri A, Fakheri M. A study of interpolation method in diagnosis of carpal tunnel syndrome. Ann Indian Acad Neurol 2013;16:623-6.
Received: 29-05-13, **Revised:** 09-07-13, **Accepted:** 25-07-13
Source of Support: Shiraz University of Medical Sciences,
Conflict of Interest: Nil