Vibrometry in Carpal Tunnel Syndrome: Correlations with Electrodiagnositic Parameters and Disease Severity†

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† *The abstract of this manuscript was presented on April 16, 2009 as poster presentation at the 4th Asian and Oceanian Congress of Clinical Neurophysiology, Seoul, Korea*
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Objective: *Find correlations among vibratory parameter, electrodiagnostic study, and severity in carpal tunnel syndrome (CTS).*
Material and Method: *The hands of 87 patients were grouped according to severity, no CTS, mild, moderate, or severe CTS. Single-frequency (100 Hz) vibrometry and conventional nerve conduction studies (NCS) were tested. Vibratory parameters included threshold of digit 1 (VT1), threshold of digit 2 (VT2), threshold difference of digit 1-5 (VTD1-5) and threshold difference of digit 2-5 (VTD2-5). The correlations were found among the data; vibratory parameters obtained from 'mild CTS' and 'no CTS' groups were compared.*
Results: *All vibratory parameters were inversely correlated with sensory nerve action potential amplitude of median distribution at low level. VTD2-5 also correlated with median distal sensory latency, median-ulnar latencies difference, and median-radial latencies difference at low level. The correlations of disease severity and vibratory testing were between 0.422-0.617 ($p < 0.001$). There were no significant differences between vibratory parameters of 'mild CTS' and 'no CTS' groups.*
Conclusion: *Vibratory parameters have low level of correlation with NCS but low to moderate magnitude of correlation with severity of CTS.*

Keywords: *Vibrometry, Carpal tunnel syndrome, Nerve conduction study, severity*

J Med Assoc Thai 2011; 94 (7): 801-6
Full text. e-Journal: *http://www.mat.or.th/journal*

The diagnosis of carpal tunnel syndrome (CTS) is based on clinical features and can be confirmed by electrodiagnostic tests. Most nerve conduction study (NCS) parameters yield high sensitivity in assessing CTS[1-3], while some can predict the outcomes of treatment[4,5]. Furthermore, electrodiagnosis provides severity grading of CTS, which may be used as a guide for therapy selection[6,7].

Vibrometry is another tool that has been investigated for a wide range of clinical applications in peripheral neuropathies from various causes, including evaluation of CTS[8,9]. This non-invasive method, relying on the patient's response to induced vibratory stimuli, can detect dysfunctions along the somatosensory pathway. It has been shown to be a reliable method for evaluation of CTS[10]. Although many authors have reported its limitations in early diagnosis of CTS[11-13], some have supported its usefulness in follow-up treatment outcomes[14,15]. Unlike electrodiagnosis, there is no widely accepted grading assessment based on vibrometry. This may be due to a lack of evidence regarding its relationship with disease severity and NCS parameters. The objective of the present study was to find correlations among vibratory parameters, electrodiagnostic study and severity in CTS.

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Material and Method

The present study included 87 patients who had suspected clinical features of CTS. The diagnosis of CTS was made when there were persistent or intermittent sensory symptoms partly in the median nerve distribution or in the whole hand with at least

one abnormal NCS parameter: distal sensory latency (DSL), distal motor latency (DML), median-ulnar latency difference (MULD) and/or median-radial latency difference (MRLD). The patients who had the following conditions were excluded: diabetes, previous wrist fractures, finger amputation, trauma of median nerve, cervical radiculopathy, ulnar neuropathy and other neurological conditions. Hands with CTS were evaluated by an orthopedic surgeon and were grouped according to severity. The following criteria was used[16], mild CTS was intermittent paresthesia or numbness with or without decreased in touch sensation, moderate CTS was persistent paresthesia or numbness with decreased or loss of sensation to pin prick testing and severe CTS was weakness or atrophy of abductor pollicis brevis with any symptoms and signs. The hands without clinical features or electrodianostic evidences were labeled as 'no CTS'.

Vibrometry was done by a computerized single-frequency vibrometer at 100 Hz, VSA-3000 (Medoc, Israel). The subjects were tested in a room with ambient temperature maintained between 28 $\pm$ 2°C and were given 15-20 minutes to adjust to the environmental temperature. An initial practice trial was administered before obtaining the vibratory threshold (VT) in digits 1, 2, and 5 by the method of limits. For each site, six trials were done with the highest and the lowest value erased and the remaining results averaged. The vibratory parameters for each subject were VT of digit 1 (VT1), VT of digit 2 (VT2), VT difference of digits 1-5 (VTD1-5) and VT difference of digits 2-5 (VTD2-5).

NCS were measured with an electrodiagnostic unit, Keypoint Portable (Dantec, Denmark). The skin temperature recorded on a subject's hands was kept over 31°C. Sensory nerve action potential (SNAP) was assessed antidromically and distal latency was measured from the initiation of the stimulus to the onset of action potential, using digit 2 for the median nerve. For median-radial comparison, the ring electrodes were placed at the thumb and two stimulations were done for each nerve keeping the conduction distances equal. For median-ulnar comparison, the difference in distal latencies from wrist to digits 2 and 5 was calculated using the same conduction distance. Compound motor action potential (CMAP) was assessed by recording on abductor pollicis brevis muscle, with a supramaximal stimulation of the median nerve at the wrist and proximally at cubital fossa. The reference values for Thai subjects from previous studies were applied[17,18].

Pearson's product-moment correlation was calculated for the relationship between vibratory and NCS parameters. For correlations with disease severity, Spearman's rank test was used. An independent student t-test was performed to analyze the parameters among 'mild CTS' and 'no CTS' groups. Wilcoxon's rank-sum test was applied for comparison of non-parametric data (CMAP amplitude). To reduce type I error, statistical significance was set at $p = 0.001$.

Results

The diagnosis of CTS was made in 126 hands of 80 patients. There were 69 women and 11 men with a mean age of 41.5 (range 25-63) years. The involvement was bilateral in 46 patients (57.50%) and unilateral in 34 patients (42.5%). Numbness was the most common presenting symptom (96.8%). After clinical assessment, 63 (50.0%) hands were classified as mild, 51 (40.5%) hands as moderate and 12 (9.5%) hands as severe.

All electrodiagnostic and vibratory parameters have significant correlations with disease severity as shown in Table 1. The inversed relations were found only in SNAP and CMAP amplitudes. The Spearman correlation coefficient was highest for DSL ($r = 0.621$) and lowest for CMAP amplitude ($r = -0.396$). For other

Table 1. Correlations of electrodiagnostic and vibratory parameters with severity of CTS

Parameters	Correlations with severity of CTS (Spearman r)
Electrodiagnostic	
DSL	0.621
DML	0.557
SNAP amplitude	-0.509
CMAP amplitude	-0.396
MRLD	0.619
MULD	0.592
Vibratory	
VT1	0.507
VT2	0.573
VTD1-5	0.422
VTD2-5	0.617

All correlations are significant at $p < 0.001$

DSL = distal sensory latency; DML = distal motor latency; SNAP = sensory nerve action potential; CMAP = compound motor action potential; MRLD = median-radial latency difference; MULD = median-ulnar latency difference; VT1 = vibratory threshold of digit 1; VT2 = vibratory threshold of digit 2; VTD1-5 = vibratory difference of digit 1-5; VTD2-5 = vibratory difference of digit 2-5

NCS parameters, the relationships were moderately strong. All of the vibratory parameters had positive correlations with severity; the r values were between 0.422 and 0.617. VTD1-5 showed the lowest value, considered as a low level of correlation. While VTD2-5 revealed the highest relationship for vibratory testing, it was still lower than two of the electrodiagnostic parameters, DSL and MRLD.

The correlations between electrodiagnosis and vibratory parameters are shown in Table 2. All vibratory parameters were inversely correlated with SNAP amplitude ranging from -0.313 to -0.370. No significant correlation existed between motor NCS and vibratory parameters. Unlike VT1 and VTD1-5, which only showed a relationship with SNAP amplitudes, VT2 also correlated with DSL and VTD2-5 with DSL, MRLD and MULD. The highest r values were noted between VTD2-5 and sensory NCS parameters, but all were at a weak level.

Forty-two hands did not meet the diagnostic criteria of CTS according to clinical and electrophysiological assessments, 31 and 11 hands respectively. The means of the parameters among 'no CTS' and 'mild CTS' groups are demonstrated in Table 3. The vibratory parameters did not significantly differ between the two groups. In addition, no meaningful difference existed for SNAP amplitude, CMAP amplitude, and DML. However, significantly higher values of DSL, MRLD, and MULD were noted in the 'mild CTS' group.

Table 2. Correlations between electrodiagnostic and vibratory parameters

Parameters	VT1	VT2	VTD1-5	VTD2-5
DSL	0.188	0.292*	0.157	0.375*
DML	0.094	0.223	0.017	0.264
SNAP amplitude	-0.313*	-0.318*	-0.319*	-0.370*
CMAP amplitude	-0.133	-0.232	-0.072	-0.270
MRLD	0.124	0.231	0.153	0.365*
MULD	0.149	0.271	0.122	0.364*

* $p < 0.001$

DSL = distal sensory latency; DML = distal motor latency; SNAP = sensory nerve action potential; CMAP = compound motor action potential; MRLD = median-radial latency difference; MULD = median-ulnar latency difference; VT1 = vibratory threshold of digit 1; VT2 = vibratory threshold of digit 2; VTD1-5 = vibratory difference of digit 1-5; VTD2-5 = vibratory difference of digit 2-5

Table 3. Electrodiagnostic and vibratory parameters in 'no CTS' and 'mild CTS' groups

Parameters	No CTS (n = 42)	Mild CTS (n = 63)
Electrodiagnostic		
DSL (msec)	2.56 ± 0.310	2.90 ± 0.56*
DML (msec)	3.94 ± 0.57	4.65 ± 1.72
SNAP amplitude (μV)	56.48 ± 23.50	50.85 ± 29.93
CMAP amplitude (mV)	12.19 ± 8.79	11.16 ± 3.250
MRLD (msec)	0.57 ± 0.39	1.15 ± 0.78*
MULD (msec)	0.27 ± 0.30	0.68 ± 0.61*
Vibratory		
VT1	0.94 ± 0.61	0.96 ± 0.51
VT2	0.87 ± 0.45	0.86 ± 0.38
VTD1-5	0.10 ± 0.36	0.22 ± 0.35
VTD2-5	0.03 ± 0.23	0.12 ± 0.23

Values are mean ± standard deviation

Vibratory parameters are expressed in microns of displacement

* $p < 0.001$

DSL = distal sensory latency; DML = distal motor latency; SNAP = sensory nerve action potential; CMAP = compound motor action potential; MRLD = median-radial latency difference; MULD = median-ulnar latency difference; VT1 = vibratory threshold of digit 1; VT2 = vibratory threshold of digit 2; VTD1-5 = vibratory difference of digit 1-5; VTD2-5 = vibratory difference of digit 2-5

Discussion

The assessment of CTS severity has an influence upon decision making for appropriate treatments; it also provides outcome measurements after intervention. This can be done several ways: clinical grading by subjective complaints and objective neurological findings[16], self-administered questionnaire[19], or electrodiagnosis[1]. Vibrometry is another simple and non-invasive method for the clinical evaluation of peripheral neuropathy. Although its role in the early diagnosis of CTS is not supported by many authors[11-13], the applications for severity grading and measuring treatment outcomes remain. Our attempts to seek the relationships between severity and vibratory parameters revealed a significant correlation at a moderately strong level, providing additional evidence to support the use of this tool in the evaluation of CTS severity.

The correlation of electrodiagnostic parameters and CTS severity has been reported in many studies[19-21]. Levine et al reported an insignificant correlation between the overall symptom severity scale and the sensory conduction velocity of the median nerve[19]. While You et al found significant

correlations between individual symptoms and NCS parameters, the highest magnitude of correlation (r = -0.58) was found between SNAP amplitude and primary symptoms: numbness, tingling, and nocturnal symptoms[20]. The varying degree of correlation from both studies may be due to different study protocols. In the present study, the severity grading was based on both symptoms and neurological examinations; this could explain why the higher magnitudes of correlations than the previous studies were found.

Low correlations between electrodiagnostic and vibratory parameters found in the study were supported by previous reports[8,12,22]. Werner et al had found that the magnitude of the correlation coefficients were stronger when comparing the vibratory threshold of the second digit to median DSL rather than SNAP amplitudes[22]. This was in contrast to the present study, in which the authors found that VT2 correlated to SNAP amplitudes at a higher magnitude than median DSL. Moreover, VT1 and VTD1-5 had significant relationships with SNAP amplitudes but not with median DSL. Another different aspect the authors found was for VTD2-5; while no significant correlations existed with MULD in Werner et al[22], the present research found a significant correlation at a low magnitude. A different setting in utilizing vibrometry and the studied populations may account for the different degrees of correlations. The previous report attempted to screen CTS in industrial workers by vibrometry with the CTS symptoms being absent in most of the workers (94/130 cases). While in the present study, the calculated correlations were done in all electrophysiologically confirmed CTS cases and the subjects with milder symptoms and more advanced cases (moderate and severe CTS) were equal in numbers. As the disease severity increases, axonal degeneration is more involved[9,23]. Vibratory threshold increases as the number of intact axons supplying the subcutaneous tissue declines. The finding of an inverse correlation between SNAP amplitudes and all vibratory parameters in our setting signifies that vibrometry serves as an index of sensory axon loss in more advanced CTS.

According to the results, vibrometry failed to distinguish between hands with mild involvement and hands with no CTS. This implies that in mild CTS the parameters would also be normal. Therefore, the test alone should not be used for outcome measurements in such cases or screening for mild CTS. In addition, since vibratory thresholds reflect the amount of axons in peripheral nerves, it would be more appropriate to use this tool for follow-up evaluation in more advanced CTS with axonal loss. With baseline evaluation, vibrometry may be used to quantitatively assess the recovery of sensory function in CTS patients who underwent surgical procedures or moderate CTS during the conservative approach. Moreover, CTS patients who had experienced pain and discomfort from prior nerve conduction study; physicians may choose vibrometry as an alternative approach for follow-up studies in such cases.

Some limitations in the present study should be noted. The widely used symptom severity scale from Boston CTS questionnaires[19] was not applied here; rather, the severity grading schemes followed the usual approach orthopedic surgeons use to assess patients. The present study was also instrument-dependent due to the vibrometry protocols and fixed vibration frequency at 100 Hz. These factors may limit the generalizability of the results. Despite this, the levels of correlation found in the present study were not much different from previous reports. Although vibrometry is not a suitable screening tool for early CTS, its use in conjunction with clinical assessment may be helpful for evaluating severity and follow-up in moderate to severe cases.

Conclusion

The severity of CTS has a moderately strong correlation with most of the vibratory parameters. Vibrometry is not suitable for screening early CTS, but may be helpful for evaluating severity.

Potential conflicts of interest

The research grant was supported by Queen Savang Vadhana Memorial Hospital, The Thai Red Cross Society.

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การศึกษาความสัมพันธ์ระหว่างการรับรู้แรงสั่นสะเทือน การตรวจไฟฟ้าวินิจฉัย และความรุนแรงของโรคในภาวะเส้นประสาทมีเดียนถูกกดทับบริเวณอุโมงค์ข้อมือ

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วัตถุประสงค์: *เพื่อศึกษาความสัมพันธ์ระหว่างการรับรู้แรงสั่นสะเทือน การตรวจไฟฟ้าวินิจฉัยและความรุนแรงของโรคในภาวะเส้นประสาทมีเดียนถูกกดทับบริเวณอุโมงค์ข้อมือ*

วัสดุและวิธีการ: *จำแนกความรุนแรงของภาวะเส้นประสาทมีเดียนถูกกดทับบริเวณอุโมงค์ข้อมือในผู้ป่วย 87 ราย เป็นระดับต่าง ๆ ได้แก่ ไม่เป็น น้อย ปานกลาง หรือ มาก ทำการตรวจการรับรู้แรงสั่นสะเทือนที่ความถี่ 100 เฮิรตซ์ และการตรวจไฟฟ้าวินิจฉัย ค่าการตรวจการรับรู้แรงสั่นสะเทือน ได้แก่ ระดับเริ่มรับรู้แรงสั่นสะเทือนของนิ้วหัวแม่มือ ระดับ เริ่มรับรู้แรงสั่นสะเทือนของนิ้วชี้ ผลต่างระดับเริ่มรับรู้แรงสั่นสะเทือนของนิ้วหัวแม่มือกับนิ้วก้อย และผลต่างระดับเริ่มรับรู้แรงสั่นสะเทือนของนิ้วชี้กับนิ้วก้อย คำนวณสัมประสิทธ์สหสัมพันธ์ระหว่าง ค่าการตรวจการรับรู้แรงสั่นสะเทือน ค่าการตรวจไฟฟ้าวินิจฉัย และกับความรุนแรงของภาวะเส้นประสาท มีเดียนถูกกดทับบริเวณอุโมงค์ข้อมือ และเปรียบเทียบค่าการตรวจระหว่างกลุ่ม 'ไม่เป็น' และกลุ่ม 'ความรุนแรงน้อย'*

ผลการศึกษา: *ค่าการตรวจการรับรู้แรงสั่นสะเทือนทุกค่ามีความสัมพันธ์เชิงลบที่ระดับต่ำกับแอมพลิจูดของเส้นประสาท รับรู้มีเดียน ผลต่างระดับเริ่มรับรู้แรงสั่นสะเทือนของนิ้วชี้กับนิ้วก้อยมีความสัมพันธ์เชิงบวกที่ระดับต่ำกับค่าการชักนำประสาทส่วนปลายของเส้นประสาทรับรู้มีเดียน ผลต่างค่าการชักนำประสาทของเส้นประสาทมีเดียน-อัลน่าและผลต่างค่าการชักนำประสาทของเส้นประสาทมีเดียน-เรเดียล ค่าสัมประสิทธิ์สหสัมพันธ์ของการตรวจการรับรู้แรงสั่นสะเทือนกับความรุนแรงของภาวะเส้นประสาทมีเดียนถูกกดทับบริเวณอุโมงค์ข้อมือได้ 0.422-0.617 ($p < 0.001$) ไม่พบความแตกต่างอย่างมีนัยสำคัญทางสถิติของค่าการตรวจการรับรู้แรงสั่นสะเทือนในกลุ่ม 'ไม่เป็น' และกลุ่ม 'ความรุนแรงน้อย'*

สรุป: *ค่าการตรวจการรับรู้แรงสั่นสะเทือนมีความสัมพันธ์ระดับต่ำกับค่าการตรวจไฟฟ้าวินิจฉัยแต่มีความสัมพันธ์ที่ระดับต่ำถึงปานกลางกับความรุนแรงของภาวะเส้นประสาทมีเดียนถูกกดทับบริเวณอุโมงค์ข้อมือ*