Original Article

Sonographic measurements of the median nerve in the diagnosis of Carpal tunnel syndrome

HSIN-PAI LEE¹, KUO-MING, WANG ², YI-CHING HUANG^{3*}

¹Department of Orthopedics, Pingtung Christian Hospital, Pingtung, TAIWAN

² Department of Rehabilitation Taoyuan Armed Forces General Hospital, TAIWAN

^{3*} Department of Exercise and Health Science, 112 National Taipei University of Nursing and Health Sciences, TAIWAN

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Abstract:

Problem statement: The relationship between Carpal tunnel syndrome (CTS) and vigorous physical activity has been well documented. The effectiveness of sport medicine is often dependent on early diagnosis.

Approach: This study used a cross-sectional survey and purposeful sampling design. It is to explore sonographic measurements of the median nerve for diagnosis of carpal tunnel syndrome and to determine the accuracy of measurements obtained on sonograms by using nerve conduction studies as gold standard.

Results: All sonographic measurements of the median nerve, including thickness ($p < 0.01$), width ($p < 0.001$) and cross-sectional area ($p < 0.001$) are significantly larger in patients with CTS than in healthy controls. High correlation between electrophysiologic studies and sonographic measurements of the median nerve cross-sectional area were found in current study.

Conclusions: It is a quick and easy method of obtaining diagnostic information with its improvement of resolution. To develop this unique imaging modality to its greatest potential in the realm of neuromuscular disease, there is a need for ongoing research that evaluates normal and diseased controls.

Key words: Sport medicine, injury management, nerve compression, physical activity

Introduction

Carpal tunnel syndrome (CTS) is a frequent cause of compression neuropathy, caused by the compression of the median nerve in the carpal tunnel (Keles, Karagulle Kendi, Aydin, Zog, & Orkun, 2005; Yesildag et al., 2004). More than 50% of CTS cases are idiopathic, but it can be secondary from many diseases such as traumatic, degenerative, inflammatory, vascular, constitutional, or space occupying lesions (Beekman & Visser, 2003; Duncan, Sullivan, & Lomas, 1999; Sarria, Cabada, Cozcolluela, Martinez-Berganza, & Garcia, 2000). CTS has been associated frequently with some chronic diseases, such as diabetes mellitus (Gazioglu, Boz, & Cakmak, 2011; Karpitskaya, Novak, & Mackinnon, 2002; Ozkul, Sabuncu, Kocabey, & Nazligul, 2002; Perkins, Olaleye, & Bril, 2002), hemodialysis (Mizumoto, Hashizume, Senda, Nagoshi, & Inoue, 2003; Takahashi et al., 2002) etc. Studies have shown that the prevalence of CTS ranges between 1.5% and 2.7% in the general population (Bland & Rudolfer, 2003; Mondelli, Giannini, & Giacchi, 2002). Symptoms of CTS usually start gradually, with burning pain, tingling, numbness and parenthesis in the palm of the hand and the fingers, especially the thumb and the index and middle fingers. Occupations or physical activities that involve repetitive wrist movements appear to increase the risk of developing idiopathic distal median neuropathy. The relationship between CTS and vigorous physical activity has been well documented (Izzi, Dennison, Noerdlinger, Dasilva, & Akelman, 2001; Mosher, 1985; Werner & Plancher, 1998). The high competitive sports usually need to be the higher loading training. Repeated flexion and extension have been suggested as the cause of median nerve compression in tennis (Werner & Plancher, 1998).

Diagnosis of CTS is usually based on a combination of clinical signs and electromyography (EMG) (Duncan et al., 1999; Gazioglu et al., 2011). Carpal tunnel syndrome (CTS) can be diagnosed by most of the clinicians only with some symptoms of the patients and clinical tests (Sarria et al., 2000). Although electromyographic examination is accepted as the gold standard for the diagnosis, it has a false negative rate of 10–20% (Buchberger, Schon, Strasser, & Jungwirth, 1991) besides it does not provide information about the nerve itself and surrounding which might be important for the etiology. In recent years, magnetic resonance imaging (MRI) and ultrasonography have become imaging alternatives (Chloros, Cartwright, Walker, & Wiesler, 2009). As an imaging method, sonography has been found to be a precise method to display the anatomy of the

median nerve, and several studies have shown sonography to have high sensitivity and specificity for the diagnosis of idiopathic CTS (Hammer, Hovden, Haavardsholm, & Kvien, 2006).

Musculoskeletal ultrasound is rapidly becoming a part of physical examination. It is a quick and easy method of obtaining diagnostic information with its improvement of resolution. MRI imaging may be better in sonography in subtle cases because of its soft tissue contrast (Wong, Griffith, Hui, Tang, & Wong, 2002) and because it has the additional diagnostic feature of showing signal changes caused by edema. Imaging has a confirmatory role like electrodiagnosis. Since ultrasound has proven to be similarly effective method like MRI; it should gain more importance in case of equivocal results from nerve conduction studies (NCS), needle electromyography (EMG) and/or prior to endoscopic surgery (Buchberger, Judmaier, Birbamer, Lener, & Schmidauer, 1992). One of the disadvantages of needle EMG is its invasive and sometimes painful nature, with a small but finite risk of direct injury to nerves, blood vessels, and vital structures (Boon, Alsharif, Harper, & Smith, 2008). Ultrasound provides high-resolution imaging of soft tissue, fascia planes, and neurovascular structures, and the use of real-time ultrasound guidance for needle placement during nerve conduction studies (NCS) and needle electromyography (EMG) can increase accuracy and decrease risk in certain settings (Boon et al., 2008). Trends toward medical cost-reduction have made musculoskeletal ultrasound an attractive alternative to other more expensive imaging methods, such as MRI. The current study is to explore sonographic measurements of the median nerve for diagnosis of carpal tunnel syndrome and to determine the accuracy of measurements obtained on sonograms by using nerve conduction studies as gold standard.

Method

Participants

One hundred and twenty three wrists of 71 consecutive patients with carpal tunnel syndrome were studied. The 52 women and 19 men in this group were 24-81 years old (mean±SD: 57.51±14.24 years). All patients had pain and sensory impairment in the distribution of the median nerve. Electrodiagnostic studies were done in all patients. Criteria used in the diagnosis of CTS were a median distal motor nerve latency of more than 4.0 ms or a median motor nerve conduction velocity of less than 50 m/s across the carpal tunnel (Werner & Andary, 2011). Forty-three wrists of 26 asymptomatic controls (21 women, 5 men) were 19-74 years old (mean±SD: 35.85±15.29 years). No electrodiagnostic studies were performed in the controls group.

Research Instruments

The ultrasound investigations and measurements were performed with a Sonosite L38/10-5 MHz linear transducer (Sonosite 180 Ultrasound system, Bothell, WA). The wrists were imaged in both longitudinal and transverse orientations. With the wrist in neutral position, the distal volar crease was used as the external landmark and the pisiform was used as internal landmark. During sonography the patient sat in a chair with both forearms and the hands in horizontal-supine position on an examination table. Sonographic measurements of the median nerve were obtained from the longitudinal and transverse images of the carpal tunnel. The cross-sectional area of the median nerve was calculated as an ellipse. The transverse dimensions (width) of median nerve were measured by transverse images. The anteroposterior dimensions (thickness) of median nerve were measured by longitudinal images.

Identification of median nerve:

1. The median nerve is best identified on axial imaging planes. The superficial tendon of index finger can be used as a landmark, as it lies just deep to the median nerve. It can be easily distinguished from the other flexor tendon by moving the fingers.
2. Another guiding structure is the tendon of the palmaris longus muscle which lies just volar to the median nerve, superficial to the flexor retinaculum.
3. On axial scans, the median nerve seems to be surrounded by a narrow echogenic rim possibly representing the perineural fibrous tissue.
4. On sagittal scans, the median nerve can be distinguished from the flexor tendons by watching the tendons gliding within the sheaths during flexion and extension of the fingers.
5. Echogenicity of the tendons and the nerve depends on the angle of ultrasound beam. They appear both echogenic when the ultrasound beam is perpendicular to their surface, and echo-poor when it is oblique.

The nerve conduction studies records included median distal motor nerve latency, median motor nerve conduction velocity, median distal sensory nerve latency and median sensory nerve conduction velocity.

Design and procedure

A cross-sectional, purposive sampling design was used. After consent was obtained from the school, students' parents and class teachers of all grades at the semester began, students were asked to complete the health screening questionnaire and basic data under the supervision of their parents to facilitate the physical fitness. Academic achievement was assessed by the weighted academic score in the 3rd month.

Data Analysis

The SPSS 17.0 statistics package was applied to analyze the collected data after coding and decoding according to the research objective and the characteristics of variants. Statistical analysis was performed with

methods such as mean, standard deviation, independent samples t-test, and Pearson's correlation coefficients. $p < 0.05$ is deemed statistically significant.

Ethical considerations

The study was approved by the Human Research Ethics Committee, National Taipei University of Nursing and Health Sciences. Participants were given detailed information of study procedures. All participation in this study was voluntary and participants were allowed to withdraw from the project during the period of the study without penalty. The experiments reported in the article were undertaken in compliance with the current laws of the country in which the experiments were performed.

Results

Means, standard deviations and t-tests for comparisons of sonographic measurements of the median nerve between patients with CTS and healthy controls are summarized in table 1. All sonographic measurements of the median nerve, including thickness ($t=3.14$, $p < 0.01$), width ($t=7.93$, $p < 0.001$) and cross-sectional area ($t=8.34$, $p < 0.001$) are significantly larger in patients with CTS than in healthy controls. Descriptive statistics of electrophysiologic studies in 71 patients (123 wrists) with CTS are shown in table 2. The mean of the median distal motor nerve latency, ranging from 3.10 ms to 12.90 ms, is more than 4.0 ms. The motor latency of median nerve is mostly, 105 of 123 wrists, more than 4.0 ms. The mean of the median motor nerve conduction velocity, ranging from 22.00 m/s to 59.00 m/s, is less than 50 m/s across the carpal tunnel. The motor nerve conduction velocity is mostly, 96 of 123 wrists, less than 50 m/s.

Table 1. Sonographic measurements of the median nerve in 71 patients (123 wrists) with CTS and 26 healthy controls (43 wrists)

Variables	Patients with CTS		healthy controls		t-test
	Mean	SD	Mean	SD	
Thickness (mm)	2.75	1.05	2.24	0.34	3.14**
Width (mm)	6.01	0.96	4.78	0.58	7.93***
Cross-sectional area (mm ²)	14.33	2.14	11.47	1.16	8.34***

SD: standard deviation; ** $p < 0.01$; *** $p < 0.001$

Table 2. Electrophysiologic studies in 71 patients (123 wrists) with CTS

Variables	mean	SD	minimum	maximum
Motor nerve latency (ms)	4.90	1.12	3.10	12.90
Motor nerve conduction velocity (m/s)	43.92	6.84	22.00	59.00
Sensory nerve latency (ms)	3.76	1.12	2.50	10.50
Sensory nerve conduction velocity (m/s)	39.57	8.72	13.00	56.00

Table 3 shows correlation between the sonographic measurements and electrophysiologic studies in 71 patients (123 wrists) with CTS. Motor nerve latency and sensory nerve latency are significantly and positively correlated with width and cross-sectional area. The correlations range from 0.35 to 0.38 ($p < 0.001$). However, motor nerve conduction velocity and sensory nerve conduction velocity are significantly and negatively related to width and cross-sectional area. The correlations range from -0.39 to -0.42 ($p < 0.001$).

Table 3. Correlation between the sonographic measurements and electrophysiologic studies in 71 patients (123 wrists) with CTS

Variables	thickness	width	cross-sectional area
Motor nerve latency	0.02	0.37***	0.38***
Motor nerve conduction velocity	-0.01	-0.39***	-0.40***
Sensory nerve latency	0.02	0.35***	0.36***
Sensory nerve conduction velocity	-0.01	-0.42***	-0.42***

*** $p < 0.001$

Different cut-off points were studied for the criterion of sonographic measurements by means of the Receiver Operating Characteristic (ROC) curve (fig. 1). The current study calculates the cut-off value of cross-sectional area of the median nerve using ROC curve and indicates that 13.12 mm² is the best estimated value. Thus, the authors define that a pathologic mean cross-sectional area of median nerve for CTS is larger than 13.12 mm². According to the cut-off point, the current study gains a sensitivity of 0.732 and a specificity of 1.000.

Ninety true positive and 43 true negative wrists are obtained, while 33 false negative and 0 false positive wrists are counted. The results yield a positive predictive value of 100%, a negative predictive value of 56.6%, and the accuracy of 80.1%.

Fig. 1 - Receiver operating characteristic curve of cross-sectional area

Discussion

We found a high correlation between electrophysiologic studies and sonographic measurements of the median nerve cross-sectional area in current study. Empirical studies have shown the same findings (Buchberger et al., 1991; Kaymak et al., 2008; Pastare, Therimadasamy, Lee, & Wilder-Smith, 2009). Musculoskeletal ultrasound is rapidly becoming a part of physical examination. It is a quick and easy method of obtaining diagnostic information with its improvement of resolution. MRI imaging may be better in sonography in subtle cases because of its soft tissue contrast (Wong et al., 2002) and because it has the additional diagnostic feature of showing signal changes caused by edema. Since ultrasound has proven to be similarly effective method likes MRI; it should gain more importance in case of equivocal results from NCS, needle EMG excluding the disadvantages of needle EMG (Boon et al., 2008).

Both MRI and sonography are non-invasive imaging tools which permit assessment of nerve compression characteristics, and the sensitivity and specificity of these diagnostic features vary widely among publishing studies (Mallouhi, Pulzl, Trieb, Piza, & Bodner, 2006; Yucel, Yilmaz, Babaoglu, Acar, & Degirmenci, 2008). However, MRI is cost intensive, time consumptive and sonography is more available and has higher resolution (Lee, Kim, Yoon, & Dhong, 2005; Mallouhi et al., 2006). Two more interesting supportive results were found in the correlative study. Firstly, there was significant positive correlation between distal motor latency and median nerve cross-sectional area, similar to literature. Nakamichi and Tachibana (2002) found a significant correlation between the cross-sectional area and distal motor nerve latency and also sensory nerve conduction velocity of median nerve. Ziswiler et al. (2005) found a high concordance between sonography and nerve conduction velocity.

Our study had several limitations. First, we performed no correlations with the body mass index or hand physiognomies (small or strong wrists), which may influence the median nerve thickness. Second, sonographic measurement is an operator-dependent test, and appropriate experience is required to ensure reliability and reproducibility. In this study, we collected no data on inter- or intraobserver variability. Third, 10%–15% of patients with CTS have an anatomic variation involving a division of the median nerve into two or three parts at the inlet of the carpal tunnel.

Conclusions

It is a quick and easy method of obtaining diagnostic information with its improvement of resolution. To develop this unique imaging modality to its greatest potential in the realm of neuromuscular disease, there is a need for ongoing research that evaluates normal and diseased controls, the most appropriate site for nerve measurement, the utility of patient-derived control measures, the effect of various body metrics, and more detailed evaluation of changes in nerves over time with different disease processes.

Cost-effectiveness measures are also necessary. Ultrasound can readily demonstrate the subtle anatomic changes even after carpal tunnel release, there is strong indication for its use in the follow-up of post carpal

tunnel release patients. The possibility of sonographically guided intervention and treatment is also another field for further work.

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