Original Article

Accuracy in the Cross-Sectional Area of the Median Nerve at the Wrist Measured by Physical Medicine and Rehabilitation Residents

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ABSTRACT

Objectives: This study aimed to evaluate the accuracy of median nerve cross-sectional area (CSA) measurements at the wrist made by Physical Medicine and Rehabilitation (PMR) residents after a single training session.

Study design: Cross-sectional study

Setting: PMR Outpatient Unit, Phramongkutklao hospital, Bangkok, Thailand

Subjects: The study enrolled patients aged 20 years or over who had undergone median nerve conduction studies and were willing to sign the consent form.

Methods: A single-session ultrasound workshop on measuring the CSA of the median nerve at the wrist was provided to 17 PMR residents. Each resident was required to measure the median nerve CSA of five different wrists of patients who visited the electrodiagnostic laboratory in 2022-2023. The CSA was averaged from three separate measurements by each of the residents. Measurement of each wrist from a single expert physiatrist was considered as a reference standard. The intraclass correlation coefficient (ICC) was used to determine the accuracy of CSA measurement. Additionally, agreement on the determination of median nerve enlargement (≥12 cm^2) was made using Cohen's Kappa coefficient.

Results: Of 82 wrists, 64.0% were diagnosed with carpal tunnel syndrome (CTS) based on the electrodiagnosis study. The median nerve was correctly identified in 79 wrists (96.3%). The overall resident's ICC was 0.948 ($p < 0.001$) compared with an expert physiatrist. The Kappa coefficient was 0.849 ($p < 0.001$), with a 92.4% agreement percentage.

Conclusions: US training sessions may benefit PMR residency programs. Further research is needed to determine optimal training duration and frequency and to assess long-term skill retention.

Keywords: median nerve, cross-sectional area, ultrasound, accuracy, residency training

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Introduction

Median neuropathy at the wrist or carpal tunnel syndrome (CTS) is one of the most common issues among those who visit the outpatient unit of the rehabilitation department. It is also the most common focal neuropathy of the upper extremity. Globally, the prevalence of this condition is between 105 and 544 cases per 100,000 population.[1] Patients generally present with pain or numbness at hand, especially during nighttime. The thumb, index, and middle finger were commonly affected, which makes it necessary to differentiate diagnoses of conditions with similar symptoms such as brachial plexopathy and cervical radiculopathy.[2] CTS can be diagnosed by taking a history, performing a physical examination, and conducting a nerve conduction study (NCS). The latter has been recognized as a gold standard diagnostic tool, but patients undergoing NCS might feel discomfort/pain from electrical stimulation.

Diagnostic ultrasound (US) has been studied and developed over the past several decades to diagnose and manage musculoskeletal disorders. It can provide additional information on structural characteristics without causing pain and in less time.[3] Cost-effectiveness was also reported when using the US as a first-line test, confirmed by NCS if the US was negative.[4] Many studies have established the use of the cross-sectional area (CSA) of the median nerve at the wrist measured by the US in diagnosing CTS with sensitivity and specificity of 71.4-96.9 and 56.5-93.6, respectively.[5-7] These results support using US imaging as a routine diagnostic tool combined with the electrodiagnosis study.

The principal limitation of diagnostic US is its operator-dependency, with more examiner experience generally corresponding to more reliable diagnoses. However, several studies have been published recently about the learning process of musculoskeletal US from expert specialists to trainee residents or fellowship doctors. Those studies showed a significant effect of teaching even with a short study time.[8,9]

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In Thailand, residency training in rehabilitation medicine, or physical medicine and rehabilitation (PMR), includes attaining knowledge and skills in the diagnostic US. In PMR, US is generally used in the diagnosis of musculoskeletal disorders but is used less frequently in the diagnosis of focal compressive neuropathies. However, this study evaluated whether measuring median nerve CSA at the wrist to determine CTS should be included in Thailand's PMR residency curriculum, considering resident doctors are new to using the US to diagnose CTS. This research hypothesized that after a single training workshop, PMR residents could accurately measure median nerve CSA at the wrist, compared with an expert in electrodiagnosis and neuromuscular US.

Methods

Study design

A cross-sectional study was conducted between July 2022 and August 2023. The Royal Thai Army Medical Department Institutional Review Board approved this study protocol (R029h/65) on May 6, 2022.

Participants

The sample size was determined using a formula for agreement studies using an interclass correlation coefficient (ICC) with a minimal acceptable reliability of 0.5 and an expected reliability of 0.7.[10] Acceptable levels of type 1 and 2 errors were set up as 0.05 and 0.20, respectively. The calculation shows that the minimum number of wrists that should be included in this study is 79. Considering that 17 resident doctors were trained during the research period, each resident was required to investigate five wrists. Considering that 17 resident doctors were trained during the research period, each resident was required to investigate five wrists. During the study period, sample selection was made with convenience sampling in patients who visited the Electrodiagnostic Laboratory of the Department of Rehabilitation Medicine, Phramongkutklao Hospital. Patients aged 20 years or over who had undergone median nerve conduction studies and were willing to sign the consent form were enrolled to the study. Any patients with wrist deformity, bifid median nerve, a history of undergoing wrist surgery, or having received steroid injection at the investigating wrist were excluded.

Outcome measurement

Before the study, 17 residents (6 for year 1, 6 for year 2, and 5 for year 3) received a 1.5-hour training session for US measurement of median nerve CSA at the wrist by a physiatrist (X.X.) with eight years of experience in the neuromuscular US. The session included a lecture on anatomy and basic sonography. US section focused on distinguishing between the median nerve and surrounding tendons based on the nerve's marked "honeycomb" pattern. The US performed at the inlet level of the wrist was also demonstrated to the group. Then, individual hands-on training was given to each of the residents. Feedback was given individually after each resident attempted to repeat the diagnostic test.[11] All residents were informed of the study's purpose before making their decision about participation. They were assured that they would receive future study opportunities equally, regardless of whether they chose to participate in this study.

The US measurements were made using a SONIMAGE HS1 (Konica Minolta, Tokyo, Japan) with an L18-4 linear array transducer. The participant sat relaxed with forearms in full supination on the examination table. The device setup was as follows: frame rate of 40 frames-per-second, grain of 25. The US transducer was located at the carpal tunnel inlet,[12], with pisiform bone as a landmark of the examined plane.[13-15] The US picture was frozen When the median nerve was located. The CSA was measured in cm^2 using the user software application's 'trace area' menu. The tracing line was drawn at the margin of the hyperechoic line surrounding the median nerve (Figure 1).

An expert and an assigned resident measured the median nerve CSA at the wrist in a private space without knowing each other's value or NCS results. Each examiner performed a US examination three times for the median nerve, and an average value was used in statistical analysis.

For NCS, both Nicolet VikingQuest (Natus Medical, San Carlos, CA, USA) and Synergy On Nicolet EDX systems (Natus Medical) were used. The median nerve's sensory profile was measured at the third digit using a ring electrode 14 cm proximal to the active electrode. In contrast, using a disc electrode, the median nerve's motor conduction study was recorded at the motor point of the Abductor pollicis brevis muscle. Motor nerve stimulation was applied at the wrist (8 cm proximal to the active electrode) and at the elbow. CTS was diagnosed in those with an electrophysiology profile as follows: 1) mild degree if prolonged sensory distal latency (> 4 ms); 2) moderate degree if both abnormal sensory and motor distal latency (> 4.5 ms); 3) severe degree if both prolonged sensory and motor distal latency, with either absent sensory nerve action potentials or abnormal compound muscle action potentials (< 4.1 mV).[16,17]

Statistical methods

For descriptive statistical analysis, mean and standard deviation were used for continuous data, while number and percentage were used for categorical data. The accuracy of CSA measurement was determined using the ICC in a mixed-effects model 18. The agreement to determine the median nerve enlargement (≥ 0.12 cm^2) was determined using Cohen's Kappa coefficient. Additionally, comparing the area under the receiver operating characteristic ROC curve (AUC) was used to establish the equality of overall diagnostic values between residents and an expert.

Figure 1. The CSA measurement of the median nerve using the 'trace area' menu.

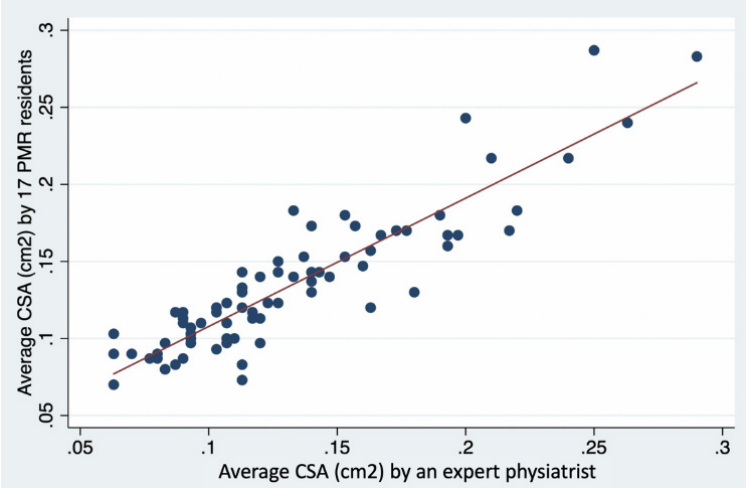

Figure 2. The scatter plot shows the accuracy of median nerve cross-sectional study (CSA) measured by 17 residents (an expert physiatrist as a standard reference).
[PMR, Physical medicine and rehabilitation; cm, centimeters.]

Results

A total of 98 wrists (49 patients) were enrolled in the study. However, 16 wrists were excluded due to the bifid median nerve (6 wrists) and a history of surgery at the wrist (10 wrists). Of the remaining 46 patients, most participants were female (68.0%), with a mean age of 59.8 (13.7). Of the 82 wrists examined, 53.0% were on the left side. Clinical symptoms of CTS were observed in 66 wrists (80.0%), although only 53 (65.0%) had electrophysiological findings of CTS.

Of the 82 wrists examined, residents correctly identified the median nerve in 79 wrists (96.3%). In three wrists, a structure other than the median nerve was misidentified as the median nerve. Thus, only those 79 were included in the statistical analysis. The accuracy of median nerve CSA measurement between residents and an expert physiatrist was represented as ICC, which was 0.948 (95% confidence interval [CI]: 0.919 to 0.967) with $p < 0.001$ (Figure 2).

Compared with the NCS result, the AUC of residents and an expert physiatrist was 0.782 (95%CI: 0.678 to 0.887) and 0.728 (95%CI: 0.613 to 0.844), respectively. However, this difference between AUCs was not statistically significant (chi2(1) = 2.82, $p = 0.093$). The measurement, defined as median nerve enlargement, had a cut-point value of 0.12 cm^2.[13,14] The agreement percentage between residents and an expert physiatrist was 92.4% (Table 1), with a Kappa coefficient of 0.849 ($p < 0.001$).[19]

Discussion

NCS has been known as the gold standard test for CTS. However, patient waiting time for NCS is usually long because this test is time-consuming and generally only available in tertiary care centers. Many studies have recommended using US measurement of median nerve CSA at the wrist to assist in CTS diagnosis. The American Association of Neuromuscular

Table 1. The inter-rater agreement of median nerve enlargement cross-sectional area ≥ 0.12 cm^2) at the wrist determined by residents and an expert physiatrist

US examiner	Expert physiatrist		Total
	≥ 0.12 cm^2	< 0.12 cm^2	
Residents			
≥ 0.12 cm^2	36 (97.3%)	5 (11.9%)	41 (51.9%)
< 0.12 cm^2	1 (2.7%)	37 (88.1%)	38 (48.1%)
Total	37 (100%)	42 (100%)	79 (100%)

CSA, cross-sectional area; US, ultrasound; cm, centimeters

and Electrodiagnostic Medicine stated that US imaging could provide an accurate test for diagnosing CTS.[20] Georgiev et al. also recommended using the US owing to several advantages, mainly the absence of unpleasant perception to patients and cost-effectiveness.[13]

Adequate US training for measuring median nerve CSA at the wrist is imperative for inexperienced operators such as PMR residents. This study found that after a single training session, measurements of median nerve CSA at the wrist by PMR residents were comparable to those by an expert physiatrist. The median nerve was misidentified in only 3 out of 82 (approximately 3.6%) wrists.

The findings of this study were similar to several previous studies. The study of Zumsteg JW et al. recruited six hand surgeon fellows for a 30-minute US training session and evaluated their competency in identifying wrist structures one month after the instruction. The evaluation was to examine several structures, including the CSA of median nerves. The results showed that all six fellows could provide the correct value of the median nerve CSA.[9] Another study focused on sonography imaging training of seven orthopedic residents and five hand fellows by Crasto et al. All participants attended a 5-minute teaching session on basic sonography and a hands-on demonstration on a single cadaver. Immediately after the instruction, all participants could identify and measure the median nerve CSA at the wrist and had increased confidence in performing US imaging.[8]

Although the overall percentage agreement between residents' and an expert physiatrist's determination of median nerve enlargement was strong, the false positive rate from residents' examinations was slightly elevated (11.0%), as shown in Table 1. This finding could reflect a tendency of the residents to overestimate the CSA. Moreover, this could be influenced by their relative inexperience in performing US imaging procedures, leading to errors; for example, US probe placement may not have been perpendicular to the median nerve, or CSA measurement may have included the nerve sheath.

Several strengths could be found in the present study. Firstly, the measurement of median nerve CSA in this study was conducted in clinical practice with 82 wrists examined and 17 inexperienced operators. Hence, the study results had good external validity. Moreover, the enrollment period of the participants was longer than in the previous studies. The accuracy of the CSA measuring was not a temporary proficiency.

Conclusion

• PMR residents' skill in measuring the CSA of the median nerve at the wrist for CTS diagnosis was good compared with an expert physiatrist after receiving a short training session.

• US training sessions would benefit PMR residency programs. Further research is needed to determine optimal training duration and frequency and to assess long-term skill retention.

Limitations

1. No control over residents' prior US experience and practice existed. Hence, year two and year three residents had some basic US skills before the study, and all residents possibly gained US experience from their practices throughout the study enrollment period.

2. Due to the exclusion criteria, residents had no experience identifying bifid median nerves. This exclusion criterion was included due to the lack of consensus on the size of the bifid median nerve that correlates with the diagnosis of CTS. However, several studies suggested that the bifid median nerve is related to CTS.[21,22]

3. The time gap between instruction time and each CSA measurement was not recorded. The difference in gap times could cause inconsistent accuracy in each resident doctor. In the future, monitoring the time since training and the reliability of US tests to schedule additional training sessions optimally would be worthwhile.

Conflict of interest declaration

There are no conflicts of interest or support from the medical equipment.

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Data availability

The data that support the findings of this study are available on request from the corresponding author, N. The data are not publicly available due to information that could compromise the privacy of research participants.

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