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# Baseline Characteristics of the Median Nerve on Ultrasound Examination

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**Abstract**

**Background:** Previous studies using ultrasound for diagnosis of carpal tunnel syndrome have reported on relatively small series of patients, leading to large standard deviations and/or confidence intervals for the mean cross-sectional area of the median nerve. The purpose of this study is to define the CSA of the median nerve in a large cohort of patients. **Methods:** Patients (n = 175) without history of carpal tunnel release were recruited. All participants were evaluated using the Carpal Tunnel Syndrome-6 questionnaire, a validated clinical diagnostic tool, with a score of 12 or greater considered positive for CTS. Ultrasound examination was performed on both wrists of all participants using a 13-6 MHz linear array transducer. **Results:** The mean median nerve CSA was significantly larger ($P < .001$) for patients with a positive (mean = 11.16, SD = 2.51) versus negative CTS-6 result (mean = 6.91, SD = 2.06). There was a significant correlation (.527, $P < .001$, n = 349) between CSA and CTS-6 score. Logistic regression analysis determined that a CSA of 10 mm2 optimized sensitivity and specificity at 80% and 88%, respectively. Accuracy was 87.9%. **Conclusions:** A significant difference in mean CSA was found between patients with and without CTS. Median nerve CSA showed a statistically significant positive correlation with CTS-6. Similar to prior studies, a CSA of 10 mm2 was determined to be the optimal cutoff. In this large series of patients, ultrasound was a sensitive, specific, and accurate test for confirmation of a clinical diagnosis of CTS.

**Keywords:** carpal tunnel syndrome, ultrasound, sonography, diagnosis, median nerve

## Introduction

Carpal tunnel syndrome (CTS) accounts for more than 4 million physician visits per year and more than 600 000 surgeries per year in the United States alone.[6] Electrodiagnostic testing is recommended in patients in whom surgery is being considered.[7] Although electrodiagnostic testing has been considered the reference standard for confirmation of a clinical diagnosis of CTS, there is a false negative rate of 16% to 34% in some series[5,8,13] and the testing is uncomfortable and time-consuming for patients.

The use of ultrasound for confirmation of a clinical diagnosis of CTS is gaining wider acceptance and has been found to have similar sensitivity and specificity to electrodiagnostic testing when using a validated diagnostic tool as the reference standard.[4] In addition, the use of ultrasound as a first-line test in the diagnostic algorithm is a more cost-effective approach than use of electrodiagnostic testing alone.[3]

The determination of normal baseline values is critical for the use of ultrasound for the diagnosis of CTS. Much of the literature is based on relatively small series that lack significant power to accurately define baseline values within a narrow confidence interval.[1,4,9,11,12,14,15] Most studies describing the use of ultrasound have used receiver-operating curves post hoc to determine the best cutoff values to maximize specificity and sensitivity. Furthermore, many of these studies examined primarily a population of patients referred for clinical symptoms of CTS, likely artificially inflating the sensitivity and specificity of the test. A cutoff value between 9 and 11 $mm^2$ is commonly quoted in the literature.[2]

The purpose of this study is to define the cross-sectional area (CSA) of the median nerve in a large cohort of patients using a clinical diagnostic tool as the reference standard.

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## Materials and Methods

Patients presenting to a hand and upper extremity clinic with a variety of complaints were recruited. Patients with a history of previous carpal tunnel release were excluded. A total of 175 patients and 349 wrists met the criteria for inclusion in this study. Demographic information including age, gender, ethnicity, and hand dominance as well as clinical information including height, weight, and presence of diabetes were recorded. All study participants were then evaluated using the CTS-6 diagnostic tool questionnaire. A score greater than or equal to 12 was considered a positive diagnosis of CTS. All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008. Informed consent was obtained from all patients for being included in the study.

Ultrasound examination was performed on both wrists of all participants using a 13-6 MHz linear array transducer (SonoSite M Turbo; SonoSite, Bothell, Washington). 13-6MHz is the range that the probe can scan over though 13 MHz was used in this study. Patients were seated with forearms resting on a table during the examination. Forearms were in a supinated position and wrists in a neutral position. The fingers were allowed to rest in a comfortable position with mild flexion at the metacarpophalangeal and interphalangeal joints. The ultrasound probe was placed just proximal to the level of the pisiform perpendicular to the long axis of the forearm. The electronic ellipse function was used to define the hyperechoic epineurium, which marked the border of the median nerve, and the area within was measured as cross-sectional area. Each measurement was performed 3 times and averaged.

Statistical analysis was then performed using Pearson correlations, independent *t* tests, and logistic regression to determine the relationship between median nerve size and CTS-6 score. Analysis was performed on the entire population of wrists as well as on two subgroups based on hand dominance status.

## Results

A total of 175 patients were administered the CTS-6 questionnaire for one or both wrists, resulting in a total of 349 wrists that were included in the analysis. Of these, the CTS-6 score was greater than or equal to 12 for 35 wrists and less than 12 for 314 wrists. Males comprised approximately 60% of each group. Mean and median age and body mass index (BMI) of the two groups were calculated (Table 1). Approximately 6% of wrists in each group belonged to diabetic patients.

The mean median nerve CSA was significantly larger ($P < .001$) for patients with a positive CTS-6 (mean = 11.16, SD = 2.51) compared with patients with a negative CTS-6 (mean = 6.91, SD = 2.06). There was a significant correlation (.527, $P < .001$, n = 349) between CSA and CTS-6 score (Figure 1). This remained true when hands were separated by dominant or nondominant status (Table 2).

**Table 1.** Patient Demographics.

| | CTS < 12 (n = 314) | CTS ≥ 12 (n = 35) |
|---|---|---|
| Gender | | |
| Male | 174 | 21 |
| Female | 140 | 14 |
| Age, y | | |
| Mean | 52.1 | 57 |
| Median | 55 | 56 |
| Diabetics | 24 | 2 |
| BMI | | |
| Mean | 27.3 | 31.4 |
| Median | 26.6 | 30.7 |

*Note.* CTS, carpal tunnel syndrome; BMI, body mass index.

Logistic regression was performed to determine the most appropriate CSA size cutoff with respect to a CTS-6 score greater than or equal to 12 as the clinical standard for diagnosis. The Youden Index was maximized at a CSA cutoff of 10 $mm^2$ for combined wrists (68.29%) as well as both dominant (64.29%) and nondominant (74.12%) hand subgroups. Likewise, sensitivity and specificity at a CSA cutoff of 10 $mm^2$ were maximized at 80% and 88%, respectively, for the combined group. The overall accuracy of ultrasound in this study was 87.9% (Table 3).

## Discussion

Ultrasound measurement of the CSA of the median nerve at the level of the carpal tunnel inlet is an accurate and cost-effective confirmatory test for a clinical diagnosis of CTS.[2-4,9,10,12,15] Intuitively, one must first understand what is normal to recognize what is abnormal. Previous studies have focused on relatively small cohorts of patients referred specifically for testing to rule out CTS. This high prevalence population likely inflates the sensitivity and specificity of the tests and also results in wide confidence intervals for mean values. The current study attempts to further delineate normal baseline CSA of the median nerve by recruiting a large cohort of patients without CTS. By examining 349 wrists (314 asymptomatic), this represents the largest series of normal controls in the literature.

Our study found the mean CSA of the median nerve at the carpal tunnel inlet to be 6.9 $mm^2$. Nakamichi and Tachibana[10] found the mean CSA of the median nerve at the carpal tunnel inlet to be 10.2 $mm^2$ in 200 control patients. The large difference in the CSA between normal controls in these 2 studies points toward the importance of

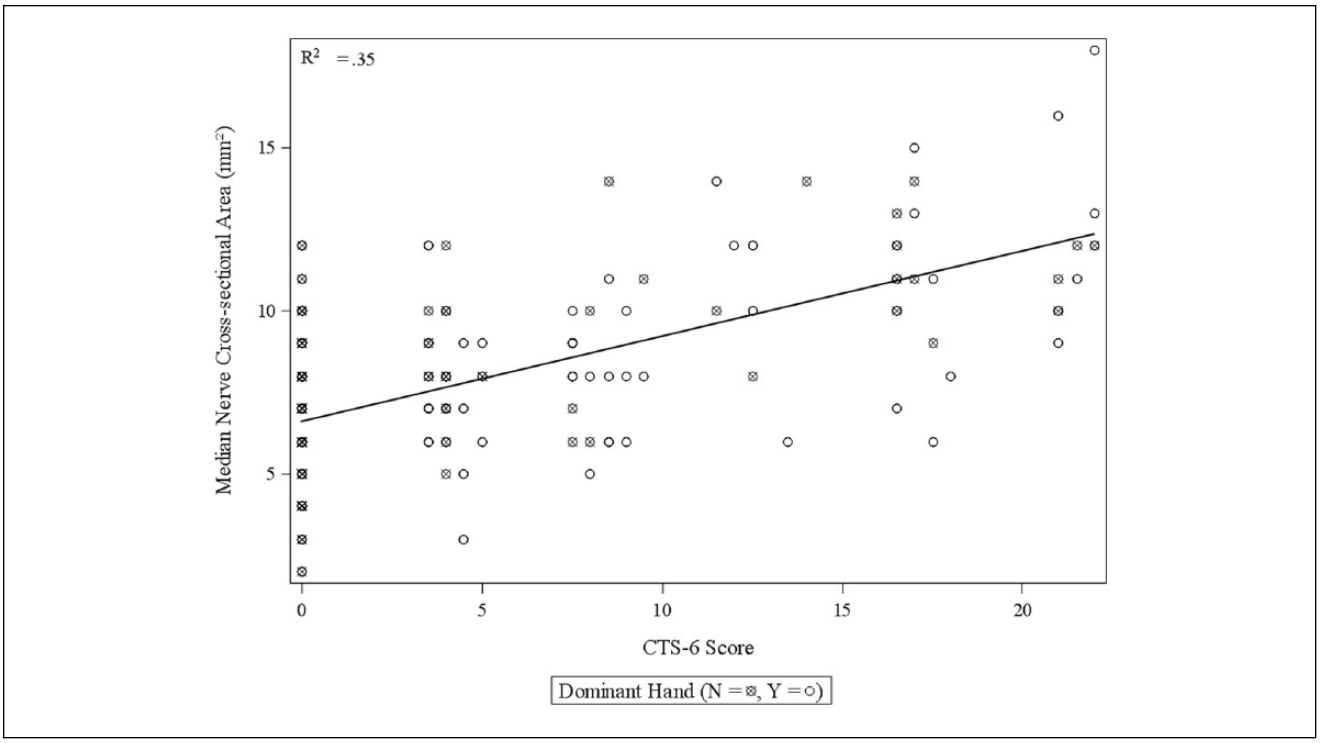


**Figure 1.** Median nerve cross-sectional area versus CTS-6 score by hand dominance.

**Table 2.** Median Nerve CSA in the Presence or Absence of CTS.

| CSA | Presence of CTS[a] Mean (SD) | Absence of CTS[b] Mean (SD) | Association correlation |
|---|---|---|---|
| Combined | 11.16 (2.51) (n = 35) | 6.91 (2.06) (n = 314) | .527* (n = 349, $P < .001$) |
| Dominant hand | 11.09 (2.98) (n = 22) | 7.14 (2.11) (n = 153) | .575* (n = 175, $P < .01$) |
| Nondominant hand | 11.31 (1.80) (n = 13) | 6.75 (2.03) (n = 161) | .599* (n = 174, $P < .01$) |

*Note.* CSA, cross-sectional area; CTS, carpal tunnel syndrome.
[a]CTS-6 score > 12.
[b]CTS-6 score < 12.
*$P < .01$.

**Table 3.** Sensitivity, Specificity, and Accuracy of Ultrasound.

| Parameter | Combined (%) | Dominant hand (%) | Nondominant hand (%) |
|---|---|---|---|
| Sensitivity | 80.00 | 77.27 | 84.62 |
| Specificity | 88.29 | 87.01 | 89.51 |
| Accuracy | 87.85 | 85.96 | 89.66 |

determining normal baseline values. The mean CSA of normal controls approaches the cutoff value for a positive test in our patient population. Nakamichi and Tachibana[10] used a lower frequency probe and studied an Asian population, both factors that could contribute to different results of ultrasound testing. Ziswiler et al[15] found a mean CSA of 7.9 $mm^2$ in patients without CTS and 12.2 $mm^2$ in patients with CTS. This more closely resembles the results of the current study.

Our data have demonstrated that ultrasound has a sensitivity of 80% and specificity of 88%, even in a lower prevalence population than previous studies. These findings mirror the results of a recent meta-analysis that pooled the results of 18 studies to determine the sensitivity and specificity of ultrasound for confirming a diagnosis of CTS.[2] Although these findings are not novel, few studies have reported on the accuracy of a diagnostic test in a large population of mostly normal controls.

This study has several weaknesses. First, the number of patients with positive clinical findings of CTS was relatively small due to the fact that recruitment was not limited to those patients specifically referred for evaluation of CTS. Previous studies have already demonstrated the ability of ultrasound to accurately differentiate between patients with and without CTS. We attempted to determine the baseline values for asymptomatic patients rather than focus on comparing the two groups. Prior studies have used a small cross-matched control group rather than attempting to analyze a large, asymptomatic population of patients. Second, the ultrasonographer was not a certified radiologist. Although this could affect the accuracy of our results, it mirrors real-world practice as hand surgeons who would be performing musculoskeletal ultrasound in the office would likely have limited experience with ultrasound.

This study examines median nerve CSA in a diverse population and uses a cutoff of 12 on CTS-6 score to define symptomatic and asymptomatic groups. No significant differences in the distribution of variables such as age, gender, diabetic status, and BMI were found between the groups, which enhances the generalizability of this study. Although ultrasound was found to be highly sensitive, specific, and accurate for confirming the diagnosis of CTS in this cohort, future studies should also investigate potential differences in CSA cutoff value based on individual patient characteristics.

## Ethical Approval

This study was approved by our Institutional Review Board.

## Statement of Human and Animal Rights

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008. Informed consent was obtained from all patients for being included in the study.

## Statement of Informed Consent

Informed consent was obtained from all individual participants included in the study.

## Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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