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Original Research

Diagnostic Value of Ultrasound in CTS in Diabetic Versus Nondiabetic Populations

Cory Demino, MD,* John R. Fowler, MD†

* Department of Orthopaedic Surgery, University of Pittsburgh Medical Center, University of Pittsburgh School of Medicine, Pittsburgh, PA

† Department of Orthopaedic Surgery, University of Pittsburgh Medical Center, Pittsburgh, PA



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Purpose: Diabetes mellitus (DM) is a well-known risk factor for carpal tunnel syndrome (CTS). However, few studies have compared differences in the cross-sectional area (CSA) of the median nerve in patients with and without DM. The purpose of this study was to compare the utility of ultrasound for the diagnosis of CTS in diabetic versus nondiabetic patients.

Method: A total of 248 hands of 155 patients were evaluated: 154 hands belonged to non-DM patients with CTS, 80 to DM patients with CTS, 13 patients with DM but no CTS, and 51 patients without DM or CTS. All hands underwent ultrasonography of the median nerve at the wrist for determination of CSA; patients completed a CTS Symptom Severity Scale and Functional Status Scale for each hand.

Results: Average CSA (mm²) of non-DM patients with CTS was 11.25 whereas the average in DM patients with CTS was 12.23 ($P = .17$). Cross-sectional area of 9.5 or greater was the most powerful predictor of CTS in patients without DM, and CSA of 10.5 or greater in patients with DM.

Conclusions: Cross-sectional area of the median nerve was similar for patients with and without DM; however, cutoff values for positive diagnosis may need to be adjusted in patients with DM. Ultrasonography of the wrist is a valuable resource for diagnosing CTS in patients with and without DM.

Type of study/level of evidence: Diagnostic II.

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Diabetes mellitus (DM) has been well-established as a risk factor for carpal tunnel syndrome (CTS).^{1,2} A suggested pathophysiology involves high blood glucose levels resulting in the glycosylation of tendon proteins restricting free motion at the carpal tunnel.³ It is estimated that the general population has a prevalence of CTS between 3.8% and 7.8%.^{4,5} A 2015 population-based cohort study found that the prevalence of CTS was higher in patients with diabetes.⁶

Ultrasound measurement of cross-sectional area (CSA) of the median nerve is a noninvasive and painless alternative diagnostic modality for CTS. There are few studies comparing and analyzing differences in CSA measurements of the median nerve in patients with and without DM. Those that exist suggest that there is no

significant difference between ultrasound measured CSA in patients with DM and non-DM patients.^{7,8} There are even fewer studies comparing CSA measurements in insulin-dependent DM (IDDM) patients and non-insulin dependent DM patients.

The purposes of this study were to evaluate median nerve CSA differences between CTS and non-CTS patients with DM and without DM and to determine whether there were differences among DM patients who require insulin therapy. In addition, this study aimed to analyze whether patient-reported severity of CTS symptoms was higher in those with or without DM. We hypothesized that there would be no significant difference in median nerve CSA between DM patients with CTS and non-DM patients with CTS.

Materials and Methods

Study participants

We evaluated and prospectively enrolled patients at our institution whom we clinically suspected had peripheral nerve compression. In patients with involvement of both hands, data for

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Corresponding author: Cory Demino, MD, Department of Orthopaedic Surgery, University of Pittsburgh Medical Center, University of Pittsburgh School of Medicine, 3471 Fifth Avenue, Suite 1010, Pittsburgh, PA 15213.

E-mail address: cjd62@pitt.edu (C. Demino).

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<i>Items</i>	<i>Answers</i>
1. Writing	1–5
2. Buttoning clothing	1–5
3. Holding a book while reading	1–5
4. Gripping a telephone	1–5
5. Opening jars	1–5
6. Household chores	1–5
7. Carrying grocery bags	1–5
8. Bathing and dressing	1–5

Answer range: 1 = no difficulty, to 5 = severe difficulty.

Figure 1. Functional Status Score.

each hand was analyzed separately. A total of 248 hands in 155 patients were included: 184 hands (154 non-DM hands and 30 diabetic hands) with clinical suspicion of CTS and 64 control hands (51 non-DM hands and 13 diabetic hands). Carpal tunnel syndrome was clinically diagnosed by symptoms in the distribution of the median nerve, including (1) decreased strength, paresthesia, or pain in the hand brought on or worsened by sustained hand or arm position or repetitive action of the hand; (2) motor deficit or atrophy of the thenar muscles; (3) physical examination demonstrating sensory deficits in the median nerve distribution of the hand; and (4) positive Phalen or Tinel sign. A clinical diagnosis of CTS was made when 2 or more of the 4 criteria were met and presentation was more suggestive of CTS than other pathologies. In all, 103 hands underwent confirmatory electromyography before inclusion at the discretion of the surgeon.

Diabetes mellitus was diagnosed by World Health Organization criteria: (1) fasting (no caloric intake for 8 or more hours) serum glucose of greater than 126 mg/dL; (2) random serum glucose greater than 200 mg/dL; or (3) 2-hour serum glucose greater than 200 mg/dL, measured during an oral glucose tolerance test and determined by chart review of all patients.

Patient-reported symptom scales

Two patient-reported symptom scales were used for each hand to measure CTS severity in this study: the CTS Functional Status Score (FSS) and the CTS Symptom Severity Scale (SSS). The FSS (Fig. 1) is a scale consisting of 8 daily activities, each of which can be rated on a scale of 1 to 5, in which 5 indicates severe difficulty and 1 is no difficulty at all. Scores were reported as an average of the 8 tasks with a maximum score of 5 and a minimum score of 1. The SSS (Fig. 2) is an 11-question survey with 5 possible answers for each question; it is scored from 1 to 5, in which 1 indicates no symptoms or difficulty and 5 means severe or constant symptoms or difficulty. This scale was reported as an average of the 11 questions scaled from 1 to 5, for a maximum score of 5 for the most severe cases and a minimum score of 1 for no symptoms at all.

Ultrasonographic assessment

All ultrasound examinations were performed by a hand surgeon in an outpatient clinic who was not blinded to the DM status of the patients. Patients were seated across from the examiner with the

elbow placed in approximately 70° flexion, with the dorsum of the hand resting comfortably against the table. The fingers were placed in a normal resting position. A 15- to 16-MHz linear transducer was used to measure the CSA (in mm²) of the median nerve at the level of the pisiform using the trace function.

Statistical analysis

A power analysis of a one-way 4-group independent analysis of variance with power set to 0.80, significance set to .05, and a large effect size demonstrated the need for a sample size of 18 hands/group. Analysis for a 2-sided *t* test to find a difference between 2 groups with power set to 0.80, significance set to .05, and a large effect size demonstrated the need for a sample size of 25 hands/group. Data for each group are presented as mean ± SD. Unpaired *t* test with Welch's correction was used to compare continuous variables across 2 groups. We used one-way analysis of variance analysis to compare data between multiple groups and determine statistical significance. Receiver operating characteristics (ROC) curve analysis was used to determine the CSA, FSS, and SSS values most predictive of CTS hands in both DM and non-DM populations. Statistical analysis was performed using GraphPad Prism 8 software (GraphPad Software, San Diego, CA). *P* < .05 was considered statistically significant and a Bonferroni correction for multiple comparisons of the same data set was used as necessary.

Results

Table 1 lists information regarding patient demographics. There was a predominance of female patients overall (65%) and in all groups except for the non-DM control group, which was predominantly (73%) male. Analysis of CSA by sex yielded no differences between males and females in this study.

Average CSA, FSS, and SSS among non-DM control and CTS hands and DM control and CTS hands are shown in Table 1. The CSA, FSS, and SSS were all significantly different among the 4 compared groups (*P* < .001). There was no significant difference between non-DM and DM control groups (*P* = .36) or between non-DM and DM CTS groups (*P* = .17). There was a significant difference in CSA between the non-DM control group and non-DM CTS patients (*P* < .001) and between the DM control group and DM patients with CTS (*P* < .001).

Name: _____ **SYMPTOM SEVERITY SCALE (CTS)**

The following questions refer to your symptoms for a typical 24hr. period during the last 2 weeks (circle one answer to each question).

<p>1. How severe is the hand or wrist pain that you have at night?</p> <ul style="list-style-type: none"> <input type="radio"/> I do not have hand or wrist pain <input type="radio"/> Mild pain <input type="radio"/> Moderate pain <input type="radio"/> Severe pain <input type="radio"/> Very severe pain 	<p>7. Do you have weakness in your hand or wrist?</p> <ul style="list-style-type: none"> <input type="radio"/> No weakness <input type="radio"/> Mild weakness <input type="radio"/> Moderate weakness <input type="radio"/> Severe weakness <input type="radio"/> Very severe weakness
<p>2. How often did hand or wrist pain wake you up during a typical night in the past two weeks?</p> <ul style="list-style-type: none"> <input type="radio"/> Never <input type="radio"/> Once <input type="radio"/> Two to three times <input type="radio"/> Four or five times <input type="radio"/> More than five times 	<p>8. Do you have tingling sensations in your hand?</p> <ul style="list-style-type: none"> <input type="radio"/> No tingling <input type="radio"/> Mild tingling <input type="radio"/> Moderate tingling <input type="radio"/> Severe tingling <input type="radio"/> Very severe tingling
<p>3. Do you typically have pain in your hand or wrist during the day time?</p> <ul style="list-style-type: none"> <input type="radio"/> I never have pain during the day <input type="radio"/> I have mild pain during the day <input type="radio"/> I have moderate pain during the day <input type="radio"/> I have severe pain during the day <input type="radio"/> I have very severe pain during the day 	<p>9. How severe is numbness (loss of sensation) or tingling at night?</p> <ul style="list-style-type: none"> <input type="radio"/> I have no numbness or tingling at night <input type="radio"/> Mild <input type="radio"/> Moderate <input type="radio"/> Severe <input type="radio"/> Very severe
<p>4. How often do you have hand or wrist pain during the daytime?</p> <ul style="list-style-type: none"> <input type="radio"/> Never <input type="radio"/> Once or twice a day <input type="radio"/> Three to five times a day <input type="radio"/> More than five times a day <input type="radio"/> The pain is constant 	<p>10. How often did hand numbness or tingling wake you up during a typical night during the past two weeks?</p> <ul style="list-style-type: none"> <input type="radio"/> Never <input type="radio"/> Once <input type="radio"/> Two or three times <input type="radio"/> Four or five times <input type="radio"/> More than five times
<p>5. How long, on average, does an episode of pain last during the daytime?</p> <ul style="list-style-type: none"> <input type="radio"/> I never get pain during the day <input type="radio"/> Less than 10 minutes <input type="radio"/> 10 to 60 minutes <input type="radio"/> Greater than 60 minutes <input type="radio"/> The pain is constant throughout the day 	<p>11. Do you have difficulty with the grasping and use of small objects such as keys or pens?</p> <ul style="list-style-type: none"> <input type="radio"/> No difficulty <input type="radio"/> Mild difficulty <input type="radio"/> Moderate difficulty <input type="radio"/> Severe difficulty <input type="radio"/> Very severe difficulty
<p>6. Do you have numbness (loss of sensation) in your hand?</p> <ul style="list-style-type: none"> <input type="radio"/> No <input type="radio"/> I have mild numbness <input type="radio"/> I have moderate numbness <input type="radio"/> I have severe numbness <input type="radio"/> I have very severe numbness 	

Figure 2. Symptom Severity Scale.

Table 1 Patient Demographics

	Non-DM Control	DM Control	Non-DM CTS	DM CTS	P Value
Hands, n	51	13	154	30	
Average age, y	47.6	50.8	52.1	59.1	
M:F	37:14	5:8	42:112	3:27	
L:R hand	30:21	7:6	58:96	14:16	
Average FSS	1.70 ± 0.78	1.90 ± 0.83	2.43 ± 0.84	2.58 ± 0.74	<.001
Average SSS	2.40 ± 0.89	2.22 ± 0.56	3.13 ± 0.78	3.01 ± 0.73	<.001
Average CSA, mm ²	8.84 ± 2.34	8.23 ± 2.05	11.25 ± 3.00	12.23 ± 3.61	<.001

An ROC curve analysis showed that a CSA 9.5 mm² or greater was the most powerful predictor of CTS in patients without DM (area under curve [AUC] = 0.74), and a CSA 10.5 mm² or greater in patients with DM (AUC = 0.85). Moreover, ROC curve analysis

revealed that an SSS 2.60 or greater was the most powerful predictor of CTS in patients without DM (AUC = 0.73), and an SSS 2.64 or greater in patients with DM (AUC = 0.78), whereas an FSS 1.89 or greater was the most powerful predictor of CTS in patients without

ROC: CSA non-DM CTS vs. non-DM Control

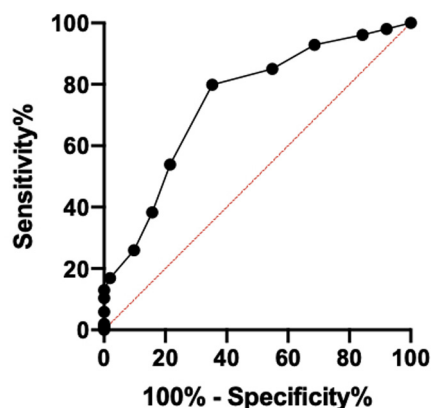


Figure 3. Receiver operating characteristics non-DM control group versus non-DM CTS group.

ROC: CSA all CTS vs. all Control (Combined)

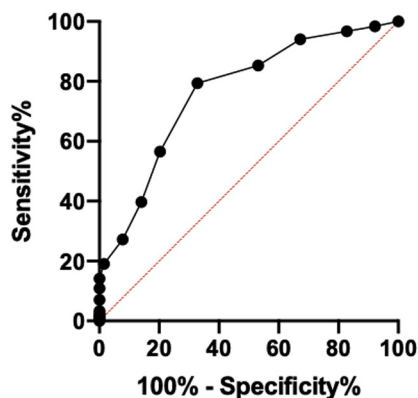


Figure 5. Receiver operating characteristics all-control group versus all-CTS group.

ROC: CSA DM CTS vs. DM Control

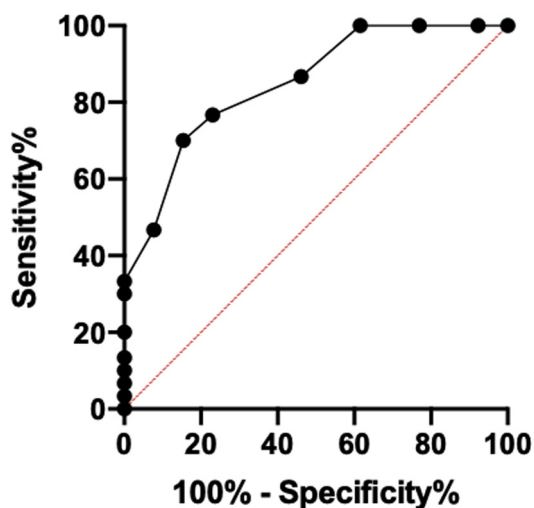


Figure 4. Receiver operating characteristics DM control group versus DM CTS group.

DM (AUC = 0.74), and an FSS 1.82 mm² or greater in patients with DM (AUC = 0.71) (Figs. 3–5).

Average CSA, FSS, and SSS of IDDM and non-IDDM patients of both CTS and control groups are shown in Table 2. The CSA and SSS were significantly different among the 4 compared groups ($P = .001$ and $P = .002$, respectively), whereas the average FSS among the 4 populations was not statistically significant ($P = .07$).

Discussion

Ultrasound measurement of the CSA of the median nerve at the wrist crease is an acceptable alternative to using electrodiagnostic testing for the diagnosis of CTS.^{9,10} However, with any diagnostic test, certain conditions may affect its accuracy. Diabetes mellitus has been proposed as a confounding variable, and patients with DM are often excluded from studies examining the diagnostic accuracy of ultrasound and electrodiagnostic testing.

Interestingly, this study yielded a DM control group that had a smaller average CSA than the control group without DM, although groups showed no statistically significant difference. Patients with DM and CTS had a CSA almost 1 mm² higher than non-DM patients with CTS; however, the difference was also not statistically significant ($P = .17$) as previously mentioned. Although this *t* test comparison between groups was not significant, the ROC analysis suggested a 10.5 mm² cutoff for diabetic patients compared with 9.5 mm² for nondiabetic patients; thus, it is possible that a higher threshold value for diagnosing CTS may be necessary for diabetic patients. Abiding by this ROC analysis, the current threshold of 10 mm² suggested for a diagnosis of CTS would result in false-positive diagnoses in patients with DM. These mixed findings warrant further investigation into whether a larger CSA threshold should be considered in diabetic patients before diagnosing CTS. Therefore, it is critical to use caution in this patient group when interpreting the results of ultrasound CSA with respect to a diagnosis of CTS and when including patients with and without diabetes in research studies.

The CSA of almost 1 mm² higher in DM patients with CTS, although not significant compared with nondiabetic CTS hands, suggests increased nerve inflammation at the time of presentation. However, the similar FSS and SSS between DM CTS and non-DM CTS hands suggest that the level of disability was no worse in this population at the time of presentation. Adopting the cutoff values for diagnosis of CTS determined by this ROC analysis could thus reduce false-positive diagnoses in patients with DM.

This study had several limitations. First, subjects included in this study were treated by a single surgeon in a tertiary referral center. The results may not be generalizable to the general population. Second, a surgeon with extensive experience in ultrasound performed the ultrasound examinations. It is unclear whether inexperienced examiners would replicate these results. However, Hirsch et al noted moderate levels of agreement between inexperienced examiners and an expert examiner¹¹. Third, the number of hands in the control DM group (13) was slightly below the suggested sample size of 18 determined by power analysis. Finally, we did not have enough subjects with insulin-dependent DM to make meaningful conclusions about the difference between non-insulin dependent and insulin-dependent diabetes.

Table 2
Insulin-Dependent DM Versus Non-Insulin Dependent DM Statistics

	Non-IDDM Control	IDDM Control	Non-IDDM CTS	IDDM CTS	P Value
Hands, n	10	3	20	10	
Average age, y	52.9	43.7	58.6	60.1	
M:F	5:5	0:3	2:18	1:9	
L:R hand	6:4	1:2	9:11	5:5	
Average FSS	1.79 ± 0.83	2.25 ± 0.87	2.71 ± 0.77	2.33 ± 0.63	.069
Average SSS	2.12 ± 0.58	2.57 ± 0.38	2.92 ± 0.73	3.20 ± 0.72	.002
Average CSA, mm ²	8.30 ± 2.00	8.00 ± 2.65	11.05 ± 3.10	14.60 ± 3.50	.001

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