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Carpal tunnel syndrome severity staging using sonographic and clinical measures

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Abstract

Introduction—Ultrasonography may be valuable in staging carpal tunnel syndrome severity, especially by combining multiple measures. This study aimed to develop a preliminary severity staging model using multiple sonographic and clinical measures.

Methods—Measures were obtained in 104 participants. Multiple categorization structures for each variable were correlated to diagnostic severity based on nerve conduction. Goodness-of-fit was evaluated for models using iterative combinations of highly correlated variables. Using the best-fit model, a preliminary scoring system was developed, and frequency of misclassification was calculated.

Results—The severity staging model with best fit (Rho 0.90) included patient-reported symptoms, functional deficits, provocative testing, nerve cross-sectional area, and nerve longitudinal appearance. An 8-point scoring scale classified severity accurately for 79.8% of participants.

Discussion—This severity staging model is a novel approach to carpal tunnel syndrome evaluation. Including more sensitive measures of nerve vascularity, nerve excursion, or other emerging techniques may refine this preliminary model.

Keywords

mononeuropathy; carpal tunnel syndrome; sonography; assessment; disease severity

Introduction

Carpal tunnel syndrome (CTS) is the most common entrapment neuropathy of the upper extremity and a common work-related musculoskeletal disorder that results in significant cost and functional disability. Clinical diagnosis of CTS has long been based on symptom reports, which are then confirmed by electrodiagnostic testing. The use of electrodiagnostics as the gold standard for CTS diagnosis has been debated within the literature.^{1–4} Electrodiagnostic testing can be uncomfortable for patients, time consuming, and has false-positive rates of 10–20% and false-negative rates of 16–34%.^{2–6} In recent years,

musculoskeletal ultrasonography has gained increasing use as a point-of-care clinical evaluation tool by orthopedists, neurologists, and other practitioners, and it has been proposed as a complementary first-line test to confirm a CTS diagnosis.^{2,5,7}

Evidence for the use of ultrasonography in the diagnosis of CTS is expanding rapidly. It is available widely, and examinations are cost-efficient, portable, timely, and well tolerated by patients. Sonographic diagnosis is made primarily when the cross-sectional area (CSA) of the median nerve within or near the carpal tunnel is found to be greater than approximately 10mm².^{8,9} As the nerve increases in size, a notched or waistline appearance can often be observed in longitudinal sonographic images due to compression of the nerve as it passes under the flexor retinaculum. This presentation has been described as a longitudinal compression sign and bulbous nerve swelling.^{10,11} Although sensitivity for this sign as a diagnostic criterion has been underwhelming, specificity rates have ranged between 95.8 and 100%.^{10,11} In addition to gray-scale imaging, higher intraneural vascularity has been observed in CTS patients compared to controls.¹² Color Doppler has been reported to have an accuracy rate of 91% for detecting CTS.¹³

Significant heterogeneity exists in accuracy of these individual measures, resulting in some patients demonstrating diagnostic neurophysiologic changes with no measureable change in sonographic parameters. However, improved sensitivity, specificity, and overall accuracy for diagnosing CTS has been achieved by combining multiple sonographic measures.^{14–16} In one study, the probability of having CTS improved from 35% when 1 sonographic measure was used, up to 90% when 3 measures were combined (i.e., CSA, echogenicity, and vascularity).¹² Furthermore, sonographic evidence suggests that there is a continuous and gradual increase in the size of the median nerve as CTS progresses.¹⁷ In early stages, these morphologic changes may exist before the nerve damage occurs that can be picked up by electrodiagnostic evaluations.^{18,19} Once physiological changes progress beyond electrodiagnostic thresholds, the continued increase in CSA has been correlated positively with severity classification.^{8,20} Similarly, intraneural vascularity may be useful for identifying stages and severity of CTS. Increased vascularity is often noted in acute, pre-clinical, and mild stages of CTS as compared to decreased perfusion in more advanced and chronic stages of the disorder.^{21,22}

These findings suggest that ultrasonography may be valuable in grading the severity of CTS, especially when multiple sonographic measures are combined. Although staging systems for CTS diagnosis using multiple sonographic measures have been proposed, optimal measurement parameters for each criterion have not been established. Furthermore, it is unclear exactly which combination of measures is most beneficial for effective diagnosis. Therefore, the purpose of this study was to develop a CTS severity staging model using multiple sonographic and clinical measures. Specifically, we evaluated how ultrasonographic measurement of median nerve CSA, longitudinal nerve appearance, and intraneural vascularity could be combined with subjective patient reports and clinical provocative tests to develop a method for identifying the severity of CTS in a cohort of patients and controls based on electrodiagnostic evaluation.

Materials and Methods

Participants

This study utilized a cross-sectional, case-control design. Patient participants were recruited prospectively at an electromyography clinic following evaluation of suspected CTS; however, patient recruitment was non-consecutive, because the researchers were only available to collect data 2 days per week. Control participants were recruited prospectively from a convenient population who were not seeking medical care. Individuals with uncontrolled diabetes, a history of fractures or surgery in the wrist or hand, previous carpal tunnel release surgery, or who were pregnant or within 3-months post-partum were excluded from either group. Following electrodiagnostic evaluation, patients with confirmed diagnosis of any systemic or peripheral neurologic condition other than CTS were excluded. Similarly, following sonographic evaluation, any participants with bifid median nerve, persistent median artery, Martin-Gruber anastomosis or other space occupying mass within the carpal tunnel were also excluded. The study was approved by the University's Biomedical Institutional Review Board and informed consent was obtained from all participants prior to data collection.

Clinical Examination

Age, gender, hand dominance, height (cm), and weight (kg) were obtained, and body mass index was calculated for each participant. A caliper was used to measure the depth (mm) and width (mm) of each participant's wrist at the distal wrist crease, and the wrist ratio was calculated by dividing the depth by the width. Phalen, Tinel, and Durkan compression tests were completed and considered positive if the individual experienced pain, tingling, or numbness in the sensory distribution of the median nerve in the wrist, hand or fingers. The Boston Carpal Tunnel Questionnaire (BCTQ) was used as a self-reported measure of symptom severity and functional deficits related to median nerve pathology.^{23,24} BCTQ symptom severity and functional deficit scores each ranged from 1 to 5, with a score of 1 indicating an absence of symptoms or deficits.

Electrodiagnostic Testing

Nerve conduction studies were completed for all patient participants by evaluating orthodromic responses with a Synergy tower (Care Fusion, Inc, Middleton, WI). The detailed nerve conduction protocol and fidelity measures used to obtain the data analyzed in this study has been reported previously.⁸ Sensory function was evaluated using sensory conduction velocities and sensory nerve action potentials. Motor function was evaluated using distal motor latencies and compound muscle action potential amplitudes. Sensory and motor impairments were interpreted using thresholds for each of these measures as defined the American Association of Neuromuscular and Electrodiagnostic Medicine standards.²⁵ For diagnostic categorization of participants in this study, findings of no sensory or motor impairment were considered negative, sensory impairments without motor deficits were deemed mild, combined sensory and motor impairments were identified as moderate, and a lack of sensory and/or motor responses were categorized as severe CTS.

Sonographic Image Acquisition

Sonograms were performed using a Logiq-i hand-carried sonographic machine and an 8–12 MHz linear array transducer (GE Healthcare Ultrasound, Milwaukee, WI). Imaging was performed using the musculoskeletal preset, tissue harmonics, and CrossBeam technology. Machine and transducer quality assurance checks were completed weekly using a standardized tissue phantom. Patient sonograms were performed the same day as nerve conduction evaluation, but the sonographers were blinded to nerve conduction study results.

For image acquisition, participants were positioned facing the sonographer with the forearm supine and resting on a flat surface, the shoulder comfortably adducted, and the elbow, wrist, and fingers in a relaxed, neutral position.²⁶ Imaging was completed on the dominant side for all participants. The length of the median nerve was scanned in a transverse plane, proximally to distally, beginning 10 cm from the distal wrist crease through the distal carpal tunnel to the carpometacarpal joint to examine the path of the median nerve and identify anomalies (e.g., bifid nerve, persistent artery). Cross-sectional images of the median nerve were obtained at the carpal tunnel inlet at the distal edge of the radius and in the mid carpal tunnel at the level of the pisiform bone. A longitudinal image of the median nerve was acquired as it passed over the distal radius, lunate, and capitate bones. Transducer positioning was optimized to ensure that the approximate medial-lateral center of the median nerve was obtained fully in plane. In this sagittal view, power Doppler was used to identify intraneural vascularity within the median nerve, and spectral Doppler tracings were obtained to validate the presence of vascularity versus noise artifacts.

Sonographic Image Analysis

Three sonographic data points were acquired for each participant by researchers blinded to group assignment, symptom severity, and nerve conduction study results: (1) median nerve cross-sectional area (CSA), (2) longitudinal irregularity, and (3) intraneural vascularity. Nerve CSA was measured using a direct trace around the inner hyperechoic border of the nerve on transverse images obtained at the carpal tunnel inlet and in the mid carpal tunnel. Each measurement was completed 5 times, the highest and lowest values were discarded, and the remaining 3 values averaged. The largest CSA between the 2 locations was recorded as the median nerve CSA for each participant. Longitudinal irregularity of the median nerve was assessed qualitatively in the sagittal image and categorized as present or absent. Irregularities in the length of the nerve through the carpal tunnel region were defined as a notable change in the smooth, linear appearance of 1 or both hypoechoic borders, or a distinct caliber change indicated by non-parallel borders due to an increase or decrease in anterior-posterior height of the nerve (Figure 1). Finally, intraneural vascularity was documented as present if at least 1 Doppler signal was identified which met the following criteria:²¹ (1) clearly optimized gray scale image, (2) spectral Doppler gate positioned within the hyperechoic borders of the median nerve, (3) color pixel within the spectral Doppler gate, (4) spectral signal greater than baseline noise, (5) more than pulsatility noted in the spectral tracing, and (6) at least 3 cardiac cycles in the spectral sample (Figure 2).

Statistical Analysis

Descriptive statistics were calculated for all variables. Analysis of variance (ANOVA) was used to evaluate differences between patients and controls for continuous variables (i.e., age, body mass index, wrist ratio, BCTQ scores, CSA), and Chi-square tests were used to evaluate group differences for categorical variables (i.e., gender, hand dominance, longitudinal irregularity, intraneural vascularity). Diagnostic variables demonstrating statistically significant differences between the groups were selected for inclusion in the severity scoring system.

As a first step toward developing a clinically relevant scoring system using multiple diagnostic variables, several categorization strategies were explored for each variable to determine the most robust method for assigning points. Provocative tests were evaluated individually using a grouped dichotomous categorization (i.e., no positive tests versus at least 1 positive test), and a 4-level categorization based on the sum of positive tests (i.e., no positive tests, 1 positive test, 2 positive tests, 3 positive tests). For the BCTQ symptoms severity, BCTQ functional deficits, and CSA, a dichotomous categorization was developed with a cut-point established at a score that was 2 SD from the average of the control group. Alternatively, a 4-level categorization was developed for each of these variables with groups divided by those <2, 2–3, 3–4, and > 4 SD from the average of the control group. Finally, published literature⁸ was used to develop a 4-level categorization system CSA with group separated at 10.30 mm², 13.56 mm², and 15.19 mm². Longitudinal irregularity and intraneural vascularity were only evaluated as dichotomous categorical variables.

Following recoding of variables into these categorization systems, the ability of each system to differentiate CTS severity was evaluated by correlating the new variables with diagnostic categorization (i.e., control, negative, mild, moderate, severe). A minimum Spearman Rho of 0.25 was set as selection criterion for inclusion of a variable into the final scoring system. If included, dichotomous variables were assigned a score of 0 or 1, and variables with a 4-level categorization were assigned a score in the range of 0 to 3. A primary scoring model was developed by combining the categorization systems with the highest Spearman correlations for each variable, followed by an iterative process to create models for every additional potential combination of the categorization systems.

Severity scores were calculated for each participant using all of the models, and these scores used to correlate each model with diagnostic categorization. The model with the highest overall Spearman Rho was identified as having the best fit. Using this model, the distribution of severity scores across diagnostic categories based on nerve conduction testing was evaluated, and a preliminary severity classification scale was developed. The frequency of misclassification for the proposed scale was calculated. Statistical significance was set at $P < 0.05$, and strength of association for all correlation coefficients was interpreted as weak (< 0.3), moderate (0.3–0.7), or strong (> 0.7).²⁷ All analyses were performed using SPSS V. 21 (IBM, Chicago, IL).

Results

Descriptive Statistics

A total of 104 participants were recruited prospectively for the study, including 59 patients and 45 controls. Descriptive statistics were calculated and compared between the 2 groups for all demographic and diagnostic variables (Table 1). Both groups were primarily women and right hand dominant. Patients were older, had a larger BMI, and a more square-shaped wrist than controls, which is consistent with the literature on CTS etiology. Clinical diagnostic variables based on the BCTQ and provocative testing were all significantly different between the 2 groups. The average CSA of the median nerve in patients (12.61 mm², SD 4.21) was significantly larger than controls (8.84 mm², SD 1.63). Approximately one-third of patients demonstrated longitudinal irregularity of the nerve, and two-thirds demonstrated intraneural vascularity compared to 15% and 49% of control participants for each measure, respectively.

Diagnostic Variable Categorization

With the exception of intraneural vascularity, all diagnostic variables were significantly different between the 2 groups and were therefore carried forward into the severity modeling process. Data were recoded, and participants were redistributed into the previously described dichotomous or multi-level categorizations for provocative tests, symptom severity rating, functional deficit rating, and CSA (Table 2). Regardless of the categorization system used, all diagnostic variables were correlated significantly with the nerve conduction diagnostic categories (Table 3). For provocative tests, a positive Tinel sign had the lowest correlation with diagnostic category (0.489) while a positive Durkan test had the highest individual correlation (0.680). Having a positive result for at least 1 of the 3 provocative tests was the categorization structure with the strongest correlation with diagnostic category (0.744). Subjective reporting of symptom severity and functional deficits on the BCTQ had a strong correlation to diagnostic category (i.e., > 0.80) using both the 2-level and 4-level categorization structures. For CSA, the 4-level system based on cut-points at 2, 3, and 4 SD from the average of the control group had the strongest correlation with diagnostic categories (0.714). Other categorization options for CSA did not increase the correlation with diagnostic categories significantly from that of the raw data; in fact, a 2-level categorization using a cut-point at 10.3mm² based on the literature reduced the strength of the correlation.

Proposed Severity Staging System

Following testing of all model iterations using combinations of the strongest variable categorization systems, the model with the best fit was identified (Rho 0.90). This model utilized dichotomous scoring for provocative tests, BCTQ symptom severity, BCTQ functional deficits, and sonographic longitudinal irregularity, combined with a 4-level CSA score (Table 4). Using this model, the average severity score for the control group was 0.36 (SD 0.65) compared to 4.10 (SD 1.58) for patients. Patients whose nerve conduction studies were negative had an average score of 3.00 (SD 0.67), whereas those diagnosed as having mild, moderate, or severe CTS by nerve conduction study had average severity scores of 3.67 (SD 1.15), 5.07 (SD 1.44), and 7.00 (SD 0.00), respectively.

Based on these averages and the distribution of scores, a preliminary interpretation was developed: negative (0–1), pre-clinical (2–3), mild (3–4), moderate (5–6), and severe (7) was established. This interpretation accurately classified 83 of the 104 participants (79.8%). The scale underestimated severity for 3 patients who were classified as pre-clinical but had mild CTS based on nerve conduction and 6 patients who were classified with mild CTS but had moderate CTS based on nerve conduction findings. The scoring system overestimated 2 of the control subjects as pre-clinical, 4 patients with negative nerve conduction as mild, 4 patients with mild CTS based on nerve conduction as moderate, and 2 patients with moderate CTS based on nerve conduction as severe.

Discussion

The purpose of this study was to investigate how multiple sonographic and clinical measures could be combined to develop a severity staging model for clinical evaluation of CTS. Intraneural vascularity was the only diagnostic sonographic measure that did not adequately discriminate between patients and controls, thus it was not included in the proposed severity scoring models. Using the model with the highest correlation with electrodiagnostic categorization, a severity scale was developed that combined patient-reported symptoms, functional deficits, provocative testing, median nerve CSA, and sonographic longitudinal appearance of the median nerve. This 8-point scoring system (i.e., range of 0–7) accurately classified CTS severity for 79.8% of participants based on nerve conduction findings.

Diagnosis of CTS has long required a combination of multiple clinical assessments, traditionally including a patient history and symptom report, provocative tests, and electrodiagnostic evaluation.²⁸ Because tissue morphology changes may occur at a different rate than physiologic damage in the etiologic progression of CTS, sonographic measures may have an additional complementary role to these traditional measures for clinical staging of diagnostic severity.^{7,29} The severity staging model and resulting scoring system developed here is a novel exploration and preliminary step in developing an enhanced framework for clinical evaluation for CTS utilizing sonographic measures.

By combining sonography with clinical measures, our preliminary model successfully classified 80% of participants. As with previous studies of sonographic measures, this model was most accurate for individuals with moderate or severe CTS. These findings support previous recommendations that sonographic screening may reduce the need for electrodiagnostic techniques in these advanced cases. However, in acute or mild stages of CTS, ultrasonography and electrodiagnostic testing have reduced sensitivity.^{9,30} In our sample, 2 controls and 3 patients with mild nerve conduction findings were classified as being pre-clinical, and 4 patients with normal nerve conduction were classified as having mild CTS. Although underestimation from mild to pre-clinical may be problematic, it is likely that similar clinical interventions will be provided in either case. In contrast, while it increases potential for provision of unnecessary interventions, what seems to be an overestimation could in fact be a valuable early identification technique that could trigger interventions to slow, stop, or remediate pathologic progression of CTS before physiological damage occurs.

CSA and caliber changes in the nerve as it passes through the carpal tunnel region are used widely as markers of CTS. Recent meta-analyses have noted that the sensitivity and specificity for diagnosing CTS using sonographic CSA range from 78% to 87%,^{2,31,32} compared with 88% sensitivity and 93% specificity for nerve conduction studies.³³ Although these data indicate that gray-scale sonographic evaluations may be useful in initial screening, ultrasonography may not be an exclusive alternative to electrodiagnostic testing for diagnosis. However, our model supports the combined use of increasing CSA and presence of longitudinal irregularities as a potential means for staging CTS severity. Although the majority of the literature supports a diagnostic cut-point for CSA at or near 10mm², our data indicate that a correlation with severity categories is best with a series of cut-points beginning at 2 SD above the average of typical individuals (i.e., 12.1mm²). The difference in our minimum cut-point used to identify severity from the cut-point identified in the literature may be the manifestation of inherent heterogeneity in the accuracy of sonographic and electrodiagnostic results, especially in acute or mild cases. Furthermore, these results suggest that there may be value for exploring how normative data could be useful in advancing the utility of sonographic measures for CTS versus establishing thresholds based on electrodiagnostic results.

Although evidence is increasing for the use of intraneural vascularity as a diagnostic criterion, our measure of vascularity could not differentiate between patients and controls. The data were analyzed using a dichotomous categorization indicating presence or absence of vascularity, a technique that may not have been sufficiently sensitive to detect differences. Measures that result in continuous-scale data, such as the number of Doppler signals within the nerve, the intensity of Doppler signals within image pixels, or the peak systolic flow on spectral tracings, may provide a more robust measure for severity scoring. Additionally, the sensitivity of vascular measures are limited due to the exceedingly small microvasculature and the inability to adequately interrogate the vessels due an incorrect Doppler angle. The use of an injectable contrast agent can increase the signal-to-noise ratio of low-volume blood flow within the nerve and could result in more accurate quantitative measures of nerve perfusion and spectral flow.^{34–36} Finally, unlike nerve caliber, changes in vascularity may not have a linear relationship with increasing severity. While vascularity seems to increase in early stages of CTS, intraneural vascular flow and tissue perfusion have an inverse relationship to severity as the disorder progresses.²¹ Better understanding of this non-linear relationship is needed to more accurately determine how measures of vascularity are included in a severity model.

In addition to the parameters evaluated in this study, other emerging sonographic measures could enhance a severity staging model. Evidence suggests that movement of the median nerve during wrist motion (i.e., excursion) in individuals with CTS may be less than half the typical movement in normal individuals.³⁷ This decrease in median nerve excursion is correlated negatively with the severity of CTS.³⁸ Similarly, decreased echogenicity of the median nerve has been documented as CTS progresses.^{12,16} In a cross-sectional image of a normal median nerve, brighter echoes from the nerve fascicles give a honey-combed appearance, whereas patients tend to present with a darker-appearing nerve. Finally, evaluation of nerve stiffness using sono-elastography could provide additional information regarding severity.

There are several limitations that must be considered when interpreting the results of this study. While all data were collected prospectively, this report is a secondary analysis of data obtained for another study. As such, recruitment methods and data collection techniques were not maximized for the analyses completed. Specifically, control participants were recruited conveniently, not matched to our patient sample, and nerve conduction data were not collected with control participants. Additionally, our patient population was skewed toward the mild category, with fewer individuals in the severe category. Furthermore, the sensitivity of diagnostic categorization using nerve conduction may not have been maximized fully, as no comparative techniques were used. Finally, non-consecutive recruitment of patients on selected days each week could lead to additional bias in our results.

Despite limitations due to the study design, our preliminary severity staging model was highly correlated with severity categorization. This suggests face validity for the use of a combination of sonographic and clinical measures as a means for identifying CTS severity. Further investigation is needed to increase accuracy and establish validity using studies with evenly distributed, case-control matched samples and carefully constructed prospective study designs. The proposed severity staging model presented in this paper provides a foundation on which this future work can build to identify the most sensitive sonographic and clinical measures that are most beneficial for enhancing clinical evaluation for CTS.

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Abbreviations

BCTQ	Boston Carpal Tunnel Questionnaire
CSA	cross-sectional area
CTS	carpal tunnel syndrome
SD	standard deviation

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Figure 1. Longitudinal appearance of the median nerve (arrowheads) as it crosses into and through the carpal tunnel demonstrating the parallel borders of a normal nerve (A), notched/irregular appearance of the nerve borders (B, C), and increased nerve caliber in the proximal (D) and distal (E) carpal tunnel region.

Figure 2.
Intraneural vascularity within the median nerve identified using power and spectral Doppler.

Table 1

Descriptive characteristics of the sample (n=104)

Evaluation Variables	Patients (n=59)	Controls (n=45)	<i>P</i> *
Demographic Variables			
Age, Years (SD)	47.6 (11.5)	38.7 (12.3)	<0.01
Gender, Women, %	74.6	68.9	0.52
Hand Dominance, Right, %	93.2	82.2	0.08
BMI	31.6 (7.8)	26.8 (6.7)	<0.01
Wrist Ratio	0.74 (0.05)	0.71 (0.04)	0.02
Clinical Diagnostic Variables			
Symptom Severity, BCTQ	3.09 (0.80)	1.10 (0.26)	<0.01
Functional Deficits, BCTQ	2.51 (0.86)	1.04 (0.09)	<0.01
Phalen, positive, %	62.7	0.0	<0.01
Tinel, positive, %	42.4	0.0	<0.01
Durkan, positive, %	72.9	2.2	<0.01
Sonographic Diagnostic Variables			
Cross-Sectional Area, mm ² (SD)	12.61 (4.21)	8.84 (1.63)	<0.01
Longitudinal Irregularity, %	37.3	15.6	0.01
Intraneural Vascularity, %	64.4	48.9	0.11

SD, standard deviation; BMI, body mass index; BCTQ, Boston Carpal Tunnel Questionnaire

* *P*-value reported based on results of ANOVA or Chi-square test as appropriate

Table 2

Distribution (%) of individuals by group for diagnostic variables with multiple levels of categorization.

Diagnostic Variable Categories	Patients (n=59)	Controls (n=45)
Positive Provocative Tests [*]		
None	20.3	97.8
One	13.6	2.2
Two	33.9	0.0
Three	32.2	0.0
Symptom Severity Rating (BCTQ) [†]		
< 1.62	1.7	93.3
1.62 – 1.88	6.8	2.2
1.88 – 2.14	1.7	4.4
> 2.14	89.8	0.0
Functional Deficit Rating (BCTQ) [†]		
< 1.22	5.1	91.1
1.22 – 1.31	1.7	4.4
1.31 – 1.40	6.8	4.4
> 1.40	86.4	0.0
Cross-Sectional Area, mm ^{2†}		
< 12.10	50.8	97.8
12.10 – 13.73	22.0	2.2
13.73 – 15.36	3.4	0.0
> 15.36	23.7	0.0
Cross-Sectional Area, mm ^{2‡}		
< 10.30	35.6	84.4
10.30 – 13.56	35.6	2.2
13.56 – 15.19	5.1	0.0
> 15.19	23.7	0.0

BCTQ, Boston Carpal Tunnel Questionnaire

^{*} Categories created by summing all positive tests per participant

[†] Categories created using cut-points at 2, 3, and 4 standard deviations from the average of the control group

[‡] Categories created based on cut-points established in published literature⁸

Table 3

Spearman Rho correlations between potential categorization systems for diagnostic variables and diagnostic category of participants based on nerve conduction testing.

Variables	Categorization System	Rho
Provocative Tests	Phalen Only	0.615
	Tinel Only	0.489
	Durkan Only	0.680
	*Two Levels: One or More Positive Test	0.744
	Four Levels: Sum of Positive Tests	0.719
Symptom Severity Rating (BCTQ)	Raw Score	0.737
	*Two Levels: 2 SD	0.834
	*Four Levels: 2, 3, and 4 SD	0.863
Functional Deficit Rating (BCTQ)	Raw Score	0.756
	*Two Levels: 2 SD	0.808
	*Four Levels: 2, 3, and 4 SD	0.836
Cross-Sectional Area	Raw Score	0.680
	Two Levels: 2 SD	0.692
	*Four Levels: 2, 3, and 4 SD	0.714
	Two Levels: Based on Literature	0.629
	Four Levels: Based on Literature	0.697
Longitudinal Irregularity		
	*Two Levels: Present or Absent	0.286

BCTQ, Boston Carpal Tunnel Questionnaire; SD, standard deviation

* Categorizations chosen for testing in the full model based on correlation

Table 4

Proposed severity-scoring system.

Clinical & Sonographic Evaluation	Score
Provocative Tests	
No Positive Tests	0
Any Positive Test	1
Symptom Severity Rating (BCTQ)	
Rating < 1.62	0
Rating > 1.62	1
Functional Deficit Rating (BCTQ)	
Rating < 1.22	0
Rating > 1.22	1
Median Nerve Cross-Sectional Area (CSA) (i.e., largest CSA in the carpal tunnel region)	
< 12.10 mm ²	0
12.10 mm ² to 13.73 mm ²	1
13.73 mm ² to 15.36 mm ²	2
> 15.36 mm ²	3
Longitudinal Irregularity	
Absent	0
Present	1
Total Score	0–7
Score Interpretation	
0–1 = Negative	
2–3 = Pre-Clinical	
3–4 = Mild CTS	
5–6 = Moderate CTS	
7 = Severe CTS	